



RECENT ADVANCES IN BIODIVERSITY OF INDIA

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PREFACE

Biodiversity comprised the whole life on earth. The word 'biodiversity' is a contraction of biological diversity. Diversity is a concept which refers to the range of variation or differences among some set of entities; biological diversity thus refers to variety within the living world. The term 'biodiversity' is indeed commonly used to describe the number, variety and variability of living organisms. This very broad usage, embracing many different parameters, is essentially a synonym of 'Life on Earth'. Biodiversity is not distributed evenly or uniformly across the globe. Certain countries, lying wholly or partly within the tropics are characterized by high species richness and a high number of endemic species. These countries are known as megadiverse countries. There are seventeen countries are rich in biological diversity, they are Bolivia, Brazil, China, Colombia, Costa Rica, Democratic Republic of Congo, Ecuador, India, Indonesia, Kenya, Madagascar, Malaysia, Mexico, Peru, Philippines, South Africa, and Venezuela.

India is one of the 17 "megadiverse" countries and is composed of a diversity of ecological habitats like forests, grasslands, wetlands, coastal and marine ecosystems and desert ecosystems. India lies between 8°04' and 37°06' N latitude and 68°07' and 97°25' E longitude with total geographical area of 329 million ha. From the biological diversity point, India is regarded as a mega diversity country. Out of the total estimated species of the world, about 8.4 million species are from India. India is very rich in terms of biological diversity due to its diversified habitat and climatic conditions. India harbours as much as 7 per cent of the total animal species of the world, though India land mass are about 2 per cent. India is known to have nearly 89,500 species, of which insect alone 59,353. The inventories of reptiles, amphibian, fish, birds, and mammals are fairly complete. More than 5150 species of plants, 16214 species of insects, 44 species of mammals, 42 species of birds, 162 species of reptiles, 121 species of amphibians and 435 species of species of fishes are endemic in India.

These living species are not uniformly distributed but are seen in those areas where their species specific ecological requirements are satisfactorily fulfilled. Even in India, biodiversity is very high in the Eastern Himalayas and the Western Ghats. These two regions are recognised as hot spots rich in biodiversity. Unfortunately, these areas are also under constant threat of destruction. About 7000 endemic species are found in India; they do not occur anywhere else in the world. Of these, the Himalayas and the Khasi Hills in Meghalaya account for about 3000 species, and the Deccan Peninsula for about 2000 species. The area of maximum diversity in India is the north-eastern region, which happens to be also the most threatened. The second major area of genetic diversity is the lower region of the Western Ghats around the Nilgiris. Around 600 species of vascular plants are facing the threat of extinction; the fate of the animal world is not much different either. About 150 species of animals are on the verge of extinction, which include 81 mammals, 47 birds, 15 other animals including 3 species of amphibians and butterflies and moths and beetles of different kinds.

Certain tropical forest areas rich in diverse endemic species, on the verge of destruction are called 'Hot Spots'. The conservation of these areas is indispensable for the survival of mankind. About 18 'Hot Spots' (of tropical forests) are identified around the world. Among them two are in India one in the Western Ghats and the other in the eastern Himalayan region. These two 'Hot Spots' together have about 5330 endemic species including flowering plants, mammals, reptiles, amphibians and butterflies. In India, forest area is fast depleting and wildlife is fast disappearing. Much of the wildlife once widely distributed is now confined to certain pockets. Many innovative schemes and projects have been launched to salvage the Indian wildlife from

extinction. The Project Tiger was started in 1973. As tiger stands at the apex of the biological pyramid, ensuring its survival implies conservation of the entire biota. Subsequently the Crocodile Project (1975) and the Project Elephant (1991) were implemented. Now, efforts are being made to establish elephant corridors, linking the various forest areas so as to ensure continuity of forest habitats. The Man and Biosphere Programme was formulated in 1986. Eco-development programmes are currently designed to involve people living in and around the protected areas, in conservation efforts with a view to improving their living conditions and thereby reducing their dependence on forest resources.

The biodiversity in India's forests, grasslands, wetlands and mountains, deserts and marine ecosystem takes many pressures. One of the major causes of biological diversity in India has been the depletion of vegetative cover in order to expand agriculture. Since most of the biodiversity rich forests also contain the maximum mineral wealth, and are also the best sites for water impoundment, mining and development projects in such areas have often led to destruction of habitats. Poaching and illegal trade of wildlife products too have adversely affected biological diversity.

About forty legislations related to biodiversity starting from 1871 to 2011. Biological diversity is not a new concept. The convention on biological diversity reaffirms the sovereign rights of the nation over their biodiversity and each nation must take appropriate steps towards inventorying, monitoring and conserving biodiversity as a part of the integrated development planning. Various components of biodiversity may fall within the jurisdiction of the States or the Central Government or the list of concurrent subjects. There are specific Central and State enactments relevant to the environment. The most intimately connected to biodiversity are the Wildlife (Protection) Act 1972, Forest Act 1927, Forest Conservation Act 1980 and Biological Diversity Act 2002. Particular mention should be made of enactments relating to water and air pollution and the all embracing Environmental Protection Act 1986. Official agencies have used these laws to good effect to conserve large stretches bio-diversity rich areas though neither of these provides for public involvement in their enforcement and so often disempowers local communities.

Considering the India's immense biological diversity, the 'National Symposium on Recent Advances in Biodiversity of India' has been organized by the Zoological Survey of India at Port Blair, Andaman and Nicobar Islands 11th to 13th March 2009 to collate the information on the current perspectives of biodiversity research in India. The outcome of the symposium is depicted as the chapters of the book, deals the multidisciplinary approach on biodiversity which will be a useful tool for the effective conservation and management of the unique biological resources of Indian nation.

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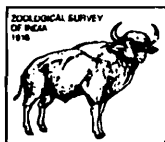
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ASSESSMENT OF FLORAL DIVERSITY IN THE WESTERN GHATS OF TAMIL NADU, INDIA

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INTRODUCTION

Biodiversity is the variability among living organisms and the ecological complexes of which they are part, including diversity within and between species and ecosystems. Biodiversity manifests at species, genetic and ecosystem levels. Biodiversity has direct consumptive value in food, agriculture, medicine and industry. It has also aesthetic and recreational value. Biodiversity manifests ecological balance and continues evolutionary process. India is one of the world's 12 mega biodiversity nations and the Indian sub-continent is one of the six Vavilovian centres of origin of species (Totey and Verma, 1996). India is recognized as a country uniquely rich in all aspects of Bio-diversity-ecosystem, species and genetic. India has the widest variety of biomass and the nation has given to the world nearly 167 economic plants (Zeven and de wet, 1982). There are 45,416 plant species described in India, from bacteria to angiosperms. This accounts for about 21 per cent of the global wealth. Amongst the 17,500 species of angiosperms found in India, 4,950 are endemic. The plant species include 850 species of bacteria 6,500 species of algae 14,500 fungi, 2,000 lichens 2,850 bryophytes, 1,100 pteridophytes and 64 gymnosperms. Tamil Nadu is endowed with

3,000 species of plants and according to the Botanical Survey of India, 123 species are listed as endangered (Anon, 1990). Eastern Himalayas and Western Ghats are recognized as the richest biodiversity landscapes. The Western Ghats have 27 per cent of India's total plant species, of which 1500 species are endemic. The Kotagiri hills form the integral and important part of Nilgiri Biosphere Reserve. The steeply increasing plantation activity and encroachment in the area pushes many endemic species of flora and fauna to the brink of endangerment. Hence, in order to safeguard the fast declining floral and faunal wealth, an assessment of available resources in the Biosphere reserve is at most important. Against these backdrops, the study was explored in the Western Ghats region of Tamil Nadu state, India.

MATERIALS AND METHODS

Location of the experimental area

The Kotagiri hills were selected as study area which comes under Coimbatore division. This division falls between 10°51' and 11°27' North Latitude and between 76°39' and 77°30' East Longitude. Random sample plots were selected at three different elevations *i.e.*, i) 300-400m asl (Lower elevation E1), ii) 700-800m asl (middle elevation E2) and iii) 1100-1200m asl (upper

elevation E3). These elevations were situated in Jaccanare Reserve Forest (1,295 ha) and Kallar Reserve Forest belongs to 6 A/C, the southern thorn forest and 5A/C3, the southern dry mixed deciduous forest (Champion and Seth, 1968).

Assessment of floral diversity

Floral diversity assessment was done using standard method established by Daniels *et al.*, 1996. Transects were fixed for sampling. Having fixed the transect, larger quadrats of 10m × 10m were marked on either side at equal intervals for measuring tree diversity. Smaller quadrats of 5m × 5m for counting shrubs and still smaller quadrats of 1m × 1m for herbs and regeneration were demarcated.

The adequacy of number of sample plots was decided using the method of species-effort curve (Daniels *et al.*, 1996). Using this method, in each experimental site, 20-30 sample plots were delimited and the total number of plant species was counted in all the plots and the species effort curve drawn by plotting number of plots against the total of plant species enumerated. Regarding plot survey, in 300-400 m asl experimental site [Elevation 1 (E1)], Forest College boundary was taken as the base line and the sample plots (or) quadrats were laid along the boundary line the quadrats were located at 500m distance across the gridlines on northern aspects. In 700-800m asl experimental site [Elevation 2 (E2)], the stream bank was taken as the base line and the sample plots (or) quadrats were laid along the bank. The quadrats were located at 500m distance across these gridlines on the southern slope. In 1,100-1200m asl experimental site [Elevation 3 (E3)], the Kunjapanai forest foot path was taken as the base line and the sample plots (or) quadrats were laid along the foot path. The quadrats were located at 500m distance across these gridlines on the eastern slope. The number of species of trees, shrubs, herbs and grasses along with their morphometric characteristics were recorded periodically in three seasons. Season 1 (S1) Nov-Dec, 2007, Season 2 (S2) Feb-March, 2008 and Season 3 (S3) April-May, 2008.

Record of observation

In the present study, trees, shrubs and herbs were distinguished based on the following criteria. All plants over 15cm girth at breast height (gbh) and above were reckoned as trees; all plants less than 15cm gbh but above 1.37m height were reckoned as shrubs; all other plants less than 15cm gbh and less than 1.37m in height were treated as herbs (Kiratiprayoon *et al.*, 1994). To investigate the vegetation of study area, line transects were established. The aim of these transect was to document the vegetation which were not previously in plot survey (Brookhouse *et al.*, 1996). The unknown plant species were identified at Botanical Survey of India, Coimabtoe. Some of the diversity indices frequently seen as indicators of the well being of any ecosystem are density (number of plants per unit area), relative density,

$$\text{Relative density} = \frac{\text{Total no. of individuals of a species}}{\text{Total no. of individuals of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Canopy or Basal covers for species}}{\text{Canopy or Basal covers for all species}} \times 100$$

$$\text{Frequency of a species} = \frac{\text{No. of sample plot in which a species occurs}}{\text{Total no. of sample plots taken}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Sum of frequencies of all species}} \times 100$$

$$\text{Important value index} = \text{Relative Dominance} + \text{Relative Density} + \text{Relative frequency}$$

The species diversity was calculated using Shanon-Wiener Index and Simpson's Index (Shannon and Wiener, 1963 and Simpson, 1949).

Shannon-Wiener Index (1963)

$$'H' = \Sigma (P_i \times \ln P_i)$$

Where, 'H' is the measure of diversity;

P_i—the proportion of the *i*th species in the landscape element

LnP_i—the Natural logarithm of the proportion of each species

Simpson's Index (1949) (modified)

$$S = \frac{1}{\Sigma P_i^2}$$

Where 'S' is the measure of diversity

P_i the proportion of *i*th species sampled

RESULTS AND DISCUSSION

The total number of plant species of the study area were 141, in which upper elevation (1100-1200m asl) recorded maximum number of plant species, comprising 36 trees from 22 families, eight shrubs from six families, nine herbs of five families and five climbers of four families, whereas it was only 44 in middle elevation (700-800 m ASL) and 39 in lower elevation (300-400m asl). This is in conformity with the trend that species diversity may increase with altitude upto certain extent. The upper elevation (1100-1200m asl) of hill slope showed maximum tree species diversity and varied in tree composition and was related to slope and exposure (Practor *et al.*, 1988). This may be due to highly mixed and randomized

regeneration in different elevation in conjunction with gravity and water activity on the viable seeds.

The absolute density (measured per hectare) was 474.07 trees/ha for higher elevation, 362.22 trees/ha for middle elevation and 261.48 trees/ha for lower elevation. The findings of the study area showed that the highest level of tree density was found in higher elevation. The dominance of tree species in higher elevation appears to be the characteristic feature of dry mixed deciduous forests (Champion and Seth, 1968). Also the reduction of tree diversity in lower elevation may be due to aridity and casual habitat destruction. Moreover evergreen forests had greater species diversity when compared to deciduous forests in higher elevations (Sundarapandian *et al.*, 1998).

The dominant tree species found in upper elevation were *Canthium dicoccum* (7.50) and *Vitex altissima* (6.87). The study from Ranjithakani *et al.*, (1993) revealed that *Canthium dicoccum* and *Memecylon hushingtonae* were dominant in upper elevation. *Commiphora caudata* (11.53) and *Dendrocalamus strictus* (11.53) were dominant species in middle elevation and lower elevation. *Euphorbia tirucalli* (14.70) and *Erythrina suberosa* (17.65) were found to be dominant species. Density and diversity of woody species significantly varied among various forest types (Rawat *et al.*, 1999) Table 1.

Table 1. Density and diversity indices of tree species at different elevation

Botanical Name	Total Number	NPS	RD	RDom	SF	RF	IVI
Density and diversity indices for trees at elevation 300-400 m asl (E-1)							
<i>Acacia catechu</i>	7	3	10.294	2.636	20.00	6.122	19.05
<i>Acacia leucophloea</i>	5	4	7.352	23.725	26.666	8.163	39.24
<i>Acacia planifrons</i>	3	2	4.411	1.594	13.333	4.081	10.01
<i>Albizia procera</i>	4	3	5.882	7.973	20.00	6.122	19.98
<i>Chloroxylon swietenia</i>	3	2	4.411	11.748	13.333	4.081	20.24
<i>Erythrina suberosa</i>	12	9	17.647	4.686	60.00	18.367	40.70
<i>Euphorbia tirucalli</i>	10	8	14.705	6.378	53.333	16.326	37.41

Table 1. Contd.

Botanical Name	Total Number	NPS	RD	RDom	SF	RF	IVI
<i>Hardwickia binata</i>	4	4	5.882	22.00	26.666	8.163	36.05
<i>Zizyphus mauritiana</i>	6	3	8.823	3.588	20.00	6.122	18.53
<i>Zizyphus trinervia</i>	6	5	8.823	3.588	33.333	10.204	22.62
<i>Zizyphus xylopyrus</i>	8	6	11.764	2.082	40.00	12.244	26.09
Density and diversity indices for trees at elevation 700-800 m asl (E-2)							
<i>Adina cordifolia</i>	3	2	2.884	1.194	13.333	2.247	6.33
<i>Aegle marmelos</i>	1	4	0.961	3.634	26.666	4.294	8.89
<i>Alangium salvifolium</i>	2	2	1.923	1.101	13.333	2.247	5.27
<i>Albizzia lebbeck</i>	3	3	2.884	1.393	20.000	3.370	7.65
<i>Albizia odoratissima</i>	5	4	4.807	1.957	26.667	4.494	11.26
<i>Atlantia monophylla</i>	4	6	3.846	0.843	40.000	6.741	11.43
<i>Buhinia racemosa</i>	1	2	0.961	4.590	13.333	2.247	7.80
<i>Butea monosperma</i>	6	7	5.769	1.794	13.333	2.247	9.81
<i>Ailanthus excelsa</i>	1	1	0.625	8.438	6.667	0.869	9.84
<i>Alstonia scholaris</i>	7	4	4.375	1.747	26.667	3.478	9.60
<i>Anogeissus latifolia</i>	8	5	5.000	4.897	33.333	4.348	14.25
<i>Artocarpus hirsutus</i>	3	2	1.875	0.795	13.333	1.739	4.41
<i>Atalantia monophylla</i>	10	7	6.250	1.092	46.667	6.088	13.43
<i>Barringtonia acutangula</i>	4	2	2.500	3.869	13.333	.739	8.11
<i>Bridelia retusa</i>	3	3	1.875	0.416	20.000	2.609	4.90
<i>Buchanania lanzan</i>	3	2	1.875	12.932	13.333	1.739	16.55
<i>Butea monosperma</i>	5	3	3.125	2.087	20.000	2.609	7.82
<i>Canthium dicoccum</i>	12	8	7.501	14.998	53.333	6.957	29.46
<i>Canthium didymium</i>	3	2	1.875	0.306	13.333	1.739	3.92
<i>Casearia tomentosa</i>	1	1	0.625	1.829	6.667	0.869	3.32
<i>Dalbergia latifolia</i>	5	3	3.215	1.747	20.000	2.609	7.48
<i>Debregeasia longifolia</i>	3	2	1.875	0.544	13.333	1.739	4.16
<i>Diospyros ebenum</i>	1	1	0.625	0.094	6.667	0.869	1.59
<i>Diospyros melanoxylon</i>	9	6	5.625	0.638	40.000	5.218	11.48
<i>Diospyros microphylla</i>	5	4	3.125	1.092	26.667	3.478	7.69
<i>Diospyros montana</i>	2	2	1.250	0.242	13.333	1.739	3.23
<i>Elaeocarpus serratus</i>	1	2	0.625	8.889	13.333	1.739	11.25
<i>Euonymus crenetatus</i>	4	2	2.500	1.092	13.333	1.739	5.33
<i>Ficus benghalensis</i>	1	1	0.625	1.999	6.667	0.869	3.49
<i>Gmelina arborea</i>	4	2	2.500	0.689	13.333	1.739	4.93

Table 1. Contd.

Botanical Name	Total Number	NPS	RD	RDom	SF	RF	IVI
<i>Grevia tiliaefolia</i>	8	6	5.000	0.639	40.000	5.217	10.86
<i>Maba buxifolia</i>	7	5	4.375	2.177	33.333	4.348	10.90
<i>Mallotus phillipensis</i>	6	4	3.750	3.749	26.667	3.478	10.98
<i>Melia composite</i>	6	3	3.750	0.908	20.000	2.609	7.27
<i>Pterocarpus marsupium</i>	3	2	1.875	1.092	13.333	1.739	4.71
<i>Santalum album</i>	2	2	1.250	0.544	13.333	1.739	3.53
<i>Sapindus emarginatus</i>	7	5	4.375	0.741	33.333	4.348	9.46
<i>Sapindus trifoliatus</i>	4	3	2.500	2.457	20.000	2.609	7.57
<i>Syzygium cumini</i>	4	3	2.510	0.242	20.000	2.609	5.35
<i>Tectona grandis</i>	2	2	1.250	0.795	13.333	1.739	3.78
<i>Terminalia bellirica</i>	1	3	0.625	1.747	20.000	2.608	3.23
<i>Terminalia chebula</i>	2	2	1.250	6.352	13.333	1.739	9.34
Density and diversity indices for trees at elevation 1100-1200 m asl (E-3)							
<i>Ailanthus excelsa</i>	1	1	0.625	8.438	6.667	0.869	9.84
<i>Alstonia scholaris</i>	7	4	4.375	1.747	26.667	3.478	9.60
<i>Anogeissus latifolia</i>	8	5	5.000	4.897	33.333	4.348	14.25
<i>Artocarpus hirsutus</i>	3	2	1.875	0.795	13.333	1.739	4.41
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<i>Butea monosperma</i>	5	3	3.125	2.087	20.000	2.609	7.82
<i>Canthium dicoccum</i>	12	8	7.501	14.998	53.333	6.957	29.46
<i>Canthium didymium</i>	3	2	1.875	0.306	13.333	1.739	3.92
<i>Casearia tomentosa</i>	1	1	0.625	1.829	6.667	0.869	3.32
<i>Dalbergia latifolia</i>	5	3	3.215	1.747	20.000	2.609	7.48
<i>Debregeasia longifolia</i>	3	2	1.875	0.544	13.333	1.739	4.16
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<i>Terminalia bellirica</i>	1	3	0.625	1.747	20.000	2.608	3.23
<i>Terminalia chebula</i>	2	2	1.250	6.352	13.333	1.739	9.34
<i>Thespesia lampas</i>	2	2	1.250	2.087	13.333	1.739	5.08
<i>Vitex altissima</i>	11	8	6.875	1.829	53.333	6.956	15.66

Note : NPS-No. of plots in which species occur, RD-Relative Density, RDom-Relative Dominance, SF-Species frequency, RF-Relative Frequency, IVI-Important value index

Canthium dicoccum (6.96) and *Vitex altissima* (6.96) species were found to be frequent in upper elevation. In the middle elevation *Commiphora caudata* (8.99) and *Dendrocalamus strictus* (5.62) were found to be frequent. In the lower elevation the higher density tree sp. of *Erythrina suberosa* (18.37) and *Euphorbia tirucalli* (16.32) and *Hardwickia binata* (8.16) were frequently found. The similar trend of *Tamarindus indica* and *Hardwickia binata* frequenting with high density was reported by Baranidharan (2000).

The shrubs, herbs and climbers show seasonal changes in their frequency. *Pavetta indica*, *Lantana camara*, *Euphorbia hirta*, *Pterolobium indicum* and *Solanum torvum* were frequently found in three elevations. This may be due to the biennial life cycle of many of the herbs and climbers found in the present study area. The dominant species of upper elevation were *Canthium dicoccum* (14.98) and *Buchanania lanzan* (12.93), which could be attributed to their higher basal area. In the middle elevation, *Terminalia bellirica* (7.83) and *Pterocarpus*

marsupium (6.65) were dominant, but these had low density. In the lower elevation *Acacia leucophloea* (23.72) and *Hardwickia binata* (22.00) were found to be the dominant species which can be attributed to different height and age of the tree. This is in accordance with Practor *et al.*, (1988) who revealed that wide range of basal area may reflect in age structure and degree of disturbance.

The maximum important value index values (IVI) of *Acacia leucophloea* and *Erythrina suberosa* were between 39 and 41 per cent in lower elevation whereas IVI of *Acacia planifrons* and *Zizyphus mauritiana* were 10-20 per cent. Considering elevations IVI of middle elevation tree species like *Hardwickia binata*, *Dendrocalamus strictus* and *Commiphora caudata* were 16 to 24 per cent and lesser IVI in *Terminalia chebula* (2.92). But in the upper elevation tree species such as *Vitex altissima*, *Buchanania lanzan* and *Canthium dicoccum* were 15 to 29 per cent and *Diospyros ebenum* had the least IVI.

Those tree species which had higher relative density, relative frequency and relative dominance were found to have more IVI which means the summation of relative density, relative frequency and relative dominance. The similar trend with greater IVI value of dominant species in lower elevation was revealed by Sundarapandian *et al.* (1998) and Baranidharan (2000). The Shannon-Wiener Index for trees (3.368) were more in upper elevation. The middle and lower elevation had low diversity indices. The possible reason for low diversity of lower elevation of trees (2.303) may be due to habitat destruction and aridity of the area (Seetharaman *et al.*, 2000).

The Shannon-Wiener and Simpson index for shrubs, herbs and climbers of upper, middle

and lower elevation were more during December and January. This may be due to Northeast monsoon precipitates received during the season. Simpson diversity index for dry mixed deciduous forest of upper elevation trees was (24.902). This diversity was higher than the scrub thorn forest of lower elevation. However, the contrary results from Seetharaman *et al.* (2000) revealed that there was no significant difference among dry deciduous and evergreen forest tree diversity.

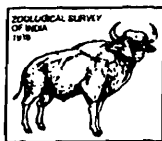
ACKNOWLEDGEMENTS

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FLORISTIC DIVERSITY OF THE JARAWA RESERVE OF ANDAMAN ISLANDS AND IMPACT OF HUMAN INTERFERENCE THEREIN

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INTRODUCTION

The Andaman and Nicobar Islands form an archipelago located in the Bay of Bengal between 6°-14° N latitudes and 92°-94° E longitudes. The archipelago consists of about 321 islands and islets located as an arc in north-southeast direction over a length of about 700 km. There are few outlying scattered islands on either side of the arc. The land area occupied by all these islands is about 8293 km². The territories surrounding these islands are mainland India in the north and west, Myanmar towards the northeast, Malaysia towards the east and the island of Sumatra in the south. The northern tip of Sumatra is about 145 km from the southern tip called Indira Point of Great Nicobar Island, the southernmost island of the archipelago. The Andaman group of Islands separates from the Nicobar group by a deep channel called 10-degree channel based on its location at 10° N latitude. The terrain of most of the islands is hilly with undulating hill ranges enclosing narrow valleys. The highest peak is the Saddle Peak (720 m above msl.) in the North Andaman and Mount Thullier (670 m above msl.) of Great Nicobar

Island. There are two volcanic islands namely Narcondam and Barren Islands in the Andaman sea on the east of the Andaman Islands.

Information on the flora of these islands remains insufficient. Due to the recent intensive explorations of Botanical Survey of India, the forests of most of the islands are becoming botanically better known. The earliest botanical studies in these islands date back to the year 1791, when Col. Kyd, founder of the Calcutta Botanic Garden, visited these islands, made collections, and added many species to the Calcutta Botanic Garden. Subsequently during the 19th and early 20th centuries, Helfer, Kurz, Prain, King, Rogers and Parkinson made extensive collections. During the post independence period, foresters or botanists like B.S. Chengappa, K. C. Sahni, K. Srinivasan, K. Thothathri, visited the islands for plant collection. With the establishment of a Circle of Botanical Survey of India at Port Blair in 1972, botanical explorations to the islands took momentum.

Among the historical publications on the botany of the islands, Kurz (1870, 1875, 1876), Prain (1891, 1893), Gamble (1903) and Parkinson

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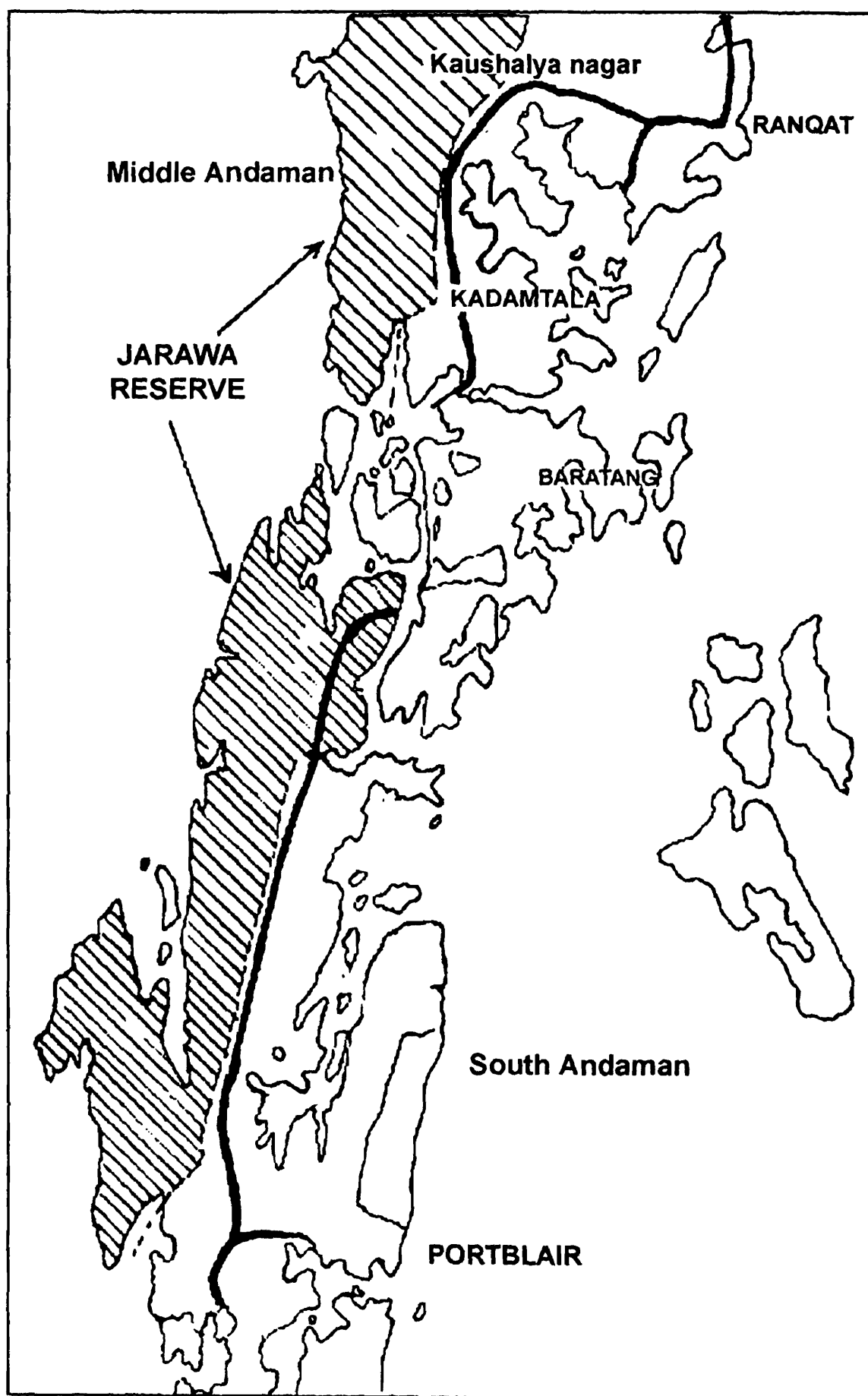


Fig. 1. Jarawa Reserve

(1923). Later, Chengappa (1944), Sahni (1953, 1958) and Thothathri (1960a, b, 1962) also made significant contributions on the vegetation of the islands. Among the numerous recent papers, noteworthy contributions are by Balakrishnan (1977, 1989), Balakrishnan *et al.* (1989), Balakrishnan and Ellis (1996), Vasudeva Rao (1986), Dagar *et al.* (1991), Chakrabarty and Balakrishnan (1992), Chakrabarty and Gangopadhyay (1990, 1992), Gangopadhyay and Chakrabarty (1992), Hajra *et al.* (1999), Sinha (1999), Chakrabarty *et al.* (2006, 2008) and Pandey and Diwakar (2008).

The Jarawa Reserve (Fig 1), with a land area of 647 km², remained botanically unexplored until the Jarawa Project was undertaken in 2001-2002. The Reserve is inhabited by the Jarawas who are semi-nomadic, food-gatherers and hunters with Stone Age civilization. At present their number is about 260. They are endogamous people, having closely knit society. They live in small groups in the dense interior forests and along the western coast. They are entirely dependent on forest resources and sea products for all their daily needs.

Few local population exist near the Reserve, particularly at Tirur, Jirkatang, Baratang and Kadamtala areas. Moreover, the Andaman Trunk Road passes through the Reserve. In the present paper, a portrait of the floristic diversity of the Jarawa Reserve is presented which will be helpful for formulating conservation strategies of the Reserve. The impact of increasing human interference is also discussed.

MATERIALS AND METHODS

In the year 2001, the Ministry of Home Affairs, Government of India constituted a Committee of Experts to undertake scientific studies to find out the cause of changes in the behavior of the Jarawas. To save the Jarawas from the danger of losing their identity and culture by contacts with 'civilized society', the Ministry asked the Committee to suggest remedial measures to enable the Government of India and the Andaman and Nicobar Administration in formulation of suitable plans and programmes. Eventually the Expert

Committee decided to depute multi-disciplinary study teams or Composite Groups to undertake studies on the Jarawas tribe. They found that the following aspects of the Jarawas tribe need intensive studies :

- a. Health and nutrition of the tribe.
- b. Social and cultural behavior of the people.
- c. Identification of plant and animal resources in the Jarawa territory.

The Directorate of Tribal Welfare, Andaman *Adim Janjati Vikas Samiti* (AAJVS) of Andaman and Nicobar Administration made all arrangements for the studies. Three Composite Groups consisting of researchers and supporting staff from various Government departments, *viz.* Anthropological Survey of India, Department of Environment and Forests, Zoological Survey of India, Botanical Survey of India, AAJVS, Directorate of Health Services and All India Institute of Public Hygiene and Health. The following areas have been surveyed in different phase.

- i. *Tirur* : South Andamans (area between Tirur and Potatang).
- ii. *R.K. Nallah* : South Andamans (area between Potatang and the Middle Straits).
- iii. Middle Andamans.

First Phase = From 10.12.2001 to 09.01.2002

Second Phase = From 12.04.2002 to 10.05.2002

Third Phase = From 10.08.2002 to 09.09.2002

During the course of the studies, an assessment of the floristic diversity of the Jarawa Reserve was done. Documentation was made through photography, collection of voucher specimens of plant parts and field observations.

RESULTS

With an average annual rainfall of 300–380 cm, mean relative humidity of 85 per cent and temperature varying from 23°–34° C, these islands exhibit warm humid tropical climatic conditions, permitting luxuriant and greatly diverse vegetation. The overall pattern of vegetation is tropical evergreen, containing

littoral (mangroves, tidal or swamp forests, beach formations and coastal forests) and inland forests (deciduous forests and moist evergreen forests at low elevations).

Luxuriant mangrove forests found in Middle Andamans, along brackish water and tidal streams. The common mangrove species are *Heritiera littoralis*, *Bruguiera cylindrica*, *Rhizophora apiculata*, *Lumnitzera littorea*, *Sonneratia caseolaris* and *Ceriops tagal*. Some species associated with the mangrove are *Acrostichum aureum*, *Acanthus illicifolius*, *Caesalpinia crista*, *Pemphis acidula* and *Chonemorpha fragrans*.

The tidal or swamp forests, which get submerged during high tides contain a number of species such as *Nypa fruticans*, *Pandanus* spp., *Avicennia officinalis*, *Manilkara littoralis*, *Cynometra iripa*, *Dodonaea viscosa*, *Sophora tomentosa*, *Caesalpinia bonduc*, *Guettarda speciosa*, *Premna corymbosa*, *Ganophyllum falcatum*, *Wedelia biflora* and *Bohemeria nivea*.

The sandy beaches are occupied by some species viz. *Capparis floribunda*, *Hibiscus tiliaceus*, *Cerbera odollam*, *Ipomoea pes-caprae*, *Euphorbia pallens* and *Crinum asiaticum*.

Some typical plant species occur along the coasts beyond the sandy beaches. Some common species of such areas are *Cycas rumphii*, *Areca triandra*, *Barringtonia asiatica*, *B. pendula*, *Syzygium samarangense*, *Calophyllum inophyllum*, *Byttneria andamanensis*, *Thespesia populnea*, *Pseudouvaria prainii*, *Pongamia pinnata*, *Erythrina variegata*, *Dalbergia pinnata*, *Tournefortia argentea* and *Dolichadrone spathacea*. Bamboos and palms are also found growing luxuriantly in coastal

forests of some areas but they also extend to the interior forests.

Behind the coastal forests, there are deciduous forests followed by evergreen forests of low altitudes. Sometimes, however, they intergrade and elements of deciduous forests may also be seen in evergreen forests. Some common species of the deciduous forests include *Artocarpus chaplasha*, *Oroxylum indicum*, *Pterocarpus dalbergioides*, *Terminalia* spp., *Canarium euphyllum*, *Dipterocarpus* spp., *Sageraea elliptica*, *Pajanelia longifolia*, *Diospyros* spp., *Duabanga grandiflora*, *Atalantia monophylla* and *Spondias pinnata*.

The common species in evergreen forests are *Pometia pinnata*, *Sterculia guttata*, *Picrasma javanica*, *Dioscorea* spp., *canes*, *Gnetum scandens*, *Dipterocarpus* spp., *Ancistrocladus tectorius*, *Goniothalamus macranthus*, and *Pterocymbium acerifolium*.

Rheophytic plants observed were *Homonoia riparia* and *Flemingia macrophylla* which prefer stream beds. Some species prefer moist places or banks of streams, viz. *Leea aequata*, *Pandanus* spp., *Hedyotis* spp., *Dracantomelon dao*, *Pogostemon auricularis*, *Memecylon angustifolium* and the sedges. Some grasses and introduced herbaceous species may be found growing along roadsides, paddy fields, waste places and cleared areas.

A list of the plant species occurring in the area along with their abundance, habitat and usefulness, if any, is given in Table 1. A floristic analysis is presented in Table 2. The dominant families are listed in Table 3 and the endemic taxa are listed in Table 4.

Table 1. Plant species recorded from Jarawa Reserve

Name of Plant	Observations
Pteridophytes	
Huperziaceae	
<i>Huperzia carinata</i> (Desv.) Trev.	Epiphytes; inland forests; scarce
Lycopodiaceae	
<i>Lycopodium circinnatum</i> (Burm.f.) Sw.	Herbs; inland forests; rare

Table 1. *Contd.*

Name of Plant	Observations
Polypodiaceae	
<i>Microsorium punctatum</i> (L.) Copel.	Epiphytes; inland forests; common
<i>Pyrrosia adnascens</i> (Sw.) Ching	Epiphytes; inland forests; common
Acrostichaceae	
<i>Acrostichum aureum</i> L.	Shrubs; mangroves and tidal or swamp forests; common
Drynariaceae	
<i>Drynaria quercifolia</i> (L.) J.J. Sm.	Epiphytes; interior forests; scarce
Lygodiaceae	
<i>Lygodium circinnatum</i> (Burm.f.) Sw.	Climbing herbs; evergreen forests; scarce
Pteridaceae	
<i>Pteris biaurita</i> L.	Herbs; hill slopes; occasional
<i>P. pellucida</i> L.	Shrubs; hill slopes, damp places; scarce
<i>P. vittata</i> L.	Shrubs; inland forest floors; scarce
Lindsaeaceae	
<i>Lindsaea cultrata</i> (Willd.) Sw.	Herbs; shaded places, inland forests; scarce
<i>L. heterophylla</i> Dryand.	Herbs; shaded places; rare
Thelypteridaceae	
<i>Trigonospora ciliata</i> (Benth.) Holtt.	Herbs; inland forests; damp areas; scarce
Aspleniaceae	
<i>Asplenium falcatum</i> Lam.	Epiphytes; coastal forests; common
Blechnaceae	
<i>Blechnum orientale</i> L.	Herbs; inland forest floors; common
Gymnosperms	
Gnetaceae	
<i>Gnetum latifolium</i> Blume	Climbers; evergreen forests; scattered
<i>G. scandens</i> Roxb.	Climbers; evergreen forests; frequent
Cycadaceae	
<i>Cycas rumphii</i> Miq.	Trees; coastal forests; abundant; seeds edible
Angiosperms	
Dicotyledons	
Dilleniaceae	
<i>Dillenia andamanica</i> C.E. Parkinson	Trees; deciduous forests; rare; endemic; fruits edible
Magnoliaceae	
<i>Magnolia andamanica</i> (King) Raju & M.P. Nayar	Evergreen forests; scattered; often near streams
Annonaceae	
<i>Anaxagorea luzonensis</i> A. Gray	Herbs or shrubs; outskirts of forests and evergreen forests; very common

Table 1. Contd.

Name of Plant	Observations
<i>Cyathostemma micranthum</i> (DC.) Sinclair	Climbers; evergreen forsts; scarce; endemic
<i>Dasymaschalon dasymaschalus</i> (Blume) I.M. Turner	Shrubs; near coasts and inland forests; very common; bark strip used as rope
<i>Goniothalamus macranthus</i> (Kurz) Boerl.	Trees; evergreen forests; common
<i>Miliusa andamanica</i> (King) Finet & Gagnep.	Undershrubs; deciduous forests; common; endemic
<i>M. horsfieldii</i> (Benn.) Baille ex Pierre	Trees; deciduous forests; scarce
<i>M. tectona</i> Hutch. ex C.E. Parkinson	Trees; deciduous to evergreen forests; scattered; <i>Jungle-saguam</i>
<i>Orophaea katschallica</i> Kurz	Trees; coastal to inland forests; abundant; endemic
<i>Polyalthia parkinsonii</i> Hutch.	Inland forests; fairly common; endemic
<i>Pseudouvaria prainii</i> (King) Merr.	Trees; coastal to inland forests; common
<i>Sageraea elliptica</i> (DC.) Hook.f. & Thomson	Deciduous forests; common; endemic; used for making bows; <i>Chai</i>
<i>S. listeri</i> King var. <i>andamanica</i> Chatterjee & Mukerjee	Deciduous forests; scarce; endemic
<i>Uvaria hamiltonii</i> Hook.f. & Thomson var. <i>kurzii</i> King	Scandent shrubs; inland forests; scarce; endemic
<i>U. rufa</i> Blume	Scandent shrubs; evergreen forests; common
Menispermaceae	
<i>Cissampelos pareira</i> L. var. <i>hirsuta</i> (Buch.Ham. ex DC.) Forman	Climbers; evergreen forests; scarce
<i>Stephania andamanica</i> Diels	Climbers; evergreen forests; rare; endemic
Barclayaceae	
<i>Barclaya longifolia</i> Wall.	Herbs; aquatic; occasional
Capparaceae	
<i>Capparis floribunda</i> Wight	Scandent shrubs; strandline, coastal forests; common
<i>C. sepiaria</i> L.	Scandent shrubs; strandline and inland forests; scarce
Violaceae	
<i>Rinorea bengalensis</i> (Wall.) O. Kuntze	Shrubs; deciduous forests; very common
<i>R. macrophylla</i> (Decne.) O. Kuntze	Shrubs; deciduous forests; scarce
Flacourtiaceae	
<i>Casearia andamanica</i> King	Trees; evergreen forests; rare; endemic
<i>Flacourtia indica</i> (Burm.f.) Merr.	Shrubs or small trees; deciduous forests; occasional
<i>Ryprosa javanica</i> (Blume) Kurz ex Koord. & Valetton	Trees; evergreen forests, often along streams; fairly common
<i>Scolopia kermodei</i> C.E.C. Fischer	Tall trees; inland forests; rare
Xanthophyllaceae	
<i>Xanthophyllum andamanicum</i> King	Trees; evergreen forests; common; endemic; <i>Letpyaw</i>

Table 1. Contd.

Name of Plant	Observations
Hypericaceae	
<i>Cratoxylum formosum</i> (Jack) Dyer	Trees; evergreen forests; rare
Clusiaceae	
<i>Calophyllum calaba</i> L. var. <i>bracteatum</i> (Wight) P. Stevens	Trees; deciduous forests; common
<i>C. inophyllum</i> L.	Trees; coastal forests; very common
<i>C. spectabile</i> Willd.	Trees; coastal and evergreen forests; common; <i>Lalchini</i>
<i>Garcinia andamanica</i> King var. <i>andamanica</i>	Trees; evergreen forests; common; endemic; fruits edible
<i>G. cowa</i> Roxb. ex DC.	Trees; deciduous forests; common; fruits edible; <i>Kowa</i>
<i>G. microstigma</i> Kurz	Trees; inland hill forests; rare; endemic; fruits edible
<i>G. speciosa</i> Wall.	Trees; evergreen forests; common; fruits edible; <i>Parawa</i>
<i>G. xanthochymus</i> Hook.f. & T. Anders.	Trees; evergreen forests; common; fruits edible.
<i>Mesua ferrea</i> L.	Trees; evergreen forests; scattered; timber useful
Theaceae	
<i>Ternstroemia wallichiana</i> (Griffith) Engler	Trees; evergreen forests; common
Dipterocarpaceae	
<i>Dipterocarpus alatus</i> Roxb. ex G. Don	Tall trees; deciduous to evergreen forests; common; timber useful; <i>Gurjan</i>
<i>D. costatus</i> Gaertn. f.	Trees; evergreen forests; scarce
<i>D. gracilis</i> Blume	Tall trees; deciduous to evergreen forests; common
<i>D. grandiflorus</i> (Blanco) Blanco	Tall trees; deciduous to evergreen forests; scattered
<i>Hopea odorata</i> Roxb.	Tall trees; evergreen forests; scattered; timber useful; <i>Safed Thingan</i>
Ancistrocladaceae	
<i>Ancistrocladus attenuatus</i> Dyer	Climbers; evergreen forests; common
<i>A. tectorius</i> (Lour.) Merr.	Climbers; evergreen forests; common
Malvaceae	
<i>Abelmoschus moschatus</i> Medikus	Shrubs; seashores; common
<i>Hibiscus scandens</i> Roxb.	Scandent shrubs; coastal to inland forests; often near streams; scattered
<i>H. tiliaceus</i> L.	Trees; sandy beaches and coastal forests; common; bark-strip used as rope; <i>Safed Chilka</i>
<i>Thespesia populnea</i> (L.) Sol. ex Correa	Trees; beach forests; common
Bombacaceae	
<i>Bombax insigne</i> Wall.	Trees; deciduous forests; common
Sterculiaceae	
<i>Byttneria andamanensis</i> Kurz	Scandent shrubs; coastal forests; scarce
<i>Firmiana colorata</i> (Roxb.) R. Br.	Trees; coastal forests; scarce

Table 1. Contd.

Name of Plant	Observations
<i>Helicteres isora</i> L.	Shrubs; deciduous forests; scarce
<i>Heritiera littoralis</i> Dryand. ex W. Aiton	Trees; seashores and mangroves; common
<i>Pterocymbium tinctorium</i> (Blanco) Merr.	Trees; evergreen forests; common
<i>Pterospermum acerifolium</i> Willd.	Trees; evergreen forests; common
<i>Pterygota alata</i> (Roxb.) R. Br.	Tall trees; inland forests, near streams; common
<i>Sterculia guttata</i> Roxb. ex DC.	Trees; evergreen forests; scattered
<i>S. rubiginosa</i> Vent. var. <i>glabrescens</i> King	Tall trees; coastal forests; common
<i>S. villosa</i> Roxb. ex Smith	Trees; deciduous forests; common; <i>Lal chilka</i>
Tiliaceae	
<i>Brownlowia tersa</i> (L.) Kosterm.	Shrubs; tidal or swamp forests; common
<i>Grewia nervosa</i> (Lour.) Panigr.	Trees; coastal to deciduous forests; common; endemic
<i>G. serrulata</i> DC.	Trees; seashores or deciduous forests; common
Malpighiaceae	
<i>Hiptage benghalensis</i> (L.) Kurz	Climbers; inland forests; fairly common
Rutaceae	
<i>Atalantia monophylla</i> (L.) DC.	Trees; deciduous forests; common; <i>Jungli nimbu</i>
<i>Euodia glabra</i> Blume	Trees; deciduous forests; scarce
<i>Glycosmis pentaphylla</i> (Retz.) DC.	Trees; deciduous forests; fairly common; endemic
<i>Murraya exotica</i> L.	Trees; deciduous forests; common
<i>M. paniculata</i> (L.) Jack	Trees; deciduous forests; common
<i>Paramignya andamanica</i> (King) Tanaka	Scandent shrubs; inland forests; scattered; endemic
<i>Zanthoxylum ovalifolium</i> Wight	Shrubs; deciduous forests; scarce
<i>Z. rhesta</i> (Roxb.) DC.	Trees; deciduous forests; common
Simaroubaceae	
<i>Ailanthus excelsa</i> Roxb.	Trees; deciduous forests; scattered
<i>Harrisonia brownii</i> A. Juss.	Straggler; deciduous forests; common
<i>Picrasma javanica</i> Blume	Trees; evergreen forests; scattered
<i>Suriana maritima</i> L.	Shrubs; tidal or swamp forests; scarce
Ochnaceae	
<i>Ochna integerrima</i> (Lour.) Merr.	Trees; deciduous forests; common; with beautiful yellow flowers
Burseraceae	
<i>Canarium euphyllum</i> Kurz	Tall trees; deciduous forests; very common; <i>Dhup</i>
<i>C. mannii</i> King	Trees; deciduous to inland forests; scattered; endemic
<i>Garuga pinnata</i> Roxb.	Trees; deciduous forests; scattered
Meliaceae	
<i>Aglaia argentea</i> Blume	Trees; deciduous forests; common
<i>Chukrasia tabularis</i> A. Juss.	Tall trees; deciduous forests; scarce

Table 1. Contd.

Name of Plant	Observations
<i>Walsura candollei</i> King	Trees; deciduous forests; scarce; endemic
<i>Xylocarpus granatum</i> J. Koen.	Trees; mangroves; common
<i>X. moluccensis</i> (Lam.) M. Roem.	Trees; beach forests; common
Dichapetalaceae	
<i>Dichapetalum gelonioides</i> (Roxb.) Engl. ssp. <i>andamanicum</i> (King) Leenh.	Shrubs or trees; evergreen forests; scarce; endemic
Olacaceae	
<i>Anacolosa frutescens</i> (Blume) Blume	Shrubs; inland forests; common
<i>Olax imbricata</i> Roxb.	Climbers; inland forests; scattered
<i>Ximenia americana</i> L.	Small trees; coastal forests; common; fruits edible
Icacinaceae	
<i>Codiocarpus andamanicus</i> (Kurz) Howard	Trees; evergreen forests; common; endemic
<i>Gomphandra comosa</i> King	Shrubs; inland forests; scarce; endemic
Opiliaceae	
<i>Cansjera rheedei</i> J. Gmelin	Scandent shrubs; inland forests; scattered
<i>Champereia manillana</i> (Blume) Merr.	Trees; tidal or swamp forests; common
Celastraceae	
<i>Bhesa robusta</i> (Roxb.) Ding Hou	Tall trees; evergreen forests; rare
<i>Glyptopetalum calocarpum</i> (Kurz) Prain	Shrubs; coastal forests; scarce
Hippocrateaceae	
<i>Salacia chinensis</i> L.	Climbers; evergreen forests; scarce
<i>S. majumdarii</i> (Chakrab. & M. Gangop.) B.D. Naithani	Climbers; inland forests; rare; endemic
Rhamnaceae	
<i>Colubrina asiatica</i> (L.) Brongn.	Shrubs; mangroves and tidal or swamp forests; common
<i>Gouania andamanica</i> King	Climbers; inland forests; common; endemic
<i>G. leptostachya</i> DC.	Lianas; inland forests; common
<i>Ventilago madraspatana</i> Gaertn.	Climbers; coastal to evergreen forests; common
<i>Ziziphus oenophila</i> (L.) Mill.	Straggling shrubs; deciduous forests; scarce
Vitaceae	
<i>Ampelocissus barbata</i> (Wall.) Planch.	Climbers; tidal or swamp or inland forests; common
<i>Cayratia japonica</i> (Thunb.) Gagnep.	Climbers; inland forests; common
<i>C. trifolia</i> (L.) Domin	Climbers; inland forests; common
<i>Tetrastigma andamanicum</i> (King) Suesseng.	Climbers; edges of evergreen forests; scarce; endemic
Leeaceae	
<i>Leea aequata</i> L.	Shrubs; marshy or damp places; scarce
<i>L. guineensis</i> G. Don	Shrubs; damp areas; shaded places in inland forests; scattered

Table 1. Contd.

Name of Plant	Observations
<i>L. indica</i> (Burm.f.) Merr.	Shrubs; inland forests; common
Sapindaceae	
<i>Allophyllus cobbe</i> (L.) Raeusch.	Shrubs; tidal or swamp forests; edges of inland forests; common
<i>Dodonaea viscosa</i> Jacq.	Shrubs; tidal or swamp forests; scarce
<i>Ganophyllum falcatum</i> Blume	Trees; tidal or swamp forests; common
<i>Harpullia cupanoides</i> Roxb.	Trees; damp places near streams, inland forests; common
<i>Lepisanthes rubiginosa</i> (Roxb.) Leenh.	Trees; deciduous forests; common
<i>Pometia pinnata</i> J.R. Forst. & J.G.A. Forst.	Trees; evergreen forests; common
Anacardiaceae	
<i>Anacardium occidentale</i> L.	Planted
<i>Bouea oppositifolia</i> (Roxb.) Meisn.	Trees; evergreen forests; scarce
<i>Buchanania splendens</i> Miq.	Trees; evergreen forests; scattered
<i>Dracantomelon dao</i> (Blanco) Merr. & Rolfe	Trees; near streams, inland forests; scarce
<i>Lannea coromandelica</i> (Houtt.) Merr.	Trees; deciduous forests; common
<i>Mangifera andamanica</i> King	Trees; deciduous forests; scarce; endemic
<i>M. camptosperma</i> Pierre	Trees; inland forests; scarce
<i>Parishia insignis</i> Hook. f.	Trees; deciduous forests; scattered
<i>Semecarpus kurzii</i> Pierre	Trees; interior forests; common; endemic
<i>Spondias pinnata</i> (L.f.) Kurz	Trees; deciduous forests; scattered
Connaraceae	
<i>Cnestis palata</i> (Lour.) Merr.	Scandent shrubs; deciduous to inland forests; common
<i>Connarus semidecandrus</i> Jack	Scandent shrubs; inland forests; scarce
Fabaceae	
<i>Canavalia cathartica</i> Thou.	Climbers; inland forests; common
<i>Crotalaria retusa</i> L.	Herbs; roadsides; occasional
<i>Dalbergia canadensis</i> (Dennst.) Prain	Climbers; mangroves and tidal or swamp forests; scarce
<i>D. pinnata</i> (Lour.) Prain	Scandent shrubs; coastal forests; scarce
<i>Derris scandens</i> (Roxb.) Benth.	Climbers; coastal forests; common
<i>D. trifoliata</i> Lour.	Climbers; tidal or swamp forests; common
<i>Erythrina vareigata</i> L.	Trees; coastal forests; common
<i>Flemingia macrophylla</i> (Willd.) O. Kuntze	Shrubs; rheophytic; fairly common
<i>Mucuna gigantea</i> (Willd.) DC.	Climbers; coastal forests; common
<i>Pongamia pinnata</i> (L.) Pierre	Trees; sea shores; common
<i>Pterocarpus dalbergioides</i> Roxb. ex DC.	Trees; deciduous forests; very common; timber valuable; <i>Padauk</i>

Table 1. Contd.

Name of Plant	Observations
<i>Sophora tomentosa</i> L.	Trees; tidal or swamp forests; common
<i>Spatholobus acuminatus</i> Benth.	Climbers; mixed deciduous forests; scattered
<i>Strongylodon lucidus</i> (Forst.) Seem.	Climbers; coastal to evergreen forests; common
Caesalpiniaceae	
<i>Caesalpinia bonduc</i> (L.) Roxb. emend. Dandy & Exell	Climber; strandline, tidal or swamp forests; common
<i>C. crista</i> L.	Climbers; mangrove and tidal or swamp forests; common
<i>C. cucullata</i> Roxb.	Climbers; coastal forests; common
<i>Cynometra iripa</i> Kostel.	Trees; tidal or swamp forests; common
Mimosaceae	
<i>Acacia auriculiformia</i> A. Cunn. ex Benth.	Trees; roadsides; introduced
<i>Albizia chinensis</i> (Os.) Merr.	Trees; inland forests; fairly common
<i>A. lebbeck</i> (L.) Benth.	Trees; coastal forests; scarce; <i>Siris</i>
<i>Archidendron clypearea</i> (Jack) Nielsen var. <i>clypearea</i>	Trees; evergreen forests, often along streams; common
<i>Entada rheedei</i> Spreng.	Climbers; inland forests; common
Rosaceae	
<i>Prunus martabanica</i> Kurz	Scandent shrubs; inland forests; common
Rhizophoraceae	
<i>Bruguiera cylindrica</i> (L.) Blume	Trees; mangroves; common
<i>B. gymnorrhiza</i> (L.) Lam.	Trees; mangroves; common
<i>B. parviflora</i> (Roxb.) Griff.	Trees; mangroves; scarce
<i>Carallia brachiata</i> (Lour.) Merr.	Trees; inland forests; scarce
<i>Ceriops tagal</i> (Perr.) C.B. Rob.	Trees; mangroves; common
<i>Rhizophora apiculata</i> Blume	Trees; mangroves; very common
<i>R. mucronata</i> Lam.	Trees; mangroves; common
<i>R. stylosa</i> Griffith	Trees; mangroves; common
Combretaceae	
<i>Combretum latifolium</i> Blume	Climbers; coastal to evergreen forests; common
<i>C. yunnanense</i> Exell	Climbers; coastal and deciduous forests; common
<i>Lumnitzera littorea</i> (Jack) Voigt	Shrubs or trees; mangroves and tidal forests; common
<i>L. racemosa</i> Willd.	Shrubs or trees; mangroves, tidal forests and marshy areas; common
<i>Terminalia bialata</i> (Roxb.) Steud.	Tall trees; coastal and deciduous forests; common; seeds edible; <i>Safed chuglam</i>
<i>T. catappa</i> L.	Tall trees; coastal and deciduous forests; common; timber valuable; seeds edible; <i>Safed bombway</i>
<i>T. citrina</i> Roxb. ex Flem.	Tall trees; coastal and deciduous forests; common; fruits edible; <i>Kala chuglam</i>

Table 1. Contd.

Name of Plant	Observations
<i>T. procera</i> Roxb.	Tall trees; deciduous forests; common; timber valuable; <i>Safed bombway</i>
Myrtaceae	
<i>Acmenosperma claviform</i> (Roxb.) Kausel.	Trees; coastal and evergreen forests; often near mangroves; common
<i>Syzygium cumini</i> (L.) Skeels	Trees; interior forests; scarce
<i>S. kurzii</i> (Duthie) N.P. Balakr. var. <i>andamanica</i> (King) N.P. Balakr.	Trees; evergreen forests; rare; endemic
<i>S. samarangense</i> (Blume) Merr. & Perry	Trees; coastal forests; common
Lecythidaceae	
<i>Planchonia valida</i> (Blume) Blume	Trees; deciduous and evergreen forests; common; <i>Lal bombway</i>
Barringtoniaceae	
<i>Barringtonia asiatica</i> (L.) Kurz	Trees; coastal; common
<i>B. racemosa</i> (L.) Spreng.	Trees; coastal, near mangroves and brackish water; common
Melastomataceae	
<i>Melastoma malabathricum</i> L.	Shrubs; hill slopes in interior forests; scarce
Memecylaceae	
<i>Memecylon andamanicum</i> King	Trees; deciduous forests; scarce
<i>M. angustifolium</i> Wight	Trees; streamsides; scarce
<i>M. caeruleum</i> Jack	Trees; deciduous forests; scarce
Lythraceae	
<i>Lagerstroemia hypoleuca</i> Kurz	Trees; deciduous forests; scattered; endemic; timber useful
<i>L. indica</i> L.	Trees; roadsides; introduced
<i>Pemphis acidula</i> J.R. Forst. & J.G.A. Forst.	Trees; mangroves; common
Sonneratiaceae	
<i>Duabanga grandiflora</i> (Roxb. ex DC.) Walp.	Tall trees; deciduous forests; scarce; timber useful
<i>Sonneratia alba</i> J. Sm.	Trees; mangroves; scarce
<i>S. caseolaris</i> (L.) Druce	Trees; mangroves; common
Crypteroniaceae	
<i>Crypteronia paniculata</i> Blume	Tall trees; evergreen forests; scarce
Cucurbitaceae	
<i>Gymnopetalum quinquelobus</i> Miq.	Climbers; deciduous forests; scarce
<i>Trichosanthes bracteata</i> (Lam.) Voigt	Climbers; deciduous forests; scattered
<i>T. tricuspidata</i> Lour.	Climbers; inland forests; common
Datiscaceae	
<i>Tetrameles nudiflora</i> R. Br. ex Benn.	Trees; deciduous forests; scarce

Table 1. Contd.

Name of Plant	Observations
Araliaceae	
<i>Arthrophyllum diversifolium</i> Blume	Trees; coastal forests; scarce
Alangiaceae	
<i>Alangium salviifolium</i> (L.f.) Wangerin	Climbers; deciduous and evergreen forests; common
Rubiaceae	
<i>Canthium glabrum</i> Blume	Trees; inland forests; frequent
<i>C. gracilipes</i> Kurz	Shrubs; deciduous forests; scattered; endemic
<i>Guettarda speciosa</i> L.	Trees; tidal or swamp forests; common
<i>Hedyotis corymbosa</i> L.	Herbs; moist places; scarce
<i>H. paradoxa</i> Kurz	Herbs; marshy areas; rare; endemic
<i>Ixora barbata</i> Roxb. ex J.E. Smith	Shrubs; inland forests; scarce; endemic
<i>I. brunnescens</i> Kurz	Trees; coastal forests; common
<i>I. cuneifolia</i> Roxb.	Shrubs; evergreen forests; common
<i>I. finlaysoniana</i> Wall. ex G. Don	Trees; deciduous forests; scarce
<i>I. grandifolia</i> Zoll. & Mor.	Shrubs; deciduous to evergreen forests; common
<i>Mitragyna rotundifolia</i> (Roxb.) O. Kuntze	Trees; inland forests; scarce
<i>Morinda citrifolia</i> L.	Trees; tidal or swamp forests; common
<i>Mussaenda frondosa</i> L.	Shrubs or trees; hill slopes, evergreen forests; common
<i>M. macrophylla</i> Wall.	Shrubs; damp inland forests; common
<i>Neolamarckia cadamba</i> (Roxb.) Bosser	Trees; deciduous forests; common
<i>Neonauclea calycina</i> (DC.) Merr.	Small trees; evergreen forests; scarce; endemic
<i>N. gageana</i> (King) Merr.	Trees; deciduous forests; common; endemic
<i>Ophiorrhiza mungos</i> L.	Herbs; forming mats in sunny places and roadsides; scarce
<i>Oxyceros longiflora</i> (Lam.) Yamazaki	Shrubs; secondary forests; common
<i>Pavetta indica</i> L.	Trees; margins of evergreen forests; common
<i>Psychotria adenophylla</i> Wall.	Shrubs; deciduous forests; scarce
<i>P. platyneura</i> Kurz	Shrubs; deciduous forests; common; endemic
<i>Pubistylus andamanensis</i> Thoth.	Trees; evergreen forests; scarce; endemic
<i>Scyphiphora hydrophyllacea</i> Gaertn.f.	Trees; mangroves; frequent
<i>Tarena weberaefolia</i> (Kurz) N.P. Balakr.	Shrubs; coastal forests; scarce; endemic
<i>Timonius flavescens</i> (Jack) Baker	Trees; evergreen forests; scarce
<i>Webera wallichii</i> Hook.f.	Trees; coastal forests; scattered
Asteraceae	
<i>Ageratum conyzoides</i> L.	Weed; waste places; scarce
<i>Blumea junghuhniana</i> (Miq.) Boerl.	Undershrubs; secondary formations; scarce
<i>Chromolaena odoratum</i> (L.) R.M. King & H. Robinson	Climbers; secondary formations, roadsides; introduced.

Table 1. Contd.

Name of Plant	Observations
<i>Mikania cordata</i> (Burm.f.) R.L. Robins.	Climbers; introduced; occasional
<i>Pluchea indica</i> (L.) Less.	Shrubs; coastal forests; common
<i>Spilanthes paniculata</i> Wall. ex DC.	Herbs; roadsides, waste places; scarce
<i>Wedelia biflora</i> (L.) DC.	Straggling herbs; tidal or swamp forests; abundant
Goodeniaceae	
<i>Scaevola taccada</i> (Gaertn.) Roxb.	Shrubs; tidal or swamp forests; frequent
Myrsinaceae	
<i>Ardisia oxyphylla</i> Wall. ex DC.	Trees; evergreen forests; common
<i>A. solanacea</i> Roxb.	Shrubs; evergreen forests; scattered
<i>Embelia ribes</i> Burm.f.	Climbers; evergreen forests; common
<i>E. viridiflora</i> (A.DC.) Scheff.	Climbers; evergreen forests; common
<i>Maesa andamanica</i> Kurz	Straggling shrubs; deciduous forests; scarce; endemic
Sapotaceae	
<i>Diploknema butyracea</i> (Roxb.) Lam.	Trees; deciduous and evergreen forests; frequent
<i>Manilkara littoralis</i> (Kurz) Dubbard	Trees; beach or tidal or swamp forests; common; endemic; <i>Mohwa</i>
<i>Mimusops andamanensis</i> King & Gamble	Trees; coastal forests; scarce; endemic
<i>M. elengi</i> L.	Trees; evergreen forests; scattered
<i>Sideroxylon ferrugineum</i> Hook. & Arn.	Trees; coastal forests; scarce
Ebenaceae	
<i>Diospyros andamanica</i> (Kurz) Bakh.	Shrubs; deciduous forests; rare
<i>D. cordifolia</i> Blume	Trees; deciduous forests; scarce
<i>D. crumenata</i> Thwaites	Trees; coastal to inland forests; scarce
<i>D. kurzii</i> Hiern	Trees; deciduous forests; frequent; fruits edible
<i>D. montana</i> Roxb.	Trees; deciduous forests; common
<i>D. oocarpa</i> Thw.	Trees; deciduous forests; common; <i>Kala lakri</i>
<i>D. pilosiuscula</i> G. Don	Trees; deciduous forests; common; <i>Tendu</i>
Oleaceae	
<i>Chionanthus mala-elengi</i> (Dennst.) P.S. Green ssp. <i>terniflorus</i> (Wall. ex D. Don) P.S. Green	Trees; deciduous forests; scarce
<i>C. parkinsonii</i> (Hutch.) Bennet & Raizada	Trees; deciduous forests; frequent
<i>Jasminum caudatum</i> Wall. ex Lindl.	Scandent shrubs; coastal to deciduous forests; scarce
<i>Myxopyrum smilacifolium</i> (Wall.) Blume	Scandent shrubs; tidal or swamp forest; scarce
Apocynaceae	
<i>Aganosma marginata</i> (Roxb.) G. Don	Climbers; evergreen forests; fairly common
<i>Alstonia kurzii</i> Hook.f.	Trees; deciduous forests, common; endemic
<i>A. macrophylla</i> Wall. ex G. Don	Shrubs or trees; deciduous and evergreen forests; scarce

Table 1. Contd.

Name of Plant	Observations
<i>Anodendron paniculatum</i> (Roxb.) DC.	Climbers; deciduous to evergreen forests; common
<i>Carissa spinarum</i> L.	Shrubs; coastal forests; scattered
<i>Cerbera odollam</i> Gaertn.	Trees; sea shores and mangroves; common
<i>Chonemorpha fragrans</i> (Moon) Alston	Liana; mangroves and coastal forests; common
<i>Hunteria zeylanica</i> (Retz.) Gardn. ex Thw.	Trees; evergreen forests; scarce
<i>Ichnocarpus frutescens</i> (Lour.) Merr.	Scandent shrubs; edges of forests; scattered
<i>Kopsia arborea</i> Blume	Trees; semideciduous and evergreen forests; common
<i>Ochrosia oppositifolia</i> (Lam.) K. Schum.	Shrubs or trees; tidal and coastal forests; common
<i>Parameria laevigata</i> (A. Juss.) Moldenke	Climbers; evergreen forests; common
<i>Parsonsia alboflavescens</i> (Dennst.) Mab.	Climbers; tidal and coastal forests; common
<i>Rhynchodia rhynchosperma</i> (Wall.) K. Schum.	Climbers; evergreen forests; scarce
<i>Stropanthus wallichii</i> DC.	Climbers; coastal or evergreen forests; fairly common
<i>Tabernaemontana crispa</i> Roxb.	Shrubs or trees; coastal to evergreen forests, often along streams; common; endemic
Asclepiadaceae	
<i>Cryptolepis buchananii</i> Roem. & Schult.	Climbers; coastal forests; common
<i>Dischidia benghalensis</i> Colebr.	Epiphytes; inland forests; common
<i>D. nummularia</i> R. Br.	Epiphytes; inland forests; scarce
<i>Hoya parasitica</i> Wall.	Epiphytes; mangroves and near streams; common
<i>Pergularia daemia</i> (Forssk.) Choiv.	Climbers; interior forests; scarce
<i>Tylophora indica</i> (Burm.f.) Merr.	Climbers; evergreen forests; common
<i>Wattakaka volubilis</i> (L.f.) Stapf	Twining; deciduous forests; scattered
Loganiaceae	
<i>Fagraea fragrans</i> Roxb.	Trees; evergreen forests; scattered
<i>F. racemosa</i> Jack	Trees; evergreen forests; common
Boraginaceae	
<i>Cordia grandis</i> Roxb.	Trees; deciduous forests; scarce
<i>C. subcordata</i> Lam.	Trees; tidal or swamp forests; frequent
<i>Tournefortia argentea</i> L.f.	Trees; coastal forests; scattered
<i>T. ovata</i> Wall. ex G. Don	Climbers; coastal forests; scarce
Convolvulaceae	
<i>Argyreia capitata</i> (Vahl) Choisy	Climbers; coastal forests; common
<i>A. hookeri</i> C.B. Clarke	Climbers; deciduous forests; scarce
<i>Ipomoea campanulata</i> L.	Climbers; deciduous forests; common
<i>I. gracilis</i> R. Br.	Procumbent herbs; coastal forests; scarce
<i>I. pes-caprae</i> (L.) R. Br.	Creepers; on sandy beaches; common
<i>Merremia peltata</i> (L.) Merr.	Climbers; secondary formations; scarce
<i>Operculina rideliana</i> (Oliv.) van Ooststr.	Climbers; beach forests; fairly common

Table 1. Contd.

Name of Plant	Observations
Scrophulariaceae	
<i>Lindernia antipoda</i> (L.) Alston	Decumbent herbs; roadsides, waste places; occasional
<i>Mecardonia procumbens</i> (Mill.) Small	Creeping herbs; roadsides, waste places; occasional
Gesneriaceae	
<i>Aeschynanthus griffithii</i> R.Br.	Scandent shrubs; inland forests; scarce
Bignoniaceae	
<i>Dolichadrone spathacea</i> (L.f.) K. Schum.	Trees; sea shores and near mangroves; frequent
<i>Oroxylum indicum</i> (L.) Kurz	Trees; deciduous forests; common
<i>Pajanelia longifolia</i> (Willd.) K. Schum.	Tall trees; deciduous forests; frequent; <i>Jhingan</i>
<i>Tecoma stans</i> (L.) H. B. & K.	Trees; deciduous forests; scarce
Acanthaceae	
<i>Acanthus ebracteatus</i> Vahl	Shrubs; mangroves; common
<i>A. illicifolius</i> L.	Shrubs; mangroves; common
<i>A. volubilis</i> Wall.	Climbers; tidal or swamp forests; scarce
<i>Hygrophila erecta</i> (Burm.f.) Hochr.	Herbs; marshy areas; scarce
<i>Hypoestes andamanensis</i> Thoth.	Herbs; interior forest floors; scarce; endemic
<i>Justicia gendarusa</i> Burm.f.	Shrubs; waste places, roadsides; scarce
<i>Mananthes sumatrana</i> (Miq.) Bremek.	Shrubs; marshy areas; scarce
<i>Pseuderanthemum album</i> (Roxb.) Merr.	Herbs; evergreen forest floors; scattered
Thunbergiaceae	
<i>Thunbergia laurifolia</i> Lindl.	Climbers; mixed forests; scattered
Verbenaceae	
<i>Callicarpa longifolia</i> Lam.	Scandent; deciduous forests; scarce
<i>Clerodendrum inerme</i> (L.) Gaertn.	Shrubs, near coast, roadsides; occasional
<i>C. infortunatum</i> L.	Shrubs; evergreen forest undergrowths; abundant
<i>Premna corymbosa</i> (Burm.f.) Rottl. ex Willd.	Trees; tidal or swamp forests; common
<i>Vitex glabrata</i> R. Br.	Trees; deciduous forests; scarce; <i>Jungli pyinma</i>
Avicenniaceae	
<i>Avicennia officinalis</i> L.	Trees; tidal or swamp forests; frequent
Lamiaceae	
<i>Anisomeles indica</i> (L.) O. Kuntze	Herbs; waste places; scarce
<i>Hyptis brevipes</i> Poiret	Herbs; roadsides; few
<i>Pogostemon auricularis</i> (L.) Hassk.	Herbs; marshy areas; scarce
Nyctaginaceae	
<i>Pisonia umbellifera</i> (J.R. Forst. & J.G.A. Forst.) Seem.	Trees; coastal to evergreen forests; abundant
Aristolochiaceae	
<i>Thottea tomentosa</i> (Blume) Ding Hou	Creepers; inland forests; scattered

Table 1. Contd.

Name of Plant	Observations
Piperaceae	
<i>Piper betle</i> L.	Twining; evergreen forests; scattered; <i>Pan</i>
<i>P. sarmentosum</i> Roxb.	Twining; coastal to evergreen forests; common
Myristicaceae	
<i>Endocomia macrocoma</i> (Miq.) de Wilde ssp. <i>prainii</i> (King) de Wilde	Trees; deciduous and evergreen forests; scattered
<i>Horsfieldia glabra</i> (Blume) Warb.	Trees; deciduous forests; rare
<i>H. irya</i> (Gaertn.) Warb.	Tall trees; beach forests; abundant
<i>Knema andamanica</i> (Warb.) de Wilde	Trees; inland forests; scarce; endemic
<i>Myristica andamanica</i> Hook.f.	Shrubs; inland forests; very common; endemic
Monimiaceae	
<i>Kibara coriacea</i> (Blume) Tul.	Trees; evergreen forests; scarce
Lauraceae	
<i>Beilschmiedia roxburghiana</i> Nees	Tall trees; evergreen forests; scarce
<i>Cryptocarya ferrarsi</i> King ex Hook.f.	Shrubs or trees; inland hill forests; scarce
<i>C. wightiana</i> Thwaites	Trees; evergreen hill forests; scarce
<i>Litsea glutinosa</i> (Lour.) C.B. Robinson	Trees; coastal to inland forests; common
<i>L. kurzii</i> King ex Hook.f.	Trees; evergreen forests; common; endemic
<i>L. panamonja</i> (Nees) Hook.f.	Trees; along streams; scarce
<i>Neolitsea cassia</i> (L.) Kosterm.	Shrubs or trees; coastal forests; scattered.
Hernandiaceae	
<i>Hernandia peltata</i> Meissn.	Trees; coastal; common
Loranthaceae	
<i>Dendrophoe falcata</i> (L.f.) Blume	Shrubs; evergreen forests; scarce
<i>Macrosolon ampuliacens</i> (Roxb.) Blume	Shrubs; inland forests; scarce
Euphorbiaceae	
<i>Actephila excelsa</i> (Dalzell) Muell. Arg. var. <i>excelsa</i>	Shrubs or trees; coastal to evergreen forests; very common
var. <i>puberula</i> (Kurz) Pax & K. Hoffm.	Shrubs or trees; coastal to evergreen forests; common; endemic
<i>Antidesma bhargavae</i> Chakrab. & N.P. Balakr.	Shrubs or trees; evergreen forests; scarce; endemic
<i>A. buniis</i> (L.) Spreng.	Shrubs or trees; inland forests; common
<i>A. montanum</i> Blume	Shrubs or trees; coastal forests; scarce
<i>A. puncticulatum</i> Miq.	Trees; coastal to inland forests; common
<i>A. velutinum</i> Tul.	Shrubs or trees; coastal to evergreen forests; common
<i>Aporosa octandra</i> (Buch.Ham. ex D. Don) A.R. Vickery	Shrubs or trees; evergreen forests, often near streams; very common
<i>Baccaurea ramiflora</i> Lour.	Trees; inland evergreen forests; common; fruits edible

Table 1. Contd.

Name of Plant	Observations
<i>Bischofia javanica</i> Blume	Trees; deciduous forests, near streams; scarce; timber useful
<i>Blachia andamanica</i> (Kurz) Hook.f. ssp. <i>andamanica</i>	Shrubs; coastal to evergreen forests; common
<i>Breynia vitis-idaea</i> (Burm.f.) C.E.C. Fischer	Shrubs or small trees; beach forests; common
<i>Bridelia ovata</i> Decne.	Shrubs, often scandent; coastal to evergreen forests; common
<i>B. stipularis</i> (L.) Blume	Scandent shrubs; deciduous forests; scattered
<i>B. tomentosa</i> Blume var. <i>tomentosa</i>	Shrubs or trees; coastal forests, scrub, inland forests; common
<i>Claoxylon indicum</i> (Reinw. ex Blume) Hassk.	Shrubs or trees; coastal to evergreen forests; common
<i>Cleidion javanicum</i> Blume	Trees; marshy areas in inland forests or streamsides; common
<i>C. nitidum</i> (Muell.Arg.) Kurz	Shrubs or trees; deciduous to evergreen forests; scattered.
<i>Cleistanthus oblongifolius</i> (Roxb.) Muell. Arg.	Trees; deciduous to evergreen forests; common
<i>Cnesmone javanica</i> Blume var. <i>javanica</i>	Twining; inland forests; fairly common
<i>Croton argyratus</i> Blume	Shrubs or trees; deciduous to evergreen forests; common; timber used for firewood or construction of hut
<i>C. sublyratus</i> Kurz	Trees; coastal to inland hill forests; scattered
<i>Dimorphocalyx balakrishnanii</i> Chakrab. & Premanath	Scandent shrubs; coastal to evergreen forests; rare
<i>Drypetes andamanica</i> (Kurz) Pax & K. Hoffm.	Trees; semievergreen forests; rare; endemic
<i>D. longifolia</i> (Blume) Pax & K. Hoffm.	Trees; evergreen forests; scattered
<i>Euphorbia hirta</i> L.	Ascending herbs; waste places, roadsides, edges of forests; common
<i>E. pallens</i> Dillwyn	Herbs; ascending; sandy beaches; occasional
<i>Excoecaria agallocha</i> L.	Shrubs or trees; sea shores and mangroves; common
<i>Flueggea virosa</i> (Roxb. ex Willd.) Voigt	Shrubs; coastal to evergreen forests; common
<i>Glochidion andamanicum</i> Kurz var. <i>andamanicum</i>	Trees; evergreen forests; rare; endemic
<i>G. jarawae</i> Chakrab. & N.P. Balakr.	Trees; beach forests; rare; endemic
<i>G. subsessile</i> N.P. Balakr. & Chakrab.	Trees; evergreen forests; rare; endemic
<i>G. zeylanicum</i> (Gaertn.) A. Juss. var. <i>arborescens</i> (Blume) Chakrab. & M. Gangop.	Shrubs or trees; deciduous to evergreen forests; scattered
var. <i>paucicarpum</i> Chakrab. & N.P. Balakr.	Shrubs; inland forests; scarce; endemic
var. <i>tomentosum</i> (Dalzell) Trimen	Bush or trees; deciduous to evergreen forests; common

Table 1. Contd.

Name of Plant	Observations
<i>Homonoia riparia</i> Lour.	Rheophytic shrubs; on stream beds; common
<i>Macaranga andamanica</i> Kurz	Shrubs or trees; edges of evergreen forests; rare
<i>M. peltata</i> (Roxb.) Muell.Arg.	Trees; coastal to evergreen forests; very common
<i>M. tanarius</i> (L.) Muell.Arg.	Trees; coastal to evergreen forests; very common
<i>Mallotus peltatus</i> (Geisel.) Muell.Arg.	Shrubs; edges of evergreen forests; very common
<i>M. philippensis</i> (Lam.) Muell.Arg.	Trees; mixed or evergreen forests; scarce
<i>M. resinosus</i> (Blanco) Merr. var. <i>resinosus</i>	Shrubs or trees; coastal and evergreen forests; common
<i>Manihot esculenta</i> Crantz	Shrubs; cultivated for the edible roots
<i>Phyllanthus amarus</i> Schum. & Thonn.	Herbs; waste places; scarce
<i>P. reticulatus</i> Poir.	Scandent shrubs; coastal forests; scattered
<i>Suregada multiflora</i> (A. Juss.) Bail.	Shrubs or trees; coastal to deciduous forests; common
<i>Trigonostemon aurantiacus</i> (Kurz ex Teijsm. & Binnend.) Boerl.	Shrubs; edges of evergreen forests; scattered
<i>T. viridissimus</i> (Kurz) Airy Shaw	Shrubs; coastal to evergreen forests; common
Urticaceae	
<i>Bohemeria nivea</i> (L.) Gaud.	Shrubs; tidal or swamp forests; common
<i>Elatostema integrifolium</i> (D. Don) Wedd.	Herbs; inland forest floors; scattered
Moraceae	
<i>Antiaris toxicaria</i> (Pers.) Lenchen.	Trees; deciduous forests; common; <i>Jungli lakuch</i>
<i>Artocarpus chaplasha</i> Roxb.	Trees; deciduous forests; common; fruits and seeds edible; <i>Kathal</i>
<i>A. gomeziana</i> Wall. ex Trec.	Trees; evergreen forests; common; <i>Kala lakuch</i> , <i>Bara lakuch</i>
<i>A. heterophyllus</i> Lam.	
<i>A. lakoocha</i> Buch. Ham.	Trees; evergreen forests; common; fruits and seeds edible; <i>Barhal</i>
<i>Ficus benjamina</i> L.	Tall trees; inland forests; scarce
<i>F. brevicuspis</i> Miq.	Trees; deciduous forests; scattered
<i>F. hispida</i> L.f.	Trees; deciduous forests, along streams; frequent
<i>F. nervosa</i> Heyne ex Roth	Trees; evergreen forests; scarce
<i>F. rumphii</i> Blume	Tall trees; deciduous forests; abundant
<i>Plecospermum andamanicum</i> King	Climbers; deciduous forests; frequent; <i>Badmas kanta</i>
<i>Streblus asper</i> Lour.	Trees; deciduous forests; common; <i>Choroot pathi</i>
Ulmaceae	
<i>Gironniera subaequalis</i> Planch.	Trees; evergreen forests; scarce
<i>Trema tomentosa</i> (Roxb.) Hara	Trees; deciduous forests; abundant
Monocotyledons	
Orchidaceae	
<i>Aerides multiflorum</i> Roxb.	Epiphytes; inland forests; fairly common

Table 1. Contd.

Name of Plant	Observations
<i>Bulbophyllum careyanum</i> (Hook.) Spreng.	Epiphytes; inland forests; common
<i>B. lepidum</i> (Blume) J.J. Smith	Epiphytes; coastal forests; common
<i>Calanthe triplicata</i> (Willmet) Ames	Terrestrial; evergreen forests; scattered
<i>Coelogyne trinervis</i> Lindl.	Epiphytes; evergreen forests; common
<i>Corymborkis veratifolia</i> (Reinw.) Blume	Terrestrial; coastal to evergreen forests; common
<i>Cymbidium aloefolium</i> (L.) Sw.	Epiphytes; tidal or swamp forests; scattered
<i>Dendrobium anceps</i> Swartz	Epiphytes; coastal forests; scarce
<i>D. aphyllum</i> (Roxb.) C.E.C. Fischer	Epiphytes; coastal to evergreen forests; common
<i>D. crumenatum</i> Swartz	Epiphytes; coastal to evergreen forests; scarce
<i>D. formosum</i> Roxb. ex Lindl.	Epiphytes; coastal forests; scattered
<i>D. secundum</i> (Blume) Lindl.	Epiphytes; coastal forests; scarce
<i>D. tenuicaule</i> Hook.f.	Epiphytes; inland forests; scarce
<i>Eria andamanica</i> Hook.f.	Epiphytes; coastal to evergreen forests; common; endemic
<i>Geodorum densiflorum</i> (Lam.) Schecht.	Terrestrial; inland forests; scarce
<i>Papilionanthe teres</i> (Roxb.) Schltr.	Epiphytes; evergreen forests; scattered
<i>Pholidota imbricata</i> (Roxb.) Lindl.	Epiphytes; coastal forests; common
<i>Pomatocalpa wendlandorum</i> (Reichb. f.) J.J. Sm.	Epiphytes; evergreen forests; common
<i>Rhyncostylis retusa</i> (L.) Blume	Epiphytes; coastal to inland forests; common
<i>Vanilla albida</i> Blume	Climbers; inland forests; common
<i>V. andamanica</i> Rolfe	Epiphytes; evergreen forests; scattered; endemic.
<i>Zeuxine nervosa</i> (Wall. ex Lindl.) Trimen	Terrestrial; evergreen forests; common
Costaceae	
<i>Costus speciosus</i> (Koen.) J.E. Smith	Undershrubs; coastal to inland forests; common
Zingiberaceae	
<i>Amomum aculeatum</i> Roxb.	Undershrubs; hill slopes and moist evergreen forests; common
Marantaceae	
<i>Actoplanes canniformis</i> (Forst.) K. Schum.	Bamboo-like herbs; stream sides, inland forests; common
<i>Phrynium pubinerva</i> Blume	Tall herbs; inland forests, hill slopes; common
Musaceae	
<i>Musa paradisiaca</i> L.	Cultivated
<i>M. sapientum</i> L.	Damp places; scattered; <i>Jungli kela</i>
Amaryllidaceae	
<i>Crinum asiaticum</i> L.	Shrubs; sea shores; common
<i>C. latifolium</i> L.	Herbs; coastal forests; common
Taccaceae	
<i>Tacca leontopetaloides</i> (L.) O. Kuntze	Herbs; near coasts; scattered

Table 1. Contd.

Name of Plant	Observations
Dioscoreaceae	
<i>Dioscorea bulbifera</i> L.	Twiners; evergreen forests; scattered; tuber edible
<i>D. glabra</i> Roxb.	Twiners; inland forests; common; tuber edible
<i>D. pentaphylla</i> L.	Climbers; coastal areas; scarce
<i>D. vexans</i> Prain & Burkill	Climbers; inland forests; scarce; endemic
Liliaceae	
<i>Gloriosa superba</i> L.	Tuberous herbs; coastal forests; common
Smilacaceae	
<i>Smilax bracteata</i> Presl. var. <i>verruculosa</i> (Merr.) T. Koyama	Climbing shrubs; inland forests; common
Dracaenaceae	
<i>Dracaena angustifolia</i> Roxb.	Shrubs; evergreen forests; common
<i>D. elliptica</i> Thunb.	Shrubs; evergreen forests; common
Commelinaceae	
<i>Aneilema ovatum</i> (Hassk.) C.B. Clarke	Herbs; roadsides, edges of forests, scarce
<i>Murdannia nudiflora</i> (L.) Brenan	Herbs; inland forest floors; scattered
<i>Polia secundiflora</i> (Blume) Backer	Tall herbs; inland forest floors; common
Flagellariaceae	
<i>Flagellaria indica</i> L.	Climbers; near coasts; common
Arecaceae	
<i>Areca catechu</i> L.	Trees; cultivated and naturalized; <i>Supari</i>
<i>A. triandra</i> Roxb.	Trees; coastal to inland forests; common; <i>Jangli supari</i>
<i>Calamus andamanicus</i> Kurz	Climbing shrubs; deciduous to evergreen forests; common endemic; provides water during emergency; <i>Mota bet</i> ; <i>Pani bet</i>
<i>C. baratangensis</i> Renuka & Vijayakumaran	Scandent shrubs; inland forests; scarce; endemic
<i>C. longisetus</i> Griffith	Climbing shrubs; deciduous to evergreen forests; common; endemic; <i>Jungli beth</i>
<i>C. palustris</i> Griffith	Scandent or climbing shrubs; inland forests; scattered; fruits edible; <i>Malai beth</i>
<i>C. viminalis</i> Willd.	Scandent shrubs; evergreen forests; common; fruits edible
<i>Caryota mitis</i> Lour.	Trees; evergreen forests; common; endemic; <i>Meri supari</i>
<i>Cocos nucifera</i> L.	Trees; cultivated; <i>Nariyal</i>
<i>Daemonorops kurzianus</i> Becc.	Scandent climbing shrubs; coastal and evergreen forests; rare; endemic
<i>D. manii</i> Becc. & Hook.f.	Climbers; evergreen forests; common; endemic
<i>Korthalsia laciniosa</i> (Griffith) Mart.	Scandent climbers; evergreen forests; common; <i>Lalbeth</i>
<i>Licuala macrophylla</i> Roxb. ex Hornem.	Shrubs; inland forests; scarce

Table 1. Contd.

Name of Plant	Observations
<i>L. peltata</i> Roxb.	Herbs or shrubs; coastal to inland forests; common; <i>Silai patti</i>
<i>L. spinosa</i> Thunb.	Shrubs; evergreen forests; common
<i>Nypa fruticans</i> Wurmb.	Shrubs with short stems; along streams, mangroves and creeks; common
<i>Phoenix paludosa</i> Roxb.	Trees; tidal forests, edges of mangroves; common; <i>Khajur</i>
<i>Pinanga andamanensis</i> Becc.	Trees; evergreen forests; rare; endemic
<i>P. manii</i> Becc.	Trees; evergreen forests; scattered; endemic
Pandanaceae	
<i>Freycinetia insignis</i> Blume	Climbers; evergreen forests; common
<i>Pandanus andamanensis</i> Kurz	Trees; coastal forests or near streams; scarce; endemic; fruits eaten
<i>P. leram</i> Jones	Trees; tidal or swamp forests or near streams; common; fruits edible.
<i>P. tectorius</i> Soland.	Trees; coastal forests or near streams; common
Araceae	
<i>Alôcasia decipiens</i> Schott	Herbs; hill slopes, forest floors; scattered
<i>Colocasia esculenta</i> (L.) Schott	Herbs; hill slopes, roadsides, marshy areas; common
<i>Pothos scandens</i> L.	Climbing shrubs; inland forests; common
Eriocaulaceae	
<i>Eriocaulon truncatum</i> Buch.Ham. ex Mart.	Scapigerous herbs; marshy areas; scarce
Cyperaceae	
<i>Cyperus cephalotes</i> Vahl	Perennial herbs; roadsides, cleared areas, waste places; common
<i>C. compactus</i> Retz.	Herbs; marshes near sea; wetlands; common
<i>C. compressus</i> L.	Herbs; waste places, roadsides; common
<i>C. distans</i> L.f.	Perennial herbs; marshy areas, roadsides; common
<i>C. laxus</i> Lam.	Herbs; shaded places, hill slopes, pathways; scattered
<i>C. javanicus</i> Hoult.	Perennial herbs; coasts, backwaters, marshy areas; common
<i>C. pilosus</i> Vahl	Perennial herbs; wetlands, paddy fields, secondary formations; common
<i>C. rotundus</i> L.	Perennial herbs; weed in borders of the Reserve; scattered
<i>Fimbristylis acuminata</i> Vahl	Perennial herbs; wetlands and marshy areas; scarce
<i>F. miliacea</i> (L.) Vahl	Annual herbs; swamps, wetlands, paddy fields; common
<i>F. quinquangularis</i> (Vahl) Kunth	Annual herbs; marshy areas, wetlands; common
<i>Kyllinga brevifolia</i> Rottb.	Perennial herbs; waste places, roadsides, secondary formations; scarce

Table 1. Contd.

Name of Plant	Observations
<i>Pycreus polystachyos</i> (Rottb.) Beauv.	Annual herbs; marshy areas; common
<i>Rhynchospora corymbosa</i> (L.) Britt.	Perennial herbs; marshy areas; near paddy fields and streams; scarce
<i>R. rubra</i> (Lour.) Makino	Annual herbs; secondary formations, roadsides; scarce
<i>Schoenoplectus lateriflorus</i> (Gmel.) Lye	Annual herbs; wetlands, ditches; scarce
<i>Scleria levis</i> Retz.	Perennial herbs; borders of forests; scarce
Poaceae	
<i>Apluda mutica</i> L.	Herbs; waste places, streamsides; common
<i>Aristida adscendens</i> L.	Herbs; roadsides, waste places, hill slopes; common
<i>Bambusa lineata</i> Munro	Bamboos; coastal forests; common
<i>Brachiaria distachya</i> (L.) Stapf	Annual herbs; roadsides, shores, waste places; common
<i>B. miliiformis</i> (C. Presl.) A. Chase	Perennial herbs; waste places, near beaches; common
<i>Cenchrus setigerus</i> Vahl	Annual herbs; roadsides, waste places, secondary formations; common
<i>Chrysopogon aciculatus</i> (Retz.) Trin.	Perennial herbs; roadsides, edges of forests, near villages, waste places; common
<i>Coix lacryma-jobi</i> L.	Annual herbs; near water courses, damp places; scarce
<i>Cynodon dactylon</i> (L.) Pers.	Perennial herbs; roadsides, cleared areas, waste places, cultivated fields; common
<i>Cyrtococcum longipes</i> (Wight & Arn. ex Hook.f.) A. Camus	Perennial herbs; edges of forests; scarce
<i>Dactyloctenium aegyptium</i> (L.) P. Beauv.	Annual herbs; roadsides, fields, cleared areas; common
<i>Dichanthium annulatum</i> (Forssk.) Stapf	Perennial herbs; roadsides, waste places, hill slopes; common
<i>Digitaria bicornis</i> (Lam.) Roem. & Schult.	Annual herbs; roadsides, waste places, sea shores; scattered
<i>D. ciliaris</i> (Retz.) Koel.	Annual herbs or undershrubs; waste places, near beaches, roadsides; common
<i>Dinochloa scandens</i> (Nees) O. Kuntze	Scandent bamboos; coastal to inland forests; common
<i>Echinochloa colonum</i> (L.) Link	Annual herbs; waste places; clearings, edges of forests, near cultivated fields; common
<i>Eleusine indica</i> (L.) Gaertn.	Annual herbs; roadsides, waste places, cleared areas, edges of forests; common
<i>Eragrostis tenella</i> (L.) P. Beauv.	Annual herbs; waste places, roadsides, paddy fields, edges of forests; fairly common
<i>E. unioides</i> (Retz.) Nees ex Steud.	Annual herbs; roadsides, waste places, near beaches, edges of forests; common
<i>Isachne globosa</i> (Thunb.) O. Kuntze	Annual herbs; marshy areas; scarce
<i>I. miliacea</i> Roth ex Roem. & Schult.	Annual herbs; marshy areas; common

Table 1. Contd.

Name of Plant	Observations
<i>Oplismenus compositus</i> (L.) P. Beauv.	Perennial herbs; roadsides, edges of forests; common
<i>Oxytenanthera nigrociliata</i> Monro	Bamboos; coastal to inland forests; common
<i>Panicum antidotale</i> Retz.	Perennial undershrubs; sandy beaches; scarce
<i>P. repens</i> L.	Perennial herbs; low areas, fields; scarce
<i>Paspalum conjugatum</i> Berg.	Perennial herbs; along streams, moist places; common
<i>P. scorbiculatum</i> L.	Annual herbs; roadsides, edges of forests; scarce
<i>Pennisetum polystachyon</i> (L.) Scult.	Annual undershrubs; roadsides, waste places, secondary formations; common
<i>Rottboellia cochinchinensis</i> (Lour.) W.D. Clayton	Annual herbs or undershrubs; roadsides, damp places, borders of forests; common
<i>Sacciolepis indica</i> (L.) A. Camus	Annual herbs; damp areas, edges of forests; common
<i>Themeda triandra</i> Forssk.	Perennial herbs or undershrubs; was places, hill slopes, near paddy fields; common
<i>Thysanolaena maxima</i> (Roxb.) O. Kuntze	Perennial undershrubs; roadsides, coastal forests; scarce

Table 2. Floristic Analysis

Group	Families	Genera	Species	Subspecies / varieties
Pteridophytes	11	12	15	
Gymnosperms	2	2	3	
Angiosperms				
Dicotyledons	86	277	389	3
Monocotyletons	19	73	110	
Total 118	364	517	3	

Table 3. Dominant Families

Sl. No.	Family	Genera	Species
	Dicotyledons		
1.	Euphorbiaceae	26	44
2.	Rubiaceae	18	27
3.	Apocynaceae	15	16
4.	Fabaceae	12	14
5.	Annonaceae	10	14
	Monocotyledons		
1.	Poaceae	25	31
2.	Orchidaceae	14	22
3.	Cyperaceae	7	16
4.	Areaceae	6	12

Table 4. Endemic Taxa

Group / Family	Species / Subspecies / Variety	Abundance
Dicotyledons		
Dilleniaceae	1. <i>Dillenia andamanica</i> C. E. Parkinson	Rare
Annonaceae	2. <i>Cyathostemma micrantha</i> (DC.) Sinclair	Scarce
	3. <i>Miliusa andamanica</i> (King) Finet & Gagnep.	Common
	4. <i>Orophea katschallica</i> Kurz	Common
	5. <i>Polyalthia parkinsonii</i> Hutch.	Scattered
	6. <i>Sageraea elliptica</i> Hook.f. & Thomson	Common
	7. <i>S. listeri</i> King var. <i>andamanica</i> Chatterjee	Common
	8. <i>Uvaria hamiltonii</i> Hook.f. & Thomson var. <i>kurzii</i> King	Scarce
Menispermaceae	9. <i>Stephania andamanica</i> Diels	Rare
Flacourtiaceae	10. <i>Casearia andamanica</i> King	Rare
Xanthophyllaceae	11. <i>Xanthophyllum andamanicum</i> King	Common
Clusiaceae	12. <i>Garcinia andamanica</i> King var. <i>andamanica</i>	Common
	13. <i>G. macrostigma</i> Kurz	Rare
Tiliaceae	14. <i>Grewia nervosa</i> (Lour.) Panigr.	Common
Rutaceae	15. <i>Glycosmis pentaphylla</i> (Retz.) DC.	Common
	16. <i>Paramignya andamanica</i> (King) Tanaka	Scattered
Burseraceae	17. <i>Canarium manii</i> King	Scattered
Meliaceae	18. <i>Walsura candollei</i> King	Scarce
Dichapetalaceae	19. <i>Dichapetalum gelonoides</i> (Roxb.) Engl. ssp. <i>andamanicum</i> (King) Leenh.	Scarce
Icacinaceae	20. <i>Codiocarpus andamanicus</i> (Kurz) Howard	Common
	21. <i>Gomphandra comosa</i> King	Scarce
Hippocrateaceae	22. <i>Salacia majumdarii</i> (Chakrab. & M. Gangop.) B. D. Naithani	Rare
Rhamnaceae	23. <i>Gouania andamanica</i> King	Common
Vitaceae	24. <i>Tetrastigma andamanica</i> (King) Susseng.	Scarce
Anacardiaceae	25. <i>Mangifera andamanica</i> King	Scarce
	26. <i>Semecarpus kurzii</i> Pierre	Common
Myrtaceae	27. <i>Syzygium kurzii</i> (Duthie) N.P. Balakr. var. <i>andamanica</i> (King) N.P. Balakr.	Rare
Memecylaceae	28. <i>Memecylon andamanicum</i> King	Scarce
Lythraceae	29. <i>Lagerstroemia hypoleuca</i> Kurz	Scattered
Rubiaceae	30. <i>Canthium gracilipes</i> Kurz	Scattered
	31. <i>Hedyotis paradoxa</i> Kurz	Rare
	32. <i>Ixora barbata</i> Roxb. ex J.E. Sm.	Scarce
	33. <i>Neonauclea calycina</i> (DC.) Merr.	Scarce
	34. <i>N. gageana</i> (King) Merr.	Common

Table 4. Contd.

Group / Family	Species / Subspecies / Variety	Abundance
	35. <i>Psychotria platyneura</i> Kurz	Common
	36. <i>Pubistylus andamanensis</i> Thoth.	Scarce
	37. <i>Tarenna weberaefolia</i> (Kurz) N.P. Balakr.	Scarce
Myrsinaceae	38. <i>Maesa andamanica</i> Kurz	Scarce
Sapotaceae	39. <i>Manilkara littoralis</i> (Kurz) Dubbard	Common
	40. <i>Mimusops andamanensis</i> King & Gamble	Scarce
Apocynaceae	41. <i>Alstonia kurzii</i> Hook.f.	Common
	42. <i>Tabernaemontana crispa</i> Roxb.	Very common
Myristicaceae	43. <i>Knema andamanica</i> (Warb.) de Wilde	Scarce
	44. <i>Myristica andamanica</i> Hook.f.	Very common
Lauraceae	45. <i>Litsea kurzii</i> King ex Hook.f.	Common
Euphorbiaceae	46. <i>Actephila excelsa</i> (Dalzell) Muell.Arg. var. <i>puberula</i> (Kurz) Pax & K. Hoffm.	Common
	47. <i>Antidesma bhargavae</i> Chakrab. & N.P. Balakr.	Scarce
	48. <i>Dimorphocalyx balakrishnanii</i> Chakrab. & Premanath	Rare
	49. <i>Drypetes andamanica</i> (Kurz) Pax & K. Hoffm.	Rare
	50. <i>Glochidion andamanicum</i> Kurz var. <i>andamanicum</i>	Rare
	51. <i>G. jarawae</i> Chakrab. & N.P. Balakr.	Rare
	52. <i>G. subsessile</i> N. P. Balakr. & Chakrab.	Scarce
	53. <i>G. zeylanicum</i> (Gaertn.) A. Juss. var. <i>paucicarpum</i> Chakrab. & N.P. Balakr.	Scarce
Monocotyledons		
Orchidaceae	1. <i>Eria andamanica</i> Hook.f.	Common
Dioscoreaceae	2. <i>Dioscorea vexans</i> Prain & Burkill	Scarce
Arecaceae	3. <i>Calamus andamanicus</i> Kurz	Common
	4. <i>C. longisetus</i> Griffith	Common
	5. <i>Caryota mitis</i> Lour.	Common
	6. <i>Daemonorops kurzianus</i> Becc.	Rare
	7. <i>D. manii</i> Becc. & Hook.f.	Common
Pandanaceae	8. <i>Pandanus andamanensis</i> Kurz	Scarce

DISCUSSION

The available data enables us to understand that the virgin forests of the Jarawa Reserve contain many rare and endangered plant species many of which are either endemic to the Andaman & Nicobar Islands or occurring nowhere else in India. Moreover, a number of economically important plants such as timber

trees and some plants of commercial value such as betel, banana, arecanut, jackfruit and mango occur in wild condition in the area. The forests of the Reserve evidently contain germplasm of many useful and potentially useful plants.

The Jarawas were so far able to preserve most of their natural habitats. However, under the changed scenario, particularly due to the

opening of the Andaman Trunk Road, which passes through the Jarawa land, and establishment of friendship with them, a threat to their habitat has emerged mainly due to the interference of the outsiders who are extracting natural resources from the Jarawa Reserve, such as hunting of wild boar and deer, fishing, sand mining, collection of "dhup", minor forest products and extraction of timber. This way, the virgin forests of the reserve are bound to deplete in given course of time, i.e. within next 10 - 15 years. It will be a great loss to the nation as well as to the Jarawas who will find it difficult to lead their normal life due to shortage of resources. Hence formulation of appropriate conservation strategies appears to be necessary.

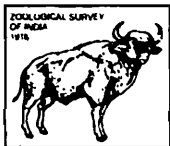
ACKNOWLEDGEMENTS

We are grateful to the Director, Botanical Survey of India, for providing all facilities and deputing us to survey the Jarawa Reserve. The Directorate of Tribal Welfare, Andaman & Nicobar Administration made all arrangements for the field work. We are also indebted to all the members of the Composite Groups for great help in conducting the surveys. The authorities of the Andaman & Nicobar Circle, Botanical Survey of India, Port Blair extended all facilities during field work and allowed us to consult their herbarium for identification. The authorities of Central National Herbarium, Howrah also allowed us to consult the herbarium for identification.

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SURVEY ON PLANT DISTRIBUTION IN SIPCOT INDUSTRIAL PARK, RANIPET, VELLORE DISTRICT, TAMIL NADU, INDIA

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INTRODUCTION

In classical terms, biodiversity was described as the total number of species present, *i.e.* species richness or species abundance, and the distribution of individuals among those species *i.e.* species evenness or species equitability. However, the incorporation of these two components into diversity indices has led to much controversy among ecologists (Atlas, 1984). The Shannon diversity index was probably the most widely used index for measuring species diversity. But this index, as many others that both richness and evenness play a role in determining the value of the index. Quite different communities, as a consequence, can have the same index. Therefore, any diversity index was a single value and thus cannot indicate the total make-up of a community. It was recommended that evenness, richness and diversity values should be calculated in order to obtain an objective assessment of community structure (Atlas, 1984). The aim was to study the effect of SIPCOT Industrial Park on Biodiversity.

MATERIALS AND METHODS

Study Area

Ranipet is well known for leather and steel industries. Bharat Heavy Electricals Ltd. (BHEL) have its extension centre in Ranipet.

Sampling

In the SIPCOT the phytosociological study was carried out using 20 randomly placed quadrats (10 × 10 m) for trees (individual with DBH more than 30 cm) within them 5 × 5 m for shrubs and climbers and 1 × 1 m for herbaceous community.

Analysis

The diversity indices were analyzed using PAST and Biodiversity Pro beta Version 2 (McAleece, 1997). The species-area was raised with the help of Estimates (Colwell, 1997).

RESULT AND DISCUSSIONS

Floral diversity

A total of 67 species were found in and surroundings of the State Industries Promotion

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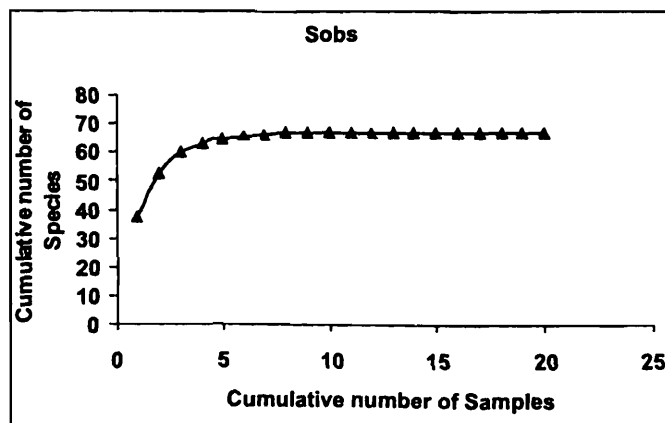
Table 1. Flora diversity indices of Ranipet

Number of Species	67
Number of Individuals	1927
Dominance index	0.035
Shannon Index	3.48
Simpson Index	0.96
Evenness Index	0.86
Menhinick	3.8
Margalef	8.04
Equitability	0.96
Fwaser Alpha diversity	23.17
Berger-Parker	0.075

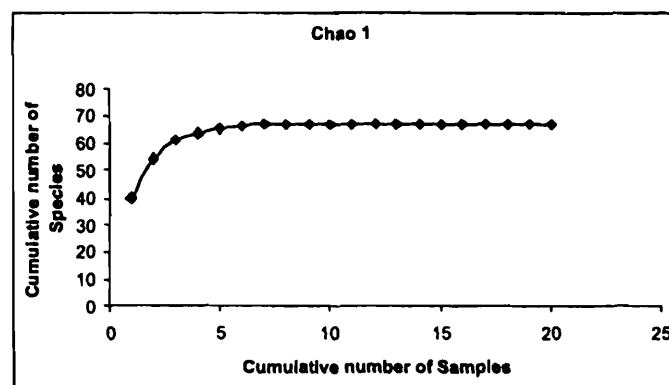
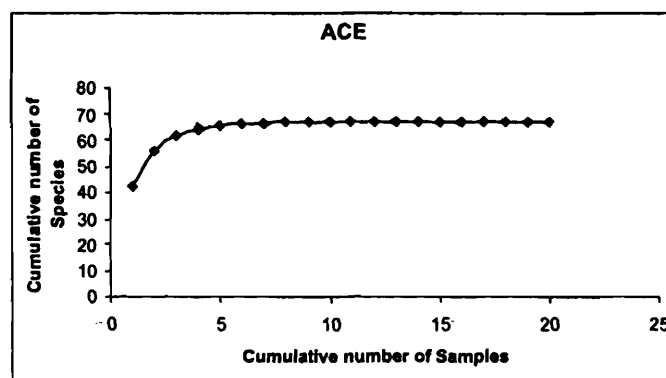
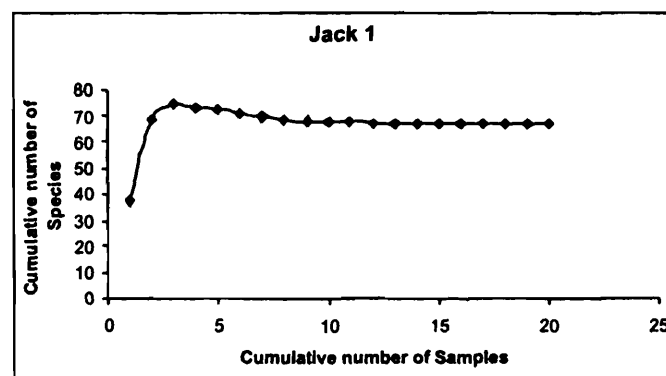
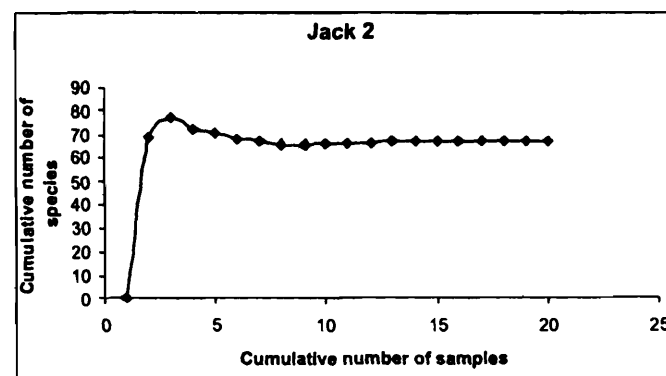
Corporation of Tamil Nadu (SIPCOT) Limited in Ranipet. Total number of individuals of the SIPC OT site was 1927. The diversity indices of Ranipet site are higher than other areas.

Species-area curve

The observed species-area curve of the SIPCOT gets stabled after 5th quadrat. The observed species richness was 67 (Fig. 1). Chao 1 an estimator showed that the curve gets stabled in 4th quadrat. After that no addition of species occurs. The estimated species richness by Chao 1 was also 67 (Fig. 2). ACE an estimator curve gets stabled in 6th quadrat. After 6th quadrat there was no addition of species up to the 20th quadrat. The estimated species- richness was also 67 (Fig. 3). Jack-knife 1 species-area curve (estimated) gets stabled in 8th quadrat. The species richness of the SIPCOT was estimated as 74. It was higher than the observed value (Fig. 4). Jack-knife 2 species-area curve

**Fig. 1.** Observed species-area curve of the SIPCOT

gets stabled in 9th quadrat. The species richness of the SIPCOT was estimated as 77. It was higher than the observed estimation (Fig. 5).

**Fig. 2.** Chao 1 estimated species-area curve of the SIPCOT**Fig. 3.** ACE estimated species-area curve of the SIPCOT**Fig. 4.** Jack-knife 1 estimated species- area curve of the SIPCOT**Fig. 5.** Jack-knife 2 estimated species- area curve of the SIPCOT

Bootstrap species-area curve (estimated) gets stabled in 14th quadrat. The species richness of the SIPCOT was estimated as 69. It was higher than the observed one (Fig. 6). Michalis-Menten species-area curve was not get stabled even up to the 20th sample. The species richness of the SIPCOT was estimated as 89. It was higher than the observed one (Fig. 7).

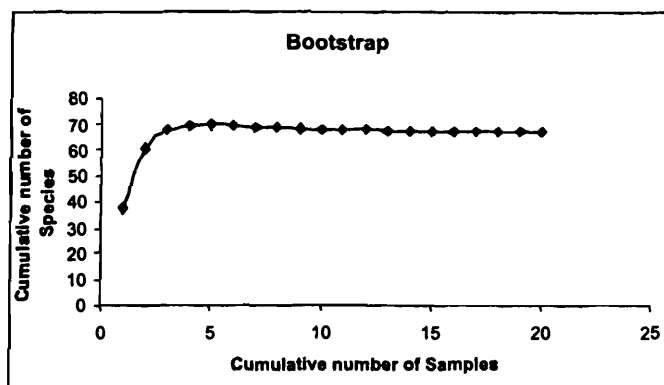


Fig. 6. Bootstrap estimated species- area curve of the SIPCOT

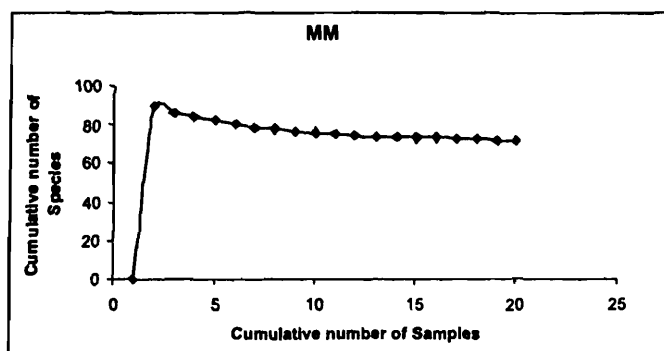


Fig. 7. Michalis-Menten estimated species-area curve of the SIPCOT

Principal Component Analysis

PCA of floral diversity in Ranipet was designed with the help of distribution of the species in the samples. Most of the species were showing similarities in their distribution. Some 10-13 species were not similar in their distribution in the studied samples (Fig. 8).

Cluster analysis

Cluster was formed by considering the distribution of species in the studied samples.

There are 3 groups formed among the species in the SIPCOT. Each group was again divided into many interior groups (Fig. 9).

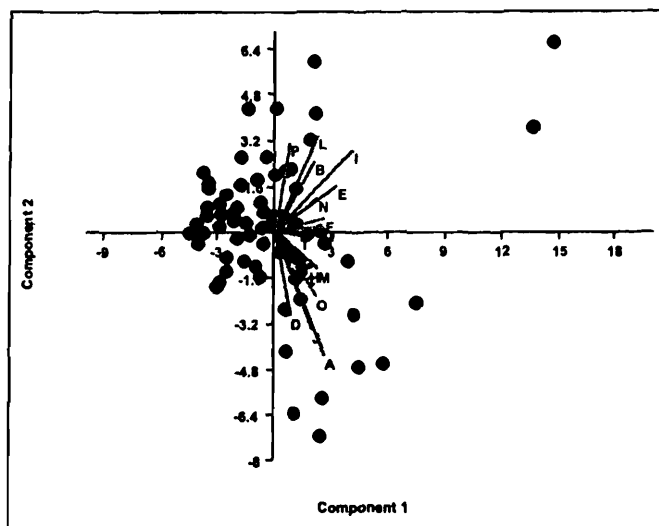


Fig. 8. Principal component analysis of flora in the Ranipet SIPCOT

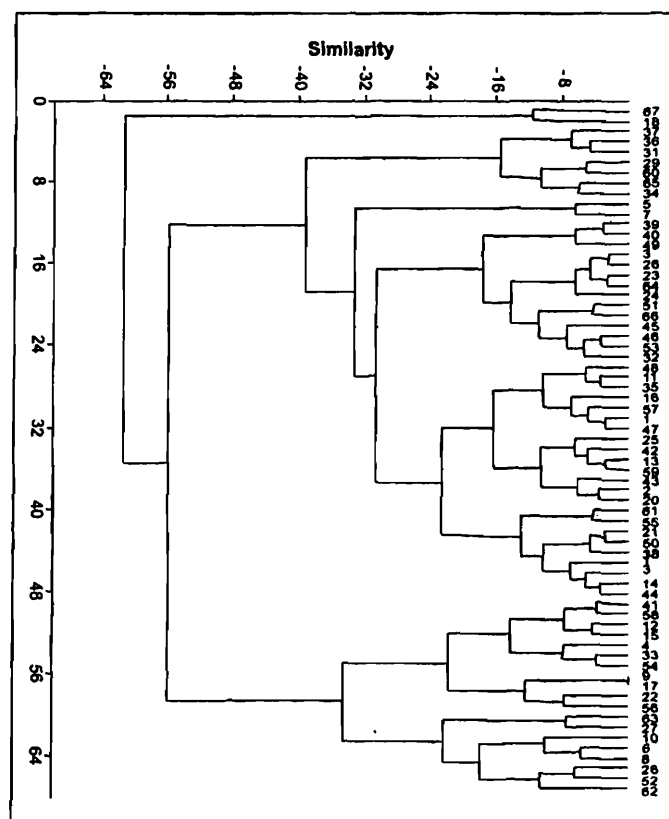
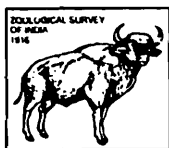


Fig. 9. Cluster diagram produced by the distribution of plant species in the sampled area of Ranipet site.

List of flora	
1. <i>Pithecellobium dulce</i> (Roxb.) Benth.	34. <i>Trianthema</i>
2. <i>Leucaena leucocephala</i>	35. <i>Achras zapota</i>
3. <i>Croto sparsiflorus</i>	36. <i>Hibiscus rosa-sinensis</i>
4. <i>Commelina</i>	37. <i>Citrus aurantifolia</i>
5. <i>Lantana camara</i>	38. <i>Pygeum granetum</i>
6. <i>Morinda tinctoria</i>	39. <i>Ceiba pentandra</i>
7. <i>Borassus flabellifer</i>	40. <i>Duranta repens</i>
8. <i>Sida acuta</i>	41. <i>Catharanthus roseus</i>
9. <i>Murraya koenigii</i>	42. <i>Bryophyllum</i>
10. <i>Murraya exotica</i>	43. <i>Tecoma stans</i>
11. <i>Azadirachta indica</i>	44. <i>Mirabilis jalapa</i>
12. <i>Albizia lebbeck</i>	45. <i>Vinca rosea</i>
13. <i>Pongamia pinnata</i>	46. <i>Musa paradisiaca</i>
14. <i>Eucalyptus globulus</i>	47. <i>Terminalia catappa</i>
15. <i>Cocos nucifera</i>	48. <i>Carrica pappaya</i>
16. <i>Acalypha indica</i>	49. <i>Jasminum indicum</i>
17. <i>Tragea</i> sp.	50. <i>Lycopersicum esculentum</i>
18. <i>Moringa oleifera</i>	51. <i>Cleome gynandra</i>
19. <i>Tridax procumbens</i>	52. <i>Ipomoea carnea</i>
20. <i>Opuntia</i>	53. <i>Chrysanthimum</i>
21. <i>Enicostema</i>	54. <i>Seasamum indicum</i>
22. <i>Tectona grandis</i>	55. <i>Abutilon</i>
23. <i>Calotropis gigantea</i>	56. <i>Phyllanthus emblica</i>
24. <i>Accacia nilotica</i>	57. <i>Plumeria</i>
25. <i>Tamarindus indica</i>	58. <i>Nerium odorum</i>
26. <i>Lawsonia inermis</i>	59. <i>Delonix regia</i>
27. <i>Acryranthus aspera</i>	60. <i>Cassia coreara</i>
28. <i>Zizypus jujuba</i>	61. <i>Agave americana</i>
29. <i>Mangifera indica</i>	62. <i>Ocimum sanctum</i>
30. <i>Partherium</i>	63. <i>Sterculia foetida</i>
31. <i>Cleome viscosa</i>	64. <i>Colacasia</i>
32. <i>Ricinus communis</i>	65. <i>Psidium gujava</i>
33. <i>Boerhavia diffusa</i>	66. <i>Syzygium cumini</i>

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SEVEN INTERESTING PLANTS FROM SOUTH INDIA

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INTRODUCTION

While studying the Angiosperm flora of southern Western Ghats, the authors found some unidentified specimens at the Madras Herbarium (MH), Botanical Survey of India, Coimbatore. On the critical studies and perusal of literature, they are identified as *Erythrina fusca* Lour.-Fabaceae; *Macropodium atropurpureum* (DC.) Urban-Fabaceae; *Meyna pubescens* (Kurz) Robyns-Rubiaceae; *Miquelia klenii* Meissner-Icacaceae, *Syzygium parameswaranii* Mohanan & A.N. Henry-Myrtaceae and *Vitex quinata* (Lour.) F. Williams-Verbenaceae. So far, they are not recorded and reported from Southern India. Hence, a short description with relevant notes is provided here for further collection and identification in field.

SYSTEMATIC TREATMENT

Erythrina fusca Lour., Fl. Cochinch. 427. 1790; V.E. Rudd. in M.D. Dassanayake, Rev. Handb. Fl. Ceylon 7 : 245. 1991. *E. glauca* Willd., Ges. Naturf. Freunde Berlin, Neue Schriften 3: 428. 1801. *E. ovalifolia* Roxb., Hort. Beng. 53. 1814, nomen; Wight, Ic. Ind. Or. 1, t. 247. 1840; Baker in Hook. f., Fl. Brit. India 2 : 189. 1876 (FABACEAE).

A weak tree; branches armed; branchlets terete, glabrous. Leaves alternate, 3-foliolate; leaflets elliptic-ovate, 4-7 × 2-4 cm, rounded or

obtuse at apex; lateral nerves ca 4 pairs; stipels modified as gland, oblong, 2-3 mm long; petiolules 5-12 mm long; petioles 3-8 cm long. Flowers 1-5 at the node, 4-5 cm long; pedicels to 4 cm long. Calyx spathaceous, campanulate. Petals deep red. Ovary stipitate, densely tomentose.

Fl. : December.

Distribution : West Indies, America, India, Sri Lanka, Malaysia, Indonesia, Philippines, Pacific Islands.

Specimens examined : India, Tamil Nadu, Nilgiri Distr., 01 Dec. 1972, 1575 m, E. Vajravelu 43159 (MH).

Note : In India, it was introduced as shade tree for Coffee and Tea plantations. Hook.f. (1876) mentioned that it is distributed in the N.E. India. So far, it was not included in the recent Floras of South India. Hence, the present report forms a new distributional record for the Peninsular India from Nilgiris, Tamil Nadu state.

Macropodium atropurpureum (DC.) Urban, Symb. Antill. 9: 457. 1828; M. Sanjappa, Leg. India: 206. 1992. *Phaseolus atropurpureus* DC. Prodr. 2: 395. 1825. *Phaseolus vestitus* Hook., Bot. Misc. 2: 26. 1831. *Phaseolus schiedeanum* Schlecht., Linnaea 12: 323. 1838. *Phaseolus canescens* Mart. ex Caleotii Bull. Acad. Burx. 1096. 1843. *Phaseolus dysophyllus* Benth. Pl. Hartw. 287.

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1848. *Phaseolus affinis* Piper, Contr. US. Nat. Herb. 22 : 682. 1926 (FABACEAE)

Scrambler, branchlets terete, grey tomentose. Leaves alternate, 3-foliolate to 13 cm long; leaflets rhombic-ovate, 4-5 × 4-5 cm, papery, sparsely pubescent above, densely beneath, 3-ribbed, truncate at base, entire at margin, obtuse at apex; nerves ca 4 pairs, prominent beneath, impressed above; petiolules 2-3 mm long; stipels subulate-lanceolate, ca 3 × 1 mm, persistent; petioles 5-8 cm long, hirsute, pulvinous at base; stipules 2, ovate-lanceolate, ca 3 × 2 mm, basifixed, recurved, broad at base, acuminate at apex. Inflorescence axillary, racemes to 25 cm long; peduncle ca 20 cm long, grey hirsute. Flowers bisexual, zygomorphic, binate, subsessile, ca 1.5 cm across. Calyx tube ca 6 mm long, campanulate, grey pubescent, 2-lobed; lobes 5 (upper 2 & lower 3-lobed), lanceolate, ca 2 × 1.5 mm, acuminate at apex. Petals 5, clawed at base; standard, orbicular, ca 1.5 × 1.2, yellow with brown tinged; wings 2, ca 2.2 × 1 cm, dark purple; keel ca 2 cm long, spirally beak. Stamens (9+1) diadelphous; staminal tube ca 1.5 cm long, vexillary ca 1.2 cm long; anthers uniform, ovate; Ovary linear, ca 5 mm long, grey pubescent; ovules 8-10, parietal placentae; style bifid, ca 1 cm long, twisted along with keel; stigma oblique, beared below, obtuse at apex. Pod linear, ca 7 × 0.3 cm, grey pubescent; seeds 8-10, oblong, ca 3 × 1 mm, smooth, pale brown, estrophiole.

Fl. & Fr. : July-Dec.

Distribution : Native of S. Africa (Equator & Peru). Introduced in India.

Specimen examined : India, Tamil Nadu, Coimbatore Distr., TNAU Campus, 11-11-2007, C. Murugan 121243 (MH).

Note : Sanjappa (1991) mentioned that this species is known to Delhi, but the present collections from Coimbatore, Tamil Nadu forming a new distributional record for South India.

Meyna pubescens (Kurz) Robyns in Bull. Jard. Bot. Brux. 11 : 235. 1928; Hara & Gourd, Env. Flow. Pl. Nepal 2 : 204. 1979; Bennet, Nam. Chan. Flow. Plant Ind: 369. 1987; N.P. Singh &

al; Fl. Bihar 241.2001. *Vangueria pubescens* Kurz. in J. Asiat. Soc. Bengal 41(2) : 314. 1872; Hains, Bor. Bihar, Orissa 4: 439.1992. *Vangueria spinosa* Roxb. Fl. Ind. 1 : 536. 1820 Pp.; Hook.f., in Fl. Brit. India. 3 : 136.1880 Pp. *Meyna spinosa* Roxb.ex Link var. *spinosa* Robyns, Bull. Jard. Bot. Brux. 11.231.1928; Saxena & Bratiman, Fl. Orissa : 850. 1995; *V. spinosa* var. *mollis* Wall. Cat. 84. (RUBIACEAE)

Armed or unarmed shrub, to 3 m high. Leaves opposite, simple, elliptic, 4-9 × 3-5 cm, cuneate at base, entire at margins, acuminate at apex, chartaceous, sparsely pubescent, glaucous below, nerves 5-7 pairs; petioles up to 3 cm long. Flowers 5-merous, sub-globose in axillary cymes to 2.5 cm long. Calyx truncate; lobes 4, acuminate at apex. Corolla tube cylindrical, ca 5 mm long; lobes oblong, ca 4 × 1.5 mm. Stamens 5, epipetalous.

Fl. : February

Distribution : India (Bihar, Orissa & Tamil Nadu), Myanmar, Java.

Specimen examined : India, Tamil Nadu, Nilgiris Distr; Rockwood R.F., 28 Feb. 1973, ca 1000m, E. Vajravelu 43766 (MH).

Note : In India, it is recorded from the Bihar and Orissa states. Hence, the present collection from the Nilgiris, Tamil Nadu forming a distributional record for the southern India. This species is closely allied to *Canthium travancoricum* but differs in leaves (pubescent) and flower (5-merous).

Miquelia kleinii Meissner, Gen. Gom. 109. 1838 & Pl. Vasc. Gen. 152. 1839; Masters in Fl. Brit. India 1 : 593. 1875; U.N. Kanjilal & Bor, Fl. Assam. 1 : 253. 1936; P.K. Hajra & al., Mat. Fl. Arunachal Pradesh 1: 290. 1996; R. Mathur in N.P. Singh & al., Fl. India 5 : 29. 2000. *M. assamica* Blume Rumphia 4 : 37. 1849. *Jenkinsia assamica* Griff in Calc. J. Nat. Hist. 4 : 231, t. 12. 1844 & Not. Pl. Asiat. 370, t. 537, f.2. 1849. *Araliaceae? kleinii* Wight & Arn. Prodr. 1 : 375. 1834. *Phytocrene* sp. Wight Ill. 2 : 62. 1839 (ICACINACEAE).

Twiner; branchlets hairy when young. Leaves alternate, simple, elliptic oblong-

lanceolate, 10-18 × 5-8 cm, coriaceous, obtuse / sub-hastate at base, entire at margins, caudate - acuminate at apex; nerves 5-6 pairs, ascending towards apex; petioles 4-5 cm long, stout. Female inflorescence on thick peduncles with 10-15 flowers on heads. Drupes obliquely ovoid, *ca* 2 × 1 cm, laterally compressed, rugose.

Fr. : January

Distribution : India (East Himalaya - Assam, Arunachal Pradesh & Meghalaya; Western Ghats-Tamil Nadu).

Specimens Examined : India : Assam, Sadiya, 26 Mar. 1894, G.A. Gamie 251 (CAL Acc. No. 83818); Bramaputra plains, *S.coll.*, *S.no.* (CAL Acc. No 83820); *S.loc.*, *S.coll.* 307 (CAL). Tamil Nadu, Tirunelveli Distr., Courtallum Hills, Vaithamalai, *ca* 1700 m, 09 Jan. 2003, C. Murugan 114571(MH).

Note : It is allied to *Miquelia dentata* but differs markedly in leaves being entire at margin. While revising the family Icacinaceae, R. Mathur (1995) stated that it is available in Eastern Himalaya. Hence, the present collection from Tirunelveli Hills, Tamil Nadu state forms a new distributional record for Peninsular India.

Scleria stocksiana Boeck. in Linnaea 38 : 474.1874; C.B. Clarke in Hook.f., Fl. Brit. India 6: 687.1874; Cooke, Fl. Pres. Bombay. 2:905. 1908; Sharma & al, Fl. Karnataka : 316. 1984; Karthik. & al., Fl. Ind. Enum. Monocot. 72. 1989; Prasad & Singh, Sedges of Karnataka : 324, t.60.2002 (Cyperaceae).

Annual or perennial herbs, to 50 cm high, stems tufted, triquetrous, striated. Leaves linear to 20 × 7 mm, scabrous. Inflorescence terminal panicle, to 5 cm long; lateral one smaller, on erect peduncles. Spikelets usually unisexual, solitary or groups of 2-3. Stamens 3; filaments up to 3 mm long; anthers linear-oblong, *ca* 1.8 mm long, apiculate at apex. Nut broadly ovoid, obtusely trigonous, *ca* 3 × 2.3 mm, somewhat rugulose or tubercled.

Fl. & Fr. : Aug.-Oct.

Distribution : Peninsular & Central India (Maharashtra, Karnataka & Kerala).

Specimens examined : India, Kerala State, Palaghat District, Silent Valley Reserve Forest, Valiyaparathode, 12 Dec. 1980, *ca* 1100 m, N.C. Nair 69566 (MH).

Note : So far, it is known to Karnataka and Maharashtra States. The present collection from the Palaghat District forms a new distributional record for Kerala state.

Syzygium parameswaranii Mohanan & A. N. Henry in J. Bombay Nat. Hist. Soc. 84: 409. 1987 & Fl. Thiruvananthapuram 192. 1994; R. Gopalan & A.N. Henry, End. Plants Ind. Region: 139. 2000; N. Mohanan & M. Sivadasan, Fl. Agasthiyamala : 264. 2002 (MYRTACEAE).

Trees, 4-6 m tall; branchlets tetragonous. Leaves opposite, sessile, ovate, rounded at base, obtuse or subacute at apex, 2.5-5 × 2-3.5 cm, coriaceous, margins recurved; lateral nerves close, prominent, joining at the intramarginal nerve. Inflorescence terminal panicle to 2 cm long. Flower *ca* 1 cm diam; pedicels *ca* 3 mm long, slender. Calyx-tube *ca* 3 mm long, bugle-shaped; lobes 4, ovate, *ca* 1 × 1 mm. Petals 4, suborbicular, *ca* 3 × 2.5 mm, gland-dotted. Stamens 3 mm long; filaments dilated at the base. Style 3 mm long; stigma simple, acute at apex.

Fl. : Jan.-April.

Distribution: India (Kerala & Tamil Nadu).

Specimens examined : India, Tamil Nadu; Tirunelveli District, Way to Agasthiar Peak, 13 10-2006, 1000-1500 m, C. Murugan 119110 (MH)

Note : So far, this species is recorded from the Western slopes of Agasthiyamalai, Kerala State. The present collection from Eastern of slopes of Agasthiyamalai, Tirunelveli Distr. is forming a distributional record for Tamil Nadu.

Vitex quinata (Lour.) F. Williams in Bull. Herb. Boiss. 11, 5 : 431. 1905; Kanj. & al, Fl. Assam 3: 482. 1939; M.K.V. Rao in J. Econ. Tax. Bot. 8: 139. 1986; N. Ramarao & Narasimhan in J. Econ. Tax. Bot. 9 : 493.1987; Deb & R.M. Dutta. in J. Econ. Tax. Bot. 10 : 48. 1987; P. Daniel & Rajendren, Ind. Verbenaceae : 374, fig. 75.2002. *Cornutia quinata* Lour., Fl. Cochinch. 2 : 387. 1790. *Vitex heterophylla* Roxb., Fl. Ind. 3 : 75. 1832. (Verbenaceae)

Tree to 4 m high, branches and branchlets obtusely 4-angular. Leaves 5-7 foliolate, leaflets oblong-lanceolate, 5-10 x 2-4 cm cuneate at base, entire or faintly serrate at margins, acute to acuminate at apex, chartaceous, glandulate; petioles 4-6 cm long. Inflorescence terminal/supra axillary, panicles; peduncles 4-angular, 4-8 cm long. Drupe obovoid or ellipsoid, ca 1 cm long, black with persistent calyx of 5 lobes.

Fr. : September

Distribution: India (Andhra Pradesh, Arunachal Pradesh, Assam, Meghalaya, Nagaland, Orissa & Sikkim, Tamil Nadu), Bangladesh, Celebes, China, Indonesia, Laos, Malaysia, Molucca Islands, Pakistan, Philippine

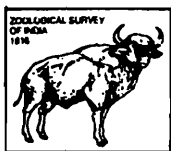
Islands, Taiwan, Thailand, Vietnam (Daniel & Rajendran, 2002).

Specimens examined : India, Andhra Pradesh, Visakhapatnam District, Minumuluru, 04 Sep. 1966, ca 100m, G.V. Subba rao 28261 (MH).

Note : It is well known to North-Eastern India and Tamil Nadu State. The present collection from Minumuluru, Visakhapatnam District is a new distributional record for Andhra Pradesh State.

ACKNOWLEDGEMENT

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FICUS DIVERSITY IN SOUTHERN WESTERN GHATS IS A BOON FOR BIODIVERSITY CONSERVATION -A GLIMPSE

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INTRODUCTION

According to the Forest Survey of India (1977), India has lost about 2400sq.km of forest cover over a period of last 10 years. The present forest cover is only 19.46% of the total geographical area of the country (Balasubramanian 1998). In Tamil Nadu 19.46% of the geographical area is covered with forest (Annamalai 2004). To increase the forest cover, Tamilnadu state forest department is undertaking various schemes (TAP, NAP, HADP, WDP and IFP) for afforestation in wastelands and degraded forests. For natural regeneration process one step forward in this line is to attract frugivores to the degraded sites which will enhance the natural regeneration considerably by dispersing the seeds along the length and breadth of the habitat (Mishra *et al.* 1987) southern Western Ghats being a hotspot has rich and varied assemblage of plants and animals (Annon 1980). Among the 40,000 plant species nearly 2500 are trees (Negi 1994). This accounts for about 12% of the global plant wealth. Among the forest tree cover of southern Western Ghats the species of family Moraceae bears the *Ficus* species which normally attract a variety of animals and this helps to preserve biodiversity (WCMC, 1992). Globally *Ficus* is a

diverse genus and found in all types of forests (Berg, 1989). *Ficus* trees are massive; grow to a very great height, girth with spreading crown and evergreen bargad (Bagla and Menon 2000). They are most imposing trees of the landscape become a keystone species in many forest ecosystems (Berg 2005). *Ficus* exhibit a seasonality of fruiting phenology throughout the tropics (Mc Clure 1966, Medway 1972, Crome 1975, Newton and Lomo 1979, Aldrich-Blake and Payne 1980, Whartson *et al.* 1981, Leighton 1982, Foster 1982, Milton *et al.* 1982, Leighton and Leighton 1983, Corelett 1984, 1987, Beehler 1985, Van schaik 1986, Winder *et al.* 1989). Their fruits are predominant resource for many frugivores. The noteworthy members are fruit bats, primates, bears and a variety of birds like barbets, pigeons, hornbills, parrots, bulbuls and myna. The pollination of *Ficus* is peculiar. Normally it bears unseen blooms which attracts species specific wasp. The inter dependency is intense to the extend of both the tree and insect cannot survive without each other (Ramirez 1970). The spreading branches with dense foliage provide shelter and help to retain moisture under the canopy. This provides an ideal habitat for many tree dwellers. Even to the predatory animals like

wild cat and predatory birds like hawk, eagle. The present study confirms that the *Ficus* species with their multipurpose properties and ability to survive in a variety of climatic region and soil conditions could be an important member for forest restoration and re-establishment in affected and degraded area.

MATERIALS AND METHODS

Present study on the *Ficus* diversity has been undertaken in five major forest types namely Thorn forest, Dry deciduous forest, Moist deciduous forest, Semi evergreen forest and Wet evergreen forest of southern Western Ghats of Tamil Nadu. Two quadrates of each forest type were made in the Western Ghats region of Nagercoil, Tirunelveli, Srivilliputhur and Theni forest division of Tamilnadu. The vegetation sampling has been done by using quadrant method in each forest type. From the sample plot only the *Ficus* trees were selected as focal plant. The species identification was done by taking digital photographs and a small sample of plant twig. After identification proper herbarium is maintained in the research centre for further reference. The identification of the plant species is confirmed by Dr. Chelladurai (Ret.) Botanist, Government Sidha Medical College, Palayamkottai and Gopalan (Ret.) Scientist, Botanical Survey of India, Coimbatore. The visits of the animal to the focal plants were carried out through extended watches during

day and night hours. Bird visitor's activities were recorded between 6.30 to 8.30 hours in the morning. Mist netting below and above the canopy near the fruiting trees confirmed the bat visitors. The left outs from the feeding roosts of the fruit bats revealed the *Ficus* plant is visited by the fruit bat species. The animal visitors visited *Ficus* plants for other purpose like nesting, roosting, perching and predation.

RESULTS

The present study on the *Ficus* plant diversity and distribution in various forest types of southern Western Ghats was done during the period January 2008 to January 2009. Five major forest types were selected for the present *Ficus* survey based on the percentage of forest area (Lakhs hectares) cover in Tamilnadu (Figure 1). Figure. 2 debated the distribution of 18 identified *Ficus* species in each forest type namely Tropical thorn forest, Tropical Dry deciduous forest, Tropical moist deciduous forest, Tropical dry and Semi Evergreen forest and Tropical wet evergreen forest showed a considerable variation.

The extended watch with the minimum duration of two hours was made on each focal plant species to study the animal visitors during day and night hours; thus indicated the importance of *Ficus* trees in the forest ecosystem to sustain biodiversity (Table 1).

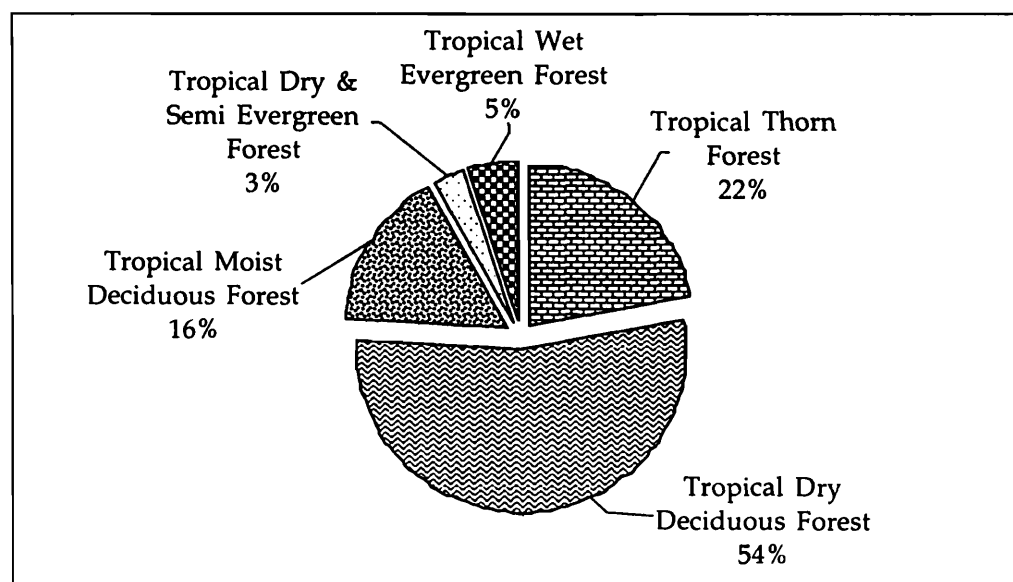


Fig. 1. Selected five major forest types for the study of *Ficus* diversity and their interaction with animal visitors

Sl. No.	Species Name	Thorn forest Below 800ft	Dry Deciduous Forest Up to 1200 ft	Moist Deciduous forest Up to 1600ft	Dry and Semievergreen forest Up to 2500ft	Evergreen forest Above 3000ft
1	<i>F. amplissima</i>					
2	<i>F. asperima</i>					
3	<i>F. beddomei</i> King					
4	<i>F. bengalensis</i>					
5	<i>F. callosa</i>					
6	<i>F. dalhousiae</i>					
7	<i>F. exasperata</i>					
8	<i>F. glomerata</i>					
9	<i>F. guttata</i>					
10	<i>F. hispida</i>					
11	<i>F. infectoria</i>					
12	<i>F. microcarpa</i>					
13	<i>F. nervosa</i>					
14	<i>F. racemosa</i>					
15	<i>F. religiosa</i>					
16	<i>F. retusa</i>					
17	<i>F. talbotii</i>					
18	<i>F. tsjahela</i>					

Fig. 2. Distribution of *Ficus* Species in the Studied Forest Types

Table. 2 shows the location of the *Ficus* species and their fruiting phenology, fruit morphology, number of visitors to the each *Ficus* plant species and their purpose of visit.

Figure. 3 describes almost all the *Ficus* species attracts frugivores, insectivores, predators and habitat dwellers belonging to the birds and mammalian group in great number.

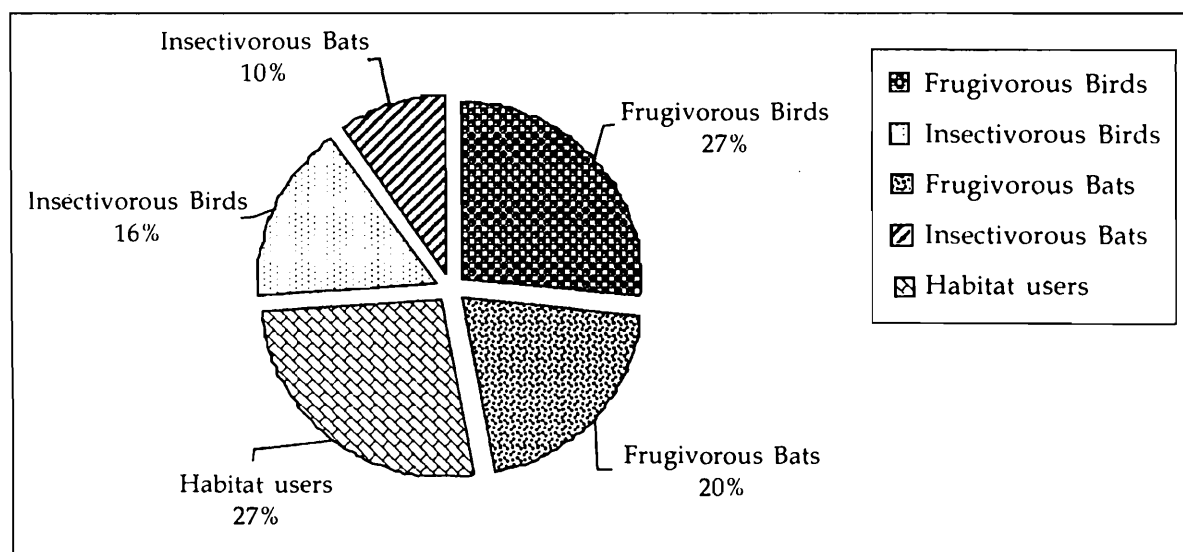
Fig. 3. Consolidated result of all animal visitors interaction with the 18 studied *Ficus* species

Table 1. Identified *Ficus* species and their Interaction with Animal and Bird Visitors
(*Indicate Endemism)

Botanical Name	Bird	Bat	Mammals	Habitat users
<i>Ficus amplissima</i>	Small bee eater (<i>Merops orientalis</i>), Starling (<i>Sturnus malabaricus</i>), Indian treepie (<i>Dendrocitta vagabunda</i>), Prinia (<i>Prinia socialis</i>), Parrakeet (<i>Loriculus vernalis</i>), Oriole (<i>Oriolus oriolus</i>), Myna (<i>Acridotheres tristis</i>)	<i>L. salimalii</i> *, Fulvous fruit bat (<i>R. leschenaulti</i>) Lesser dog-faced fruit bat (<i>C. brachyotis</i>), Short nosed fruit bat (<i>C. sphinx</i>), Indian flying fox (<i>P. giganteus</i>), Dormer's bat (<i>Pipestrellus dormeri</i>), Horsfields mouse eared bat (<i>Myotis horsfieldii</i>)	Lion-tailed macaque (<i>Macaca silenus</i> *), Common langur (<i>Semnopithecus entellus</i>), Nilgiri langur (<i>Trachypithecus johnii</i> *)	Leopard (<i>Panthera pardus</i> *), Common palm squirrel (<i>Funambulus palmarum</i>), Indian moorhen (<i>Gallinula chloropus</i>)
<i>Ficus asperima</i>	Babbler (<i>Turdoides caudatus</i>), Wood pecker (<i>Dinopium javanense</i>), Warbler (<i>Hippolais caligata</i>), Oriole (<i>Oriolus oriolus</i>), Myna (<i>Acridotheres tristis</i>), Starling (<i>Sturnus malabaricus</i>)	<i>C. brachyotis</i> , <i>C. sphinx</i> , Dormer's bat (<i>Pipestrellus dormeri</i>), Horsfields mouse eared bat (<i>Myotis horsfieldii</i>)	Lion-tailed macaque (<i>Macaca silenus</i> *), Nilgiri langur (<i>Trachypithecus johnii</i> *)	Indian river tern (<i>Sterna aurantia</i>), White-tailed wood rat (<i>Cremnomys blanfordi</i>), Great Egret (<i>Casmerodius albus</i>)
<i>Ficus beddomei</i>	Oriole (<i>Oriolus oriolus</i>), Wood pecker (<i>Dinopium javanense</i>), Warbler (<i>Hippolais caligata</i>), Parrakeet (<i>Loriculus vernalis</i>)	<i>R. leschenaulti</i> , <i>C. sphinx</i> , Dormer's bat (<i>Pipestrellus dormeri</i>)	Common palm civet (<i>Paradoxurus hermaphroditus</i>)	Great Horned Owl (<i>Bubo virginianus</i>), Indian long-tailed tree mouse (<i>Vandeleuria oleracea</i>) Bonnet macaque (<i>Macaca radiata</i>)
<i>Ficus bengalensis</i>	Drongo (<i>Dicrurus macrocercus</i>), Oriole (<i>Oriolus oriolus</i>), Fly catcher (<i>Terpsiphone paradisi</i>), Red vented bulbul (<i>Pycnonotus cafer</i>), Red whiskered Bulbul (<i>Pycnonotus jocosus</i>), Koel (<i>Eudynamis scolopacea</i>), Myna (<i>Acridotheres tristis</i>) Parakeet (<i>Psittacula</i>	<i>P. giganteus</i> , <i>R. leschenaulti</i> , <i>C. brachyotis</i> , <i>C. sphinx</i> , schneider's leaf nosed bat (<i>Hipposideros speoris</i>), Dusky leafnosed bat (<i>Hipposideros ater</i>), Indian false vampire (<i>Megaderma lyra</i>),	Nilgiri langur (<i>Trachypithecus johnii</i> *)	Indian flying fox (<i>Pteropus giganteus</i>), Common Indian mongoose (<i>Herpestes edwardsi</i>)

Table 1. Contd.

Botanical Name	Bird	Bat	Mammals	Habitat users
	columboides), Oriole (<i>Oriolus oriolus</i>), Crow (<i>Corvus macrorhynchos</i>)	Horsfields mouse eared bat (<i>Myotis horsfieldii</i>)		
<i>Ficus callosa</i>	Warbler (<i>Hippolais caligata</i>), Great Hornbill (<i>Buceros bicornis</i>), Parakeet (<i>Psittacula columboides</i>)	<i>C. brachyotis</i> , <i>C. sphinx</i> , Dormer's bat (<i>Pipistrellus dormeri</i>)	Common langur (<i>Semnopithecus entellus</i>)	Grizzled giant squirrel (<i>Ratufa macrura</i> *),
<i>Ficus dalhousiae</i>	Red vented bulbul (<i>Pycnonotus cafer</i>), Red whiskered Bulbul (<i>Pycnonotus jocosus</i>), Parrakeet (<i>Loriculus vernalis</i>), Great Hornbill (<i>Buceros bicornis</i>)	<i>C. brachyotis</i> , Dormer's bat (<i>Pipistrellus dormeri</i>)	Lion-tailed macaque (<i>Macaca silenus</i> *), Nilgiri langur (<i>Trachypithecus johnii</i> *)	Myna (<i>Acridotheres tristis</i>)
<i>Ficus exasperata</i>	Babbler (<i>Turdoides caudatus</i>), Red vented bulbul (<i>Pycnonotus cafer</i>), Red whiskered Bulbul (<i>Pycnonotus jocosus</i>)	<i>C. brachyotis</i> , Dormer's bat (<i>Pipistrellus dormeri</i>)	Lion-tailed macaque (<i>Macaca silenus</i> *), Nilgiri langur (<i>Trachypithecus johnii</i> *)	Indian moorhen (<i>Gallinula chloropus</i>)
<i>Ficus glomerata</i>	Drongo (<i>Dicrurus macrocerus</i>), Oriole (<i>Oriolus oriolus</i>), Fly catcher (<i>Terpsiphone paradisi</i>), Parrakeet (<i>Loriculus vernalis</i>)	<i>R. leschenaulti</i> , <i>C. sphinx</i> , <i>C. brachyotis</i> , schneider's leaf nosed bat (<i>Hipposideros speoris</i>), Dusky leafnosed bat (<i>Hipposideros ater</i>), Indian false vampire (<i>Megaderma lyra</i>)	Common langur (<i>Semnopithecus entellus</i>)	Common Indian mongoose (<i>Herpestes edwardsi</i>)
<i>Ficus guttata</i>	Oriole (<i>Oriolus oriolus</i>), Red vented bulbul (<i>Pycnonotus cafer</i>), Red whiskered Bulbul (<i>Pycnonotus jocosus</i>), Tailed bird (<i>Orthotomus sutorius</i>), Starling (<i>Sturnus malabaricus</i>)	<i>R. leschenaulti</i> , <i>C. brachyotis</i> , <i>C. sphinx</i> , <i>L. salimalii</i> , Rufous horseshoe shaped bat (<i>Rhinolophus rousii</i>)	Common palm civet (<i>Paradoxurus hermaphroditus</i>), Common palm squirrel (<i>Funambulus palmaru</i>)	Indian river tern (<i>Sterna aurantia</i>), White-tailed wood rat (<i>Cremnomys blanfordi</i>), Great Egret (<i>Casmerodius albus</i>)
<i>Ficus hispida</i>	Fly catcher (<i>Terpsiphone paradisi</i>), Black Kite (<i>Milvus migrans</i>)	Dormer's bat (<i>Pipistrellus dormeri</i>), Blyth's	Sloth bear (<i>Melursus ursinus</i>), Indian giant	Grey Heron (<i>Ardea cinerea</i>)

Table 1. Contd.

Botanical Name	Bird	Bat	Mammals	Habitat users
		horseshoe bat (<i>Rhinolophus lepidus</i>)	squirrel (<i>Ratufa indica</i>), Lion-tailed macaque (<i>Macaca silenus</i> *), Nilgiri langur (<i>Trachypithecus johnii</i> *), Giant squirrel (<i>Ratufa macrura</i>)	
<i>Ficus infectoria</i>	Small bee eater (<i>Merops orientalis</i>), Starling (<i>Sturnus malabaricus</i>), Indian treepie (<i>Dendrocitta vagabunda</i>), Red vented bulbul (<i>Pycnonotus cafer</i>), Red whiskered Bulbul (<i>Pycnonotus jocosus</i>), Prinia (<i>Prinia socialis</i>), Tailer bird (<i>Orthotomus sutorius</i>), Great Hornbill (<i>Buceros bicornis</i>), Spotted Dove (<i>Streptopelia chinensis</i>)	<i>L.salimalii</i> *, <i>C.brachyotis</i> , Dormer's bat (<i>Pipestrellus dormeri</i>), Rufous horseshoe shaped bat (<i>Rhinolophus rousii</i>)	Common palm civet (<i>Paradoxurus hermaphroditus</i>), Indian giant squirrel (<i>Ratufa indica</i> *), Lion-tailed macaque (<i>Macaca silenus</i> *), Nilgiri langur (<i>Trachypithecus johnii</i> *)	Leopard (<i>Panthera pardus</i> *), Common palm squirrel (<i>Funambulus palmarum</i>), Indian moorrhen (<i>Gallinula chloropus</i>)
<i>Ficus microcarpa</i>	Red vented bulbul (<i>Pycnonotus cafer</i>) Red whiskered Bulbul (<i>Pycnonotus jocosus</i>), Oriole (<i>Oriolus oriolus</i>)	<i>C. brachyotis</i> , <i>C. sphinx</i>	Common palm civet (<i>Paradoxurus hermaphroditus</i>), Sambar (<i>Cervus unicolor</i>)	Leopard (<i>Panthera pardus</i> *), Common palm squirrel (<i>Funambulus palmarum</i>), Indian moorrhen (<i>Gallinula chloropus</i>)
<i>Ficus nervosa</i>	Starling (<i>Sturnus malabaricus</i>), Great Hornbill (<i>Buceros bicornis</i>), Small bee eater (<i>Merops orientalis</i>), Prinia (<i>Prinia socialis</i>)	<i>R. leschenaulti</i> , <i>C. brachyotis</i> , <i>C. sphinx</i> , Dormer's bat (<i>Pipestrellus dormeri</i>)	Common palm civet (<i>Paradoxurus hermaphroditus</i>), Common langur (<i>semnopithecus entellu</i>)	Great Cormorant (<i>Phalacrocorax carbo</i>), Little Cormorant (<i>Phalacrocorax niger</i>)
<i>Ficus racemosa</i>	Koel (<i>Eudynamys scolopacea</i>), Red vented Bulbul (<i>Pycnonotus cafer</i>), Red whiskered Bulbul (<i>Pycnonotus jocosus</i>), Myna (<i>Acridotheres tristis</i>) Parakeet	<i>L. salimalii</i> *, <i>C. brachyotis</i> , Dormer's bat (<i>Pipestrellus dormeri</i>)	Sloth bear (<i>Melursus ursinus</i>), Indian giant squirrel (<i>Ratufa indica</i>), Lion-tailed macaque (<i>Macaca silenus</i> *),	Great Cormorant (<i>Phalacrocorax carbo</i>), Little Cormorant (<i>Phalacrocorax niger</i>)

Table 1. Contd.

Botanical Name	Bird	Bat	Mammals	Habitat users
	(<i>Psittacula columboides</i>), treepie (<i>Dendrocitta vagabunda</i>)		Nilgiri langur (<i>Trachypithecus johnii</i> *), Grizzled giant squirrel (<i>Ratufa macrora</i> *)	
<i>Ficus religiosa</i>	Koel (<i>Eudynamys scolopacea</i>) Emerald dove (<i>Chalcophaps indica</i>)	<i>R. leschenaulti</i> , <i>C. brachyotis</i> , <i>C. sphinx</i> , schneider's leaf nosed bat (<i>Hipposideros speoris</i>), Dusky leafnosed bat (<i>Hipposideros ater</i>), Indian false vampire (<i>Megaderma lyra</i>)	Common palm squirrel (<i>Funambulus palmarum</i>), Grizzled giant squirrel (<i>Ratufa macrura</i>) Indian giant flying squirrel (<i>Petaurista philippensis</i>)	Great Cormorant (<i>Phalacrocorax carbo</i>), Little Cormorant (<i>Phalacrocorax niger</i>)
<i>Ficus retusa</i>	Great Hornbill (<i>Buceros bicornis</i>), Parrakeet (<i>Loriculus vernalis</i>), Starling (<i>Sturnus malabaricus</i>)	<i>L. salimalii</i> *, <i>C. brachyotis</i> , Dormer's bat (<i>Pipestrellus dormeri</i>)	Lion-tailed macaque (<i>Macaca silenus</i> *), Nilgiri langur (<i>Trachypithecus johnii</i> *)	Common palm squirrel (<i>Funambulus palmarum</i>), Indian moorhen (<i>Gallinula chloropus</i>)
<i>Ficus talbotii</i>	Parrakeet (<i>Loriculus vernalis</i>), Koel (<i>Eudynamys scolopacea</i>), Red vented Bulbul (<i>Pycnonotus cafer</i>), Red whiskered Bulbul (<i>Pycnonotus jocosus</i>)	<i>C. brachyotis</i> , Dormer's bat (<i>Pipestrellus dormeri</i>), Blyth's horseshoe bat (<i>Rhinolophus lepidus</i>)	Lion-tailed macaque (<i>Macaca silenus</i> *), Nilgiri langur (<i>Trachypithecus johnii</i> *)	Lion-tailed macaque (<i>Macaca silenus</i> *), Nilgiri langur (<i>Trachypithecus johnii</i> *)
<i>Ficus tsjahela</i>	Oriole (<i>Oriolus oriolus</i>), Starling (<i>Sturnus malabaricus</i>), Great Hornbill (<i>Buceros bicornis</i>), Small bee eater (<i>Merops orientalis</i>)	<i>L. salimalii</i> *, <i>C. brachyotis</i> , Dormer's bat (<i>Pipestrellus dormeri</i>), Horsfields mouse eared bat (<i>Myotis horsfieldii</i>)	Lion-tailed macaque (<i>Macaca silenus</i> *), Nilgiri langur (<i>Trachypithecus johnii</i> *), Sambar deer (<i>Cervus unicolor</i>)	Leopard (<i>Panthera pardus</i> *)

Table 2. Studied *Ficus* species and their interaction with the animal visitors during extended watch

Sl. No.	Botanical Name	Phenology	Fruit Morphology	Seed dispersers		Habitat dwellers		
				Bird	Bat	Nesting & Roosting	Predation	Perching
1	<i>Ficus amplissima</i>	September	Soft pinkish red fruit. drupe, achene.	20	15	2	14	20
2	<i>Ficus asperima</i>	April	Greenish yellow fruit	22	10	4	17	18
3	<i>Ficus beddomei</i>	November	Green, spotted with yellow when ripe, peduncle stout; achenes, obovoid, smooth.	23	-	2	15	14
4	<i>Ficus benghalensis</i>	Apr-June	Fruit is round. attain red colour when it ripens.	59	18	5	19	16
5	<i>Ficus callosa</i>	July-Aug	Greenish gray and powdery, the fleshy seed covering, is pinkish.	27	12	2	15	18
6	<i>Ficus dalhousiae</i>	May-June	Soft pinkish fruit	35	17	1	20	15
7	<i>Ficus exasperata</i>	Aug-Sep	Pinkish red fruit	23	14	2	19	16
8	<i>Ficus glomerata</i>	Apr-June	Yellowish green fruit	21	16	3	13	19
9	<i>Ficus guttata</i>	Aug-Sep	Reddish fruit with yellow dots	24	12		16	14
10	<i>Ficus hispida</i>	Sep-Oct	Pinkish red soft fruit	10	-		14	12
11	<i>Ficus infectoria</i>	November	Pink to purple soft fruit	62	20	2	13	13
12	<i>Ficus microcarpa</i>	Aug-Sep	Yellowish fruit	57	15	4	10	13
13	<i>Ficus nervosa</i>	July-Aug	Greenish fruit, dark brown barks	27	16	-	11	19
14	<i>Ficus racemosa</i>	May- June	Soft pinkish red fruit	29	25	2	14	12
15	<i>Ficus religiosa</i>	Nov- Jan	Soft pinkish red fruit	30	18	6	15	13
16	<i>Ficus retusa</i>	July-Aug	Pinkish purple soft fruit	25	16		21	19
17	<i>Ficus talbotii</i>	October	Soft pinkish fruit	29	16	3	10	13
18	<i>Ficus tsjahela</i>	May-July	Soft greenish red fruit	25	17	2	14	11

DISCUSSION

Fig (*Ficus*) species is an important resource for a diverse array of organisms in all forests. It is well known that *Ficus* trees are key mutualistics in forest and other ecosystems. *Ficus* species with their multipurpose properties and ability to survive in a variety of climatic regions and soil conditions could therefore play an important role in India's wasteland development efforts and also biodiversity conservation (Sharma *et al.* 1983). The present study supports the distribution of 18 *Ficus* species represented in the five major forest types of southern Western Ghats. Among them *Ficus bengalensis*, *F. infectoria* and *F. racemosa* are distributed in all the forest types. *F. microcarpa* and *F. beddomei* are the endemic species confined to the dry and moist forest cover of southern Western Ghats (Annamalai 2004). *Ficus* species in general shows a peculiar reproductive phenomenon. Each *Ficus* species needs a specific pollinating wasp in order to reproduce (Ramirez 1970). Without this special pollen carrying wasps from one synconium to another there would be no propagation.

Ficus attracts the dispersers by offering huge crops of fruit. These trees produce hundreds and thousands of fruits over a limited time to attract many varieties of frugivores. Because of these fruiting strategies the trees are patchily distributed within the forest. Individual trees fruit asynchronously thus providing species rely on figs (Mickledberg *et al.* 1992). *Ficus* species produce fleshy attractive fruits for the dispersal mainly through bats and birds (Whittaker and Jones 1994). The present observation in each *Ficus* species confirms birds and bats are the major dispersers for all the *Ficus* species.

Ficus - Bird Interaction

The comparative study on the role of *Ficus* fruit consumption by the birds and bats showed that birds outnumbered the bats in number of visits and the encounter with a variety of species. In addition to the frugivorous birds the insectivorous birds also play a part in seed dispersal when they attempt to catch insects.

The seeds with the sticky covering get stuck to the bill of the insectivorous birds. When the bird cleans its beak by rubbing it against the branch of another tree, adhered fig seeds get transferred to a new substrate that supports its epiphytic growth (Scott and Martin 1984). The consolidation results of animal visitors' interaction with all 18 *Ficus* species insist their similarity in their interaction with the ecosystem. In the present study 16% of insectivorous birds visit the *Ficus* plant species for insect predation. During the extended observation bird visitors are observed in the *F. bengalensis* followed by *F. microcarpa* and *F. infectoria*. To attract the bird visitors these *Ficus* species produce large number of fruits during summer months (Borges 1993, Kannan 1994). Some bird species are not normally referred as frugivores were seen to eat fruits for example Magpie robin eats fruits of *Ficus microcarpa*. This highest avian diversity visit reveals the importance of these *Ficus* genus to the bird community.

According to Ali and Ripley (1983) the most frequent visitors to the dry deciduous forest are Red-vented Bulbul, Red whiskered Bulbul, white browed Bulbul and common myna. The four most frequent visitors to the riverine forest species are Red-vented bulbul, Yellow-browed bulbul, Pompadour green pigeon and the Malabar grey hornbills depending to feed *Ficus* species. Similar instance were recorded in the forests of Mahendragiri, Nagercoil, Sengalthaeri and Kalakad hills at higher elevation.

Ficus-Bat interaction

Despite the bird's visit during the day time, the bat's visit the *Ficus* plant during night time. They play a major role in far away dispersal of seeds in the forest ecosystem. The *Ficus* trees such as *F. callosa*, *F. guttata*, *F. glomerata*, and *F. racemosa* are referred as Chiropterophilic trees because they bear fruits in such a way the bats get easy access, composition, colour, texture and specific odor just to attract bats for dispersal. The most frequent visitors to the *Ficus* species in the foot hill forest below 1500ft elevations are *Pteropus giganteus*, *Cynopterus sphinx*, *C. brachyotis* and *Rousetus leschenaulti*.

With their rich population count they forage starting from foot hill forest slopes to the temperate evergreen montane forest of southern Western Ghats. *Latidens salimalii* is an endangered species that restricts its distribution and foraging activity to the evergreen forest of southern Western Ghats (Vanitharani *et al.* 2004, Vanitharani 2006). In fruit bat species individual's home range appears to track the availability of ripe figs, because fig fruits are pivotal resource (Bonaccorso *et al.* 2002). *C. sphinx* in India forages on steady state crops early in the evening and switches to big bang resources like *Ficus* later in the night (Elangovan 1999).

Bats being a flying mammal depend on energy offering balanced diet providing fruits with compounds rich in Carbohydrates, Minerals, Amino acids and lipids. They rely solely in figs trees by feeding on a combination of different fig species (Wendeln *et al.* 2000). Barclay (1994) in his earlier studies suggested that calcium content in the diet of bat is constraint during reproduction, because calcium is an essential resource that maintains cellular processes and lactation (Nordin and Frankel 1989). O'Brien *et al.* (1998) has reported figs are higher in Calcium content than any other sympatric fruit. Wendeln *et al.* (2000) also confirmed diet of mixed fig species can provide bats all the nutrients they require. Thus all these literature support that Fruit bat species cannot survive without these *Ficus*. studies by Vanitharani (2005) on feeding behaviour of *L. salimalii* fruit bats also confirmed that the major composition of food preference is mainly the fig varieties and the *L. salimalii* is referred as a fig specialist in selection and processing of *Ficus* seeds.

***Ficus*-Primates Interaction :**

The fig species assemblage of southern Western Ghats provides a natural food resource for the primates like Bonnet macaque, Common langur, Lion tailed macaque and Nilgiri langur. Similarly *Ficus* is the primary source for Howler monkeys of Mexico (Estrada and Coates-Estrada 1984, 1985) and for arboreal mammals in Malayan forest (Lambert 2002).

Interaction with Other Animals :

The *Ficus* fruits are also eaten by the Three-striped palm squirrel, Malabar giant squirrel, Grizzled giant squirrel, Palm civet etc. Seeds of *Ficus* species were noticed in the pellets of the deer, bear and scats of civets. Ripe fruits fallen in the ground might have been consumed up by the terrestrial mammals.

Habitat dwellers :

Apart from providing food for birds, insects, bats and other animals, their spreading crown and dense foliage provide shelter and ideal nesting and also roosting places, for animals and birds. Vanitharani (2006) observed several *P. giganteus* colonies with hundreds of members use *F. bengalensis* as day roost in the foot hill riverine areas of southern Western Ghats. Providing the required habitat and the foraging ground for the seed dispersers and pollinators is the sign for Biodiversity Conservation. The present study has confirmed three *Ficus* species *F. bengalensis*, *F. infectoria* and *F. racemosa* are showing high interaction with all feeding levels of animals and distributed throughout all the forest types of southern Western Ghats. Thus helps to sustain biodiversity using these plant species for afforestation programmes in the various forest types of southern Western Ghats will be a boon for biodiversity conservation.

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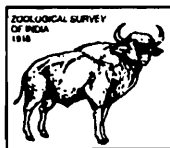
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DIVERSITY OF SOIL MICRO FLORA AND MICRO FAUNA IN KOTHAGIRI HILLS OF WESTERN GHATS, TAMIL NADU, INDIA

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INTRODUCTION

India is one of the world's 12 mega biodiversity Countries and Indian subcontinent is one of the six Vivilovian centers of origin of species (Totey and Verma, 1996). Eastern Himalayas and the Western Ghats of India are recognized as the richest biodiversity landscapes. The Western Ghats have 27 per cent of India's total plant species of which 1500 species are endemic. The hot spot of Western Ghats are not just with high diversity and endemism; they are also under very high levels of threat with only 12.28 per cent of the original extent of the hot spots remaining in intact condition (Hannah *et al.*, 1994). The study was conducted during 2007-2008 to assess the diversity of soil microflora and microfauna of the Kothagiri hills lying in the Nilgiris of Western Ghats, Tamil Nadu, India.

MATERIALS AND METHODS

Location of the experimental area

The Kothagiri hills were selected as study area which comes under Coimbatore division, (10°51' and 11°27' N; 76°39' and 77°30' E). Random sample plots were selected at three different elevations, viz., i) 300-400 MSL (Lower

elevation-E1), ii) 700-800 MSL (middle elevation-E2) and iii) 1100-1200 MSL (upper elevation-E3). The sampling were carried out at different seasons viz., season 1(S1) November to December, 2007; season 2 (S2) February to March, 2008; season 3 (S3) April to May, 2008. These study area is situated in Jaccanare Reserve Forest (1,295 ha) and Kallar Reserve forest belongs to 6 A/C, the southern thorn forest and 5A/C3, the southern dry mixed deciduous forest.

Soil Micro flora

a. Estimation of microbial population

Soil samples were collected from the excrement sites during November 2007, February 2008 and May 2008 and analyzed for microbial population and enumeration was done using the serial dilution techniques of Parkinson *et al.*, 1971. Soil microbial analysis was done for Bacteria, Actinomicets and Fungi population using serial dilution of 10-5, 10-4, 10-6 and in appropriate medium (Kent nutrient agar, Knights medium and Rose Bengal agar) in sterile plate. The composition of medium is given in (Table 1). Enumeration was done after 24 h for bacteria, 48h for fungi, 7 days for Actinomycets.

Table 1. Composition of nutrient media used for soil microbial analysis

Nutrient agar medium (for isolation of bacteria)	
Major elements	g/litter
Peptone	5
Beep extract	3
NaCl	5
Distilled water	1000 ml
Martin Rose Bengal medium (for isolation of fungi)	
Glucose	10 gm
Peptone	5 m
KH ₂ PO ₄	1 gm
MgSO ₄ .7H ₂ O	0.5 gm
Rose Bengal	0.33 gm
Stereptomycin in sulphate(10% solution)	3
Agar	15
Distilled water	1000 ml
Ken Knight medium (for isolation of actinomycetes)	
KH ₂ PO ₄	1
NaNO ₃	0.1
KCl	0.1
MgSO ₄ .7H ₂ O	0.1
Cellulose (filter paper strip for enrichment)	10
Distilled water	1000 ml
PH	7.0-7.2

Soil Micro fauna

a. Estimation of nematode population

Soil samples were taken from two distance of 0.5 m and 1.5 m away from the tree base and depths of 10, 20 and 30 cm. in each, sampling was done at three locations for apart from one another to represent three replications. The nematode population was counted by modified Burman method (Schilndler, 1961). In each replication, 100g of soil sample was taken in a plastic container and vigorously stirred with 700 ml of water until the clods were broken and the sample become homogenous. After allowing it to settle for 10 seconds, the muddy supernatant was decanted through a 20 mesh sieve into a second plastic container leaving the heavy particles behind. Residue on

the sieve was washed again and washed water also collected. The decanted water was passed through 100 and 35 mesh sieve successfully. The residue on each sieve was washed into a molded sieve of wire gauge containing one layer of paper tissue trimmed down to the edge of the gauge. The small sample of soil was then washed with sufficient water and the extract collected in a petridish. Nematode collected in the petridish was counted under microscope.

b. Determination of micro arthropods

Soil samples were collected in each elevation and season from the top 30 cm profile at three different locations. The soil invertebrates were assayed by the method described by Eaton and Chandler (1942) using Berlese funnel. From each replication 200 gm of soil samples was

taken crumpled by hand and placed in a copper screen of 3mm mesh. This screen was rested on the top of a modified Berlese funnel made of a cylindrical galvanized can 15cm in diameter and 10cm in depth. The can was provided with the funnel shaped bottom with 1 cm opening. The entire cylinder was covered with a galvanized lid carrying a 60 V bulb. Beneath the opening of the funnel, it was placed in a beaker containing 70 per cent ethyl alcohol to a height of 1 cm. A negatively phototrophic arthropods activated by the heat were driven to the beaker. After allowing a period of three days for the expulsion of a representative fraction of the organism, counts were made with a low power microscope by decanting the liquid in to a counting dish.

RESULTS

Soil Micro Floral Population

a) Soil bacteria Population

The diversity of soil bacteria varied significantly at different elevation and different seasons. The bacterial population was higher in E3 elevation ($26.31 \times 10^6 \text{ g}^{-1} \text{ soil}$) and less in E1 and E2 elevation. Season wise, S2 showed more population of bacteria ($27.62 \times 10^6 \text{ g}^{-1} \text{ soil}$) than S1 and S3 season. The interaction effect revealed that soil sample collected for E3 during S2 expressed higher bacterial population ($30.21 \times 10^6 \text{ g}^{-1} \text{ soil}$) than in the soil collected from E1 and E2 during S1 and S3 respectively (Table 2).

b) Soil fungi

Fungal population differs significantly due to the seasons, elevation and their interactions. Comprising the elevations, E2 recorded high level of fungal population ($17.74 \times 10^4 \text{ g}^{-1} \text{ soil}$) than E1 and E3. Compared to season, S1 recorded more number of fungi ($16.98 \times 10^4 \text{ g}^{-1} \text{ soil}$) and the same was less in S2 and S3. The interaction result exhibited the soil sample collected from E1 elevation during S1 ($31.19 \times 10^4 \text{ g}^{-1} \text{ soil}$) possessed maximum fungal population and it was lowered in E2 and E3 during S2 and S3 respectively (Table 3).

c) Soil Actinomycetes

Actinomycetes population differed significantly in three elevation and seasons. The interaction also differs significantly. In E2 elevation soil Actinomycetes population was higher ($23.11 \times 10^5 \text{ g}^{-1} \text{ soil}$) than other two elevations (E1, E3). Although Actinomycetes population was recorded in all seasons S1 alone showed more number ($20.43 \times 10^5 \text{ g}^{-1} \text{ soil}$) than S2 and S3. In the interaction of three elevation and seasons it was noticed that E2 expressed high level at S1 ($24.34 \times 10^5 \text{ g}^{-1} \text{ soil}$) (Table 4).

Soil Microfauna Population

a. Soil nematodes

The interaction effect of soil nematodes showed that the number of nematode observed in all the three seasons were in decreasing order viz., 25.083/kg soil at S1, 21.542/kg soil at

Table 2. Population of micro flora-Bacteria ($\times 10^6 \text{ g}^{-1} \text{ soil}$)

Elevation	Seasons			Mean
	S1	S2	S3	
E1	21.73	27.33	22.62	23.89
E2	19.38	25.31	20.38	21.69
E3	23.59	30.21	25.12	26.31
Mean	21.57	27.62	22.71	
	E	S	E x S	
SED	0.2646	0.2646	0.2646	
CD(P = 0.05)	0.5321	0.5321	0.9217	

Table 3. Population of micro flora-Fungi ($\times 10^4$ g⁻¹ soil)

Elevation	Seasons			Mean
	S1	S2	S3	
E1	31.19	12.69	12.09	12.66
E2	16.35	18.55	15.32	17.74
E3	18.38	17.49	13.67	16.51
Mean	16.98	16.24	13.69	

	E	S	E x S
SED	0.0797	0.0797	0.1380
CD (P = 0.05)	0.1603	0.1603	0.2776

Table 4. Population of micro flora-Actinomycetes ($\times 10^5$ g⁻¹ soil)

Elevation	Seasons			Mean
	S1	S2	S3	
E1	14.89	13.19	12.65	13.58
E2	24.34	23.88	21.09	23.11
E3	22.05	20.19	18.93	20.39
Mean	20.43	19.09	17.56	

	E	S	E x S
SED	0.02541	0.02541	0.04401
CD (P = 0.05)	0.05109	0.05109	0.08848

S2 E2 and 8.875/kg soil at S2 E2. The minimum number of nematode was 4.208/kg of soil at S3 E3. Considering the nematode population with regard to differ seasons and elevations, saprophytic nematodes recorded maximum mean value of 73.11/kg soil than all other plant parasitic nematodes which recorded maximum mean of only 22.47/kg soil (Table 5).

B. Micro Arthropod Population

a. Acarina

Among elevation, E3 (82.81/kg soil) recorded higher population than E1 and E2. Considering seasons, more number was observed in S1 (89.57/kg soil) than S2 and S3. When comparing season and elevations, E3 S1 (100.43/kg soil) should more population than other interactions (Table 6).

b. Collembolans

At the three different elevations, E3 (11.71/kg soil) showed higher population of collembolan than E1 and E2. Moderate populations recorded in E1 and E2. Considering seasons, S1 (11.62/kg soil) recorded high level of population when comparing interaction effects, among three elevation and seasons. E3S1 (13.86/kg soil) observed more collembolan population than other interactions individual values (Table 7).

DISCUSSION

a. Soil micro flora diversity

Bacterial populations were more in upper elevation (30.12×10^6 g⁻¹ soil) during the month of February which can be attributed by high

Table 5. Population of micro fauna-Nematodes per kg soil

Nematode species	Season											
	S1				S2				S3			
	E1	E2	E3	Mean	E1	E2	E3	Mean	E1	E2	E3	Mean
Saprophyte	50.33	141.67	27.33	73.11	47.33	120.33	24.33	64.01	43.33	106.67	20.00	56.67
Xipohinema	5.33	9.00	0.67	5.00	1.67	6.00	0.67	2.78	1.67	4.67	0.00	2.11
Meloidogyne	56.67	10.67	0.07	22.47	49.67	10.67	0.07	20.11	45.67	11.00	0.00	18.89
Helicotylenchus	8.33	23.00	20.67	17.33	7.33	20.00	18.33	15.22	5.00	17.33	13.67	12.00
Reniform	8.00	0.00	0.00	2.67	7.33	0.00	0.00	2.44	6.00	0.00	0.00	2.00
Root knot	0.00	0.67	11.67	4.11	0.00	1.00	7.67	2.89	0.00	0.00	0.00	0.00
Dorylaimellus	0.00	6.33	1.33	2.55	0.00	6.00	20.00	8.67	0.00	5.33	0.00	1.78
Tylenchorhynchus	0.00	9.33	0.00	3.11	0.00	8.33	0.00	2.78	0.00	5.67	0.00	1.89
Mean E	16.083	25.083	7.708		14.167	21.542	18.833		7.708	8.875	4.208	
Mean S	16.29				16.625				6.930			

	E	S	E x S
SED	0.2699	0.4409	0.7626
CD[P = 0.05]	0.5338	0.8719	1.5098

Table 6. Population of microarthropod-Acarina (per kg Soil)

Elevation	Seasons			Mean
	Nov	Feb	May	
E1	78.29	63.00	46.14	62.48
E2	9.00	74.00	58.71	74.24
E3	100.43	85.71	62.29	82.81
Mean	89.57	74.24	55.71	73.17

	E	S	E x S
SED	1.0978	1.0978	1.9015
CD (P = 0.05)	2.2074	2.2074	3.8234

Table 7. Population of micro arthropod-Collembola (per kg Soil)

Elevation	Seasons			Mean
	Nov	Feb	May	
E1	9.86	7.57	7.29	8.24
E2	11.14	8.71	6.86	8.90
E3	13.86	7.14	10.74	11.71
Mean	11.62	9.14	8.09	9.62

	E	S	E x S
SED	0.4906	0.4906	0.8497
CD (P = 0.05)	0.9865	0.9865	1.7086

level of nitrogen and organic matter decomposition. But low population was observed in the middle and lower elevation. In the middle elevation, higher numbers of fungal populations ($17.71 \times 10^4 \text{ g}^{-1} \text{ soil}$) were observed in February which can be attributed to high organic carbon and phosphorus. Fungal population showed positive correlation with soil moisture and organic matter content (Behera *et al.*, 1991). Ben (1997) showed that greater number in middle elevation was due to available nutrients. During summer fungal population decreased in all three elevations. This may be due to low moisture content and nutrients. This is accordance with Yasmeen and Kauser Jahan (1998) who observed the low number of fungal population in May.

Actinomycetes population was observed more number ($23.11 \times 10^5 \text{ g}^{-1} \text{ soil}$) in the middle elevation during the month of February which can be supported by more availability of more nutrients (phosphorus, potassium and organic carbon). In lower and upper elevation, observations showed less number of Actinomycetes during May. The reason for this may be due to a pattern of low-high-low microbial quantity found in forest soil (Xu-Qiofang *et al.*, 1998).

b. Soil micro faunal diversity

Considering elevations and seasons, middle elevation showed maximum number of nematode population during November which can be attributed by high level of organic matter decomposition. This was supported by the

work done by Twin (1974). The minimum number of nematodes was observed in upper elevation in the month of May. This may be due to low population size and deficiency of resources. The plant parasitic nematodes were observed under different tree species. Among the nematode population with regard to different seasons and elevations, saprophytic nematodes were observed in maximum number than parasitic nematodes. Within parasitic nematodes meloidogyne had maximum number. This similar to the work by Parthiban (1991) who observed xiphinema vand meloidogyne under different tree species.

In the upper elevation higher of micro arthropod population viz., Acarina and Collembolan populations were noticed. This may be due to high soil moisture content and suitable temperature. This is in accordance with Narula *et al.* (1998) who revealed that the micro arthropod population was collectively regulated by soil moisture and temperature. During November, the population of Acarina and collembolan were high ($82.81/\text{kg soil}$ and $11.71/\text{kg soil}$ respectively) in middle and lower elevation. Low number of population was observed during the month of May. This study is in contrary to the report that the population was more in the month of May (Mir, 2000).

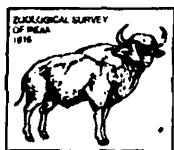
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CURRENT STATUS OF DISTRIBUTION OF PALMS OTHER THAN RATTANS IN ANDAMAN AND NICOBAR ISLANDS

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INTRODUCTION

The Andaman and Nicobar Islands are the largest archipelago system in the Bay of Bengal consisting of a group of 572 big and small Islands and Islets situated between the latitudes of 6°-14° N and the longitudes of 92° to 94°E. The northern most 'Landfall Island' is separated by a sea of about 180 km from the main land Myanmar and the southern most 'Great Nicobar Island' is about 150 km away from Sumatra (Indonesia). The Andaman group is separated from the Nicobar group by sea of about 155 km including the dreaded 10° channel. The total geographical area is about 82,449 km². Out of which about 86 per cent is forest cover. The terrains of most of the islands are hilly with undulating mountains. The highest hill in the Andaman group is the Saddle peak of about 670 MSL. The islands receive South West monsoon from May to September and North East monsoon from October to January. The annual rainfall is about 3200 mm. The insular nature of the territory, physical isolation from the mainland as well as between the islands has resulted in the evolution of a rare and unique flora in these island groups.

The geographical continuity of Andaman and Nicobar Islands with Myanmar in north and Indonesia in south has resulted into the mosaic of floristic elements, both in forms of luxuriance and species diversity, owing to a very congenial phytoclimatic condition. Floristically, the region contains Indo-Chinese and Indo-Malayan elements. A substantial number of species are endemics not seen elsewhere in the world (Ellis, 1989 and Subba Rao, 1989). However, many parts of the territory are still unexplored and or under explored and therefore our knowledge on the flora of the islands at present can be said to be inadequate. Hence, the present study, to fill the lacunae of our knowledge on diversity, distribution and conservation status of this unique and biologically important group of plants.

Previous work

The literature on the rich flora of Andaman and Nicobar Islands lies scattered. The history of plant collection in this region has been dealt in detail by Thothathri (1977). Parkinson (1923) published the "Forest Flora of Andaman Islands" Some of the earlier floristic studies

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worth mentioning from this Bay Islands are of Kurz (1870, 1875 and 1877), Prain (1891a, b, and 1893), and Sahni (1953). Champion and Seth (1968) while classifying the forest types of Andaman and Nicobar Islands reported the occurrence of many palms and rattans in abundance in valleys of tropical forests. Balakrishnan (1979) made studies on the floristic wealth of these unique phytogeographical regions. Rao (1986) further enriched our knowledge on floral wealth of the Bay Island by publishing 'A preliminary report on the angiosperms of Andaman-Nicobar Islands'. Subsequently, Mathew and Abraham (1994) based on the floristic study on these islands pointed out that the palm resources are diminishing fast and emphasized the need for conservation. The other remarkable contribution to the study of palm wealth of the islands is by Renuka (1995), who studied diversity of rattans from these islands and reported many new species.

MATERIALS AND METHODS

The forest areas of Andaman and Nicobar Islands have been thoroughly surveyed for collection of different taxa of palms, during September-October 2008. Correct identity of the specimens was established by referring to the herbarium material in herbaria of KFRI, Peechi and BSI, Andamans. Standard monographs were referred for identification of these plants (Beccari, 1908, 1911, 1913; Blatter, 1926; Griffith, 1844-45; Hooker, 1872-1897; Parkinson, 1923; Renuka, 2001; Uhl and Dransfield, 1987). In order to find out the distribution of palms in other geographical regions of the world Kew check list of palms were consulted. Voucher herbarium specimens prepared for all palms collected have been deposited in the Herbarium of Kerala Forest Research Institute, Peechi, Kerala.

RESULTS AND DISCUSSION

The study has revealed that the palm resources of Andaman and Nicobar Islands are quite rich and unique. The palm flora of Andaman and Nicobar Islands (excluding

rattans) is represented by ten genera and seventeen species (Table 1). In addition to indigehous palms there were few exotic palms cultivated in Botanic Gardens (Table 2). Of the eleven reported genera five are monotypic (*Bentinckia*, *Caryota*, *Corypha*, *Nypa* and *Rhopaloblaste*) represented by single species. Seven genera with nine species (*Bentinckia nicobarica*, *Caryota mitis*, *Corypha utan*, *Licuala paludosa*, *Phoenix andamanensis*, *Pinanga andamanensis*, *P. coronata* *P. manii* and *Rhopaloblaste augusta*) are endemic to these Islands. The taxa such as *Arenga pinnata*, *Bentinckia nicobarica*, *Corypha utan*, *Licuala paludosa*, *Nypa fruticans*, *Phoenix andamanensis*, *Pinanga andamanensis*, *P. coronata*, *P. manii* and *Rhopaloblaste augusta* shows very restricted distribution and their population size is very small, and are facing high threat of extinction. Some of the taxa like *Bentinckia nicobarica*, *Nypa fruticans*, *Pinanga andamanensis*, *P. manii* are already been entered into the RED data book as rare and threatened plants (Nayar and Sastry, 1983). The dire need to protect these palm resources from extinction is very much emphasized. The flora of Andaman group of islands show striking dissimilarities with that of Nicobar group. The taxa such as *Arenga pinnata*, *A. westerhoutii*, *Corypha utan*, *Licuala paludosa*, *L. spinosa*, *Phoenix andamanensis*, *Pinanga andamanensis*, *P. coronata* and *P. manii* which are present in Andamans are not met with in the Nicobars. So, also, the genera like *Bentinckia* and *Rhopaloblaste* are confined to the Nicobar and are seldom found in the Andamans. While the Andamans have more species common to NE India and Myanmar (*Areca triandra*, *Arenga pinnata*, *A. westerhoutii*, *Licuala peltata*), the Nicobars have more in common with Indonesia and Malaysia (*Licuala* sp., *Nypa* sp.).

Recently during the course of intensive explorations in the vicinity of Austin I & II near Mayabunder (North and Middle Andaman district) the authors located one more palm taxa, *Arenga pinnata* (Wurmb.) Merr. (Fig. 1. A-D) which is so far not reported from this region. Though this taxon is widespread in NE India,

Table 1. Diversity of palms in Andaman & Nicobar Islands

Sl. No.	Taxa	Local name	Andaman	Nicobar	Mainland India	Other places
1	<i>Areca catechu</i> L.	Supari	South Andaman Islands.	Great Nicobar, Katchal Island and Car Nicobar and also cultivated in other islands.	Cultivated throughout India.	Cultivated in Malaysia.
2	<i>Areca triandra</i> Roxb. ex Buch.-Ham.	Jungly supari	Chidiyatapu, Baratang Island, Austin-I & II, Mayabunder, Rangat, Diglipur,	Laful bay, Great Nicobar (E-W & N-S Road), Car Nicobar.	Assam	Trop. & Subtrop. Asia
3	<i>Arenga pinnata</i> (Wurmb.) Merr.	Jungly Narial	Very rare, few plants only in Austin-I & II near Mayabunder	-	NE India	S. China to C. Malaysia
4	<i>A. westerhoutii</i> Griff.	-	Reported from N. Andaman Could not be collected.	-	Arunachal Pradesh, Manipur	Bhutan to Pen. Malaysia
5	<i>Bentinckia nicobarica</i> (Kurz) Becc.	-	-	Endemic to Nicobar Is. Car Nicobar, Nan cowry	-	-
6	<i>Caryota mitis</i> Lour.	Madipathy	Mount Harriet, Chidiyatapu, Ross & Smith Island, Mayabunder, Little Andaman,	Great Nicobar, Car Nicobar	-	Indo- China and Malaysia.
7	<i>Corypha utan</i> Lam.	-	Endemic to Andaman Is. Rossland Island, Baratang Island, Mayabunder.	-	-	NE India to N. Australia.
8	<i>Licuala paludosa</i> Griff.	-	Endemic Baratang Island, Rutland Island, Rangat Bakulthala.	-	-	Indo-China to W. Malaysia.
9	<i>L. peltata</i> Roxb. ex Buch.-Ham.	Salai pathi	Lime stone cave, Mud volcano (Baratang) Rangat (Parnasala), Bakulthala,	Laful bay, Great Nicobar, Car Nicobar,	Assam, Bihar, Manipur Tripura.	Bhutan to Pen. Malaysia.
10	<i>L. spinosa</i> Wurmb.	Salai pathi	Shoal bay, Chidiyatapu, Baratang Island, Rutland Island, Ross & Smith Island	-	-	Indo-China to Philippines

Table 1. Contd.

Sl. No.	Taxa	Local name	Andaman	Nicobar	Mainland India	Other places
11	<i>Nypa fruiticans</i> Wurmb.	Dhani ped	Dhanikari, Sippighat.	Laful bay, Car Nicobar	West Bengal	Sri Lanka to Caroline Is.
12	<i>Phoenix andamanensis</i> S. Barrow	Jungly kajur	Endemic Saddle peak, Kalli Ghat, Rutland Island, Cinique Island.	–	–	–
13	<i>P. paludosa</i> Roxb.	Jungly kajur	Shoal bay, Mud volcano, Lime Stone Cave (Baratang Island) Sound Island, Interview Island, Ross & Smith Island, 'D'-sector, Mohanpur, Mayabunder.	+	Orissa, West Bengal	+
14	<i>Pinanga andamanensis</i> Becc.	Komba	Endemic to Andaman Islands found in Baratang Island, Mount Harriet, & Shoal bay.	–	–	–
15	<i>P. coronata</i> (Blume ex Mart.) Blume	Bada komba	Rare, found in South Andaman Is. Mount Harriet, Shoal bay.	–	–	Lesser Sunda
16	<i>P. manii</i> Becc.	Bada komba	Endemic to Andaman Island Chidiyatapu, Mount Harriet.	Car Nicobar, Shaful bay	–	–
17	<i>Rhopaloblastae augusta</i> (Kurz) H.E. Moore	–	–	Endemic to Nicobar Is. Car Nicobar, Great Nicobar – Galatea, Laful bay. Grows in the moist hill valleys and slopes of high rainfall areas.	–	–

Table 2. Cultivated palms

<i>Areca catechu</i> L.	Andaman Is., cultivated throughout India
<i>Borassus flabellifer</i> L.	A& N Is., throughout tropical India.
<i>Chrysalidocarpus lutescens</i> H.Wendl.	Introduced one, grown as ornamental in gardens in Port Blair
<i>Cocos nucifera</i> L.	Cultivated in A & N Is. and in other parts of India especially along coastal belt.
<i>Elaeis guineensis</i> Jacq.	Cultivated in Great Nicobar, South Indian States.
<i>Livistona chinensis</i> (Jacy.) R. Br.ex Mart.	Introduced one, grown as ornamental in gardens.
<i>Phoenix sylvestris</i> (L) Roxb.	Andhra Pradesh, Chandigarh, Orissa & throughout the hotter parts of India.
<i>Roystonea regia</i> (Kunth) O.F. Cook	Introduced one, grown as ornamental in gardens.

Note : Source used for distribution of Palms in out side India is : 'World Checklist of Palms'-(Eds.) Rafael Govaerts and John Dransfield. 2005. 'Published by Royal Botanic Gardens, Kew Richmond, Surrey, TW9 3AB, UK.

it was not reported from Andaman & Nicobar Is. The present collection establishes the extended distribution of taxon in Andaman Is. Further the occurrence of this taxon is also reported from South China to Central Malaysia depicting its disjunctive distribution. *Phoenix andamanensis* is endemic and is unique in its distribution, found to be growing at very high altitudes (Fig. 2. A). They are distributed in Saddle Peak at 700 m above MSL, in eastern slope of Mt Ford, in Cinque Island, in Rutland Island (Brandis, 1906 and Parkinson 1923). Recently, the present authors also found this taxon in Kalighat (N. Andaman district) in the vicinity of hydro electric power station.

Damage due to Tsunami

The massive Earthquake followed by Tsunami on 26.12.2004 has completely incurred unbearable damage by biodiversity loss. The major islands affected by Tsunami are North Andaman, Middle Andaman, South Andaman, Little Andaman, Car Nicobar, Teressa, Katchal, Nancowry, Kamorta, Little Nicobar and Great Nicobar. During field survey, it was found that, the swamps and mangrove creeks in Shoal bay (South Andaman) and Austin I & II, 'D'- sector, Sound Island, Long Island, Mayabunder, which

were once covered with dense population of the *Phoenix paludosa* have been badly affected by tsunami (Fig. 2. B). Vegetations loss is more in Islands of Nicobar group than in middle and south Andaman and there is vast inundation of seawater in the low-lying areas. *Rhopaloblaste augusta*, an endemic palm with threatened conservation status concentrated in Galatea bay, Indira Point, Chengappa bay and Joginder Nagar area was destroyed by high tides of Tsunami. In Car Nicobar entire coconut palm plantations near Tee top Forest Range Office was succumbed by Tsunami waves (Fig. 2. C). There is a considerable damage to mangrove palm *Nypa* throughout their distributional range.

Conservation status

Many taxa of palms have become vulnerable due to habitat destruction and overexploitation. There is a phenomenal reduction in the natural population of *Rhopaloblaste augusta*, *Bentinckia nicobarica*, *Corypha utan* and *Phoenix andamanensis*. This may be attributed to the failure of taxa to cope up with the altered environment, low regeneration capacity, reproductive failure and very narrow distributional range. Mathew and Abraham

(1994) based on the field survey reported that *Corypha utan* occurs only in type collection and they were unable to locate it. This clearly depicts that, their natural population has come down below threshold level. Interestingly, during intensive survey in forest areas around Mayabunder we found few plants in the forest areas between Mayabunder and Mohanpur and one of them near Mayabunder was in the flowering stage. This was reported to the Forest Department authorities.

Some of the species like *A. westeroutii* could not be relocated in their natural habitat (N. Andaman) during the present survey, indicating that their population have become severely decreased during recent years. Hence, there is an urgent need for habitat preservation for *in situ* conservation. Effective measures are to be taken to conserve and propagate this group of plants. Although the Forest Department, Botanical Survey of India and Ministry of Environment and Forests, have taken measures to protect these valuable resources by establishing sanctuaries or national parks (to mention a few) such as Wandoor Marine National Park extending over an area of about 282 km² covering a total area of about 640 km², Interview Island Sanctuary (133.87 km²), Mount Harriet National Park (32.53 km²) and Saddle Peak National Park (46.62 km²), with regard to the extent of protected areas they do not represent fully the biological diversity in the Islands, and their size may not permit the maintenance of viable populations. In addition the tribal reserve areas—Jarawa reserve, Shompen reserve etc. also fulfils the function of conservation of biological diversity, due to the fact that these tribals seldom bring about any significant ecological changes. However, there are many endemic taxa present out side the reserve, in low lying forest areas and are easily prone to be effected by the ecological variations. Therefore, while establishing nature reserves it is necessary to examine each island from the point of its unique features and conservation areas should be selected accordingly. Ecosystem conservation

together with *ex situ* conservation of Palms in Botanical gardens/parks etc. will guarantee the conservation of the species.

CONCLUSIONS

Andaman and Nicobar Islands are home to one of the richest and most exciting palm floras of the world. It is regarded as one of the 'hot-spots' of biological diversity. It shows very high level of endemism at both the generic and species levels. The vast majority of island biota is, however, at the present time under serious pressure from the activities and influence of man who is destroying their natural ecosystems at an alarming rate. In addition, natural calamities like tsunami posed severe threat to their survivability. Any destruction to the habitat will lead to depletion of the natural population and endangers the survival of the species. Several species are in immediate danger of extinction. For the prevention of further genetic erosion of these species, the development and adoption of appropriate conservational strategies are very much warranted.

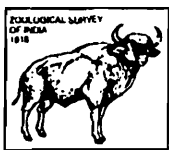
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DIVERSITY AND CONSERVATION STATUS OF RATTANS IN ANDAMAN & NICOBAR ISLANDS

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INTRODUCTION

The flora and fauna of Andaman and Nicobar islands are unique to India because of the tropical humid climate and the insular nature of the territory. The physical isolation from the mainland and between the islands through millennia has resulted in the evolution of a rare and unique flora in these island groups. Most of the islands are covered with luxuriant vegetation. The total Forest cover in the Andaman and Nicobar Islands is about 6964 km² which is about 84.41 per cent of total geographical area of the Islands. The overall pattern of vegetation belongs to the tropical evergreen type. Many parts of the territory are still unexplored or under explored and therefore our knowledge on the flora of the islands at present can be said to be inadequate. The Campbell Bay National Park area (520 km²) with high mountain ranges reaching to a height of 670 m (Mt. Thullier) constitutes one of the 'hottest hotspots' in the world and the Galathea National Park, which encompasses deep valleys, steep slopes are the biologically richest but yet unexplored. The geographical continuity of Andaman and Nicobar islands with Myanmar in north and Indonesia in south

has resulted into the mosaic of floristic elements, both in forms of luxuriance and species diversity, owing to a very congenial phytoclimatic condition. Kerala Forest research Institute had conducted a field survey for the rattans of Andaman and Nicobar Islands during the years 1992-1995 (Renuka, 1995). Another field survey was taken up during the year 2008 by the first two authors, which helped to review the present distribution and conservation status of rattans in these islands which is discussed in this paper.

Rattans are a group of climbing, spiny palms with characteristic scaly fruits. Dransfield and Uhl (1986) have placed them under a distinct subfamily, Calamoideae of Arecaceae (Palmae). With about 600 species under 13 genera, they are mainly distributed in Paleotropics with the maximum species diversity in South East Asia (Uhl and Dransfield, 1987). Only four genera - *Calamus*, *Daemonorops*, *Korthalsia* and *Plectocomia* represent the Indian rattans which are found in three major regions: Western Ghats of Peninsular India, Andaman and Nicobar Islands and North and North-eastern India. Geographically isolated from the mainland, Andaman and Nicobar islands are characterised by a distinctive flora and are treasure-houses

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of several rare and endemic taxa. This is particularly true of rattans, which have been represented by *Calamus* (11 species), *Daemonorops* (5 species) and *Korthalsia* (2 species) (Renuka, 1999 and 2001).

MATERIALS AND METHODS

The forest areas of Andaman and Nicobar Islands have been thoroughly surveyed for collection of different species of rattans, during September-October, 2008. Collection and preservation was done as per standard procedure. Correct identity of the specimens was established by referring to the herbarium material present at herbaria of ANRC/BSI/Port Blair, and KFRI, Peechi. Standard literatures were followed for identification of these plants (Hooker, 1872-1897; Kurz, 1877; Beccari, 1908, 1911 and 1913; Parkinson, 1923; Blatter, 1926; Basu, 1992 and Renuka, 1995). Voucher herbarium specimens prepared have been deposited in the Herbarium of Kerala Forest Research Institute, Peechi, Kerala. For knowing distributional status in other parts of the world, Kew check list of palms was consulted.

RESULTS AND DISCUSSION

The study has revealed that Andaman and Nicobar Islands are quite rich in rattan diversity comprising of three genera (*Calamus*, *Daemonorops* and *Korthalsia*), with eighteen species. *Calamus* with 11 species forms major rattan flora, followed by *Daemonorops* with five species and *Korthalsia* with two species. The most remarkable feature is the high level of endemism both at generic and species level (Balakrishnan, 1977; Balakrishnan and Nair, 1977; Ellis, 1989 and Subba Rao, 1989). Of the 18 reported species, eight species (*Calamus*-3 species, *Daemonorops* 4 species and *Korthalsia* 1 species) are endemics. Some of the taxa such as *Calamus basui*, *C. dilaceratus*, *C. semierectus*, *C. unifarius*, *Daemonorops manii*, *D. rarispinosus*, *D. wrightmyoensis* and *Korthalsia rogersii* show very low population density in their natural habitat. While *C. andamanicus* and *K. laciniosa* occur in both the Andaman and Nicobar groups of islands, most others have restricted

distribution in certain parts only (Table 1). Eleven species are confined to Andamans and five to the Nicobar group. Of the later, *C. pseudorivalis*, *C. dilaceratus* and *C. unifarius* are seen only in Great Nicobar, while *C. semierectus* is confined to Car Nicobar. In the Andaman, six species are confined to South Andaman, while *C. basui* and *D. rarispinosus* are confined to Little Andamans. Sahni (1953), Thothathri (1977), Nair (1989) and Balakrishnan (1989) points out the extensive availability of *C. andamanicus* and *K. laciniosa* throughout the archipelago and restricted distribution of *C. pseudorivalis*, *C. palustris*, *C. viminalis*, *C. longisetus* and *D. kurzianus*. Mathew and Abraham (1994) based on field studies, probably restricted to few islands, mentioned that the *K. rogersii* is confined to its type locality, Havelock Island in South Andaman and *C. dilaceratus* known only from their type collection and has never been collected again. Later, Renuka (1995) could collect *C. dilaceratus* from Great Nicobar Island. She made some noteworthy contribution to rattan flora by reporting few more new rattans from Bay islands. It includes *C. basui* and *D. rarispinosus* from Little Andaman; *C. baratangensis*, *D. aureus*, *D. wrightmyoensis* from South Andaman and *C. semierectus* from Car Nicobar. During present collection we are able to locate *C. dilaceratus* (Fig. 1. A & B) from Laful bay area (Great Nicobar) which is a protected reserve for Shompen tribes, *K. rogersii* (Fig. 1. C and D) in Chidiyatapu (S. Andaman) and in forest areas of Parnasala, near Rangat (N. Andaman), and *C. unifarius* from Car Nicobar. This forms a new distributional record. Champion and Seth (1968), while classifying the forest types of Andaman and Nicobar Islands, reported the occurrence of rattans in abundance in valleys of tropical forests of Andaman and Nicobar Islands. Renuka (1995) reported that severe pressure from rattan industries in the mainland together with the unscientific extraction and over-exploitation of the raw materials resulted in the depletion of the rattan resources at a faster rate in some of the Islands. Recent survey revealed that the over-exploitation is continuing and the resource is getting dried up rapidly.

Table 1. Diversity of rattans in Andaman & Nicobar Islands

Sl. No.	Taxa	Local name	Andaman	Nicobar	Mainland India	Other places
1	<i>Calamus andamanicus</i> Kurz*	Motta beth	Widely distributed in Andaman Is.	Widely distributed in Nicobar Is.	–	–
2	<i>C. baratangensis</i> Renuka and Vijayakumaran*	Malay beth/ Rassi beth	Endemic to Andaman Is. Shoal bay, Chidiyatapu, Baratang Island, Little Andaman, Ross & Smith Island, Rangat.	–	–	–
3	<i>C. basui</i> Renuka and Vijayakumaran*	Safed beth	Very rare and Endemic to Little Andaman.	–	–	–
4	<i>C. dilaceratus</i> Becc.*	Lal beth	–	Endemic and rare found in Laful bay, Great Nicobar (E-W & N-S Road).	–	–
5	<i>C. longisetus</i> Griff.	–	Shoal bay, Chidiyatapu, Baratang Island, Little Andaman, Ross & Smith Is., Rangat.	–	–	Indo-China to Pen. Malaysia.
6	<i>C. nicobaricus</i> Becc. *	Dahya	–	Rare and Endemic to Car Nicobar, Katchal, Great Nicobar.	–	–
7	<i>C. palustris</i> Griff.	Dunda beth	S. Andaman (Shoal bay, Chidiyatapu, Mount Harriet) and Little Andaman	–	–	S. China, Pen. Malaysia. Cambodia, Laos.
8	<i>C. pseudorivialis</i> Becc.*	–	–	Endemic to Great Nicobar	–	–
9	<i>C. semierectus</i> Renuka and Vijayakumaran*	–	–	Rare, Endemic to Car Nicobar.	–	–
10	<i>C. unifarius</i> H. Wendl. var. pentong Becc.	Hara beth	–	Endemic to Great Nicobar, Car Nicobar.	–	–

Table 1. Contd.

Sl. No.	Taxa	Local name	Andaman	Nicobar	Mainland India	Other places
11	<i>C. viminalis</i> Willd.	Jungli beth	Chidiyatapu, Ross & Smith Island, Rangat.	–	Andhra Pradesh, Bihar, Manipur, Orissa, Sikkim, Tripura, West Bengal.	Chittagong (Bangladesh SC. China to Lesser Sunda Is. (Bali).
12	<i>Daemonorops aureus</i> Renuka and Vijayakumaran*	–	Restricted in distribution only in S. Andaman-in Shoal bay, Chidiyatapu, Mount Harriet.	–	–	–
13	<i>D. kurzianus</i> Hook.f. ex Becc.	Sanka beth	Endemic to S. Andaman, Wandoor, Tharmugali, Chidiyatapu, Shoal bay	–	–	W. Thailand
14	<i>D. manii</i> Becc.*	Sanka beth	Highly endemic to S. Andaman, found in Wrightmyo.	–	–	–
15	<i>D. rarispinosus</i> Renuka and Vijayakumaran*	–	Endemic to Little Andaman.	–	–	–
16	<i>D. wrightmyoensis</i> Renuka & Vijayakumaran*	–	Endemic to S. Andaman found in Shoal bay, Wrightmyo.	–	–	–
17	<i>Korthalsia laciniosa</i> (Griff.) Mart.	Lal beth/ Myanmar beth	Shoal bay, Mount Harriet, Chidiyatapu, Ross & Smith Island, Mayabunder, Little Andaman, Baratang Island, Rutland,	Laful bay, Great Nicobar (E-W & N-S Road), Car Nicobar	–	Indo-China to Philippines
18	<i>K. rogersii</i> Becc.*	Myanmar beth	Endemic to Andaman Is. Rangat, Chidiyatapu.	–	–	–

Note : Source of information for distribution of rattans outside India is : 'World Checklist of Palms'-(Eds.) Rafael Govaerts and John Dransfield. 2005. Published by Royal Botanic Gardens, Kew Richmond, Surrey, TW9 3AB, UK.

‘*’= Endemic to Andaman & Nicobar Islands

C. nicobaricus reported earlier, could not be relocated during later surveys. There is a drastic reduction in population size in all the localities. Some of the taxa such as *Calamus basui*, *C. dilaceratus*, *C. semierectus*, *C. unifarius*, *Daemonorops manii*, *D. rarispinosus*, *D. wrightmyoensis* and *Korthalsia rogersii* show very low population density in their natural habitat. During the last decade the significant change had occurred due to habitat destruction, low regeneration, and inability to compete with other plants.

In addition, catastrophic events like Tsunami posed severe threat to their survivability. The effect of 24 Dec. 2004 tsunami is unimaginable and it caused unbearable loss to rattan biodiversity. The effect of Tsunami is more on Nicobar group of Islands, than in Andaman groups. A vast forest area which forms natural habitat of the rattans around Galathea bay, Indira Point, Chengappa Bay, and Laful Bay become completely devoured in the tsunami currents. Our observation on the distribution of the species also revealed that most of the species are highly habitat specific. Most of the endemics in these islands occur in very limited localities and habitats in small populations. Destruction of even a small forest area in these islands may render the endemics living there extinct. Hence there is a dire need to conserve these invaluable rattan taxa immediately to save them from becoming extinct shortly. Table 1 gives the analysis of the distribution of the species, number of endemics and the number of taxa occurring in mainland India and else where to assess the approximate percentage of endemism. Andamans have one species (*C. viminalis*) common to North East India, Bangladesh, China to Indonesia and four species common to South East Asian countries.

Rarity-Cause for Concern

Incidence of rarity and extinction in plant kingdom has been the reason for much concern in recent years from both the conservation as well as the biodiversity point of view. Geographical restrictedness, altitude, vegetation, and habitat specialization may have

an influence on the status of plant species. *C. andamanicus* is a common cane of Andaman and Nicobar islands. Other species of rattans show very restricted distribution and small population size. The species diversity of rattans taxa is given in Table. 1. Many of the endemic rattans of India are under severe threat due to destruction of their habitat and over exploitation (Biswas and Dayal, 1995; Balakrishnan and Rao, 1983 and Rao, 1986). *C. dilaceratus* and *K. rogersii* of Andaman and Nicobar Islands have been already enlisted in the Red Data Book of Indian plants prepared by Botanical Survey of India (Ahmedulla and Nayar, 1986). According to Sharma and Bhat (1982) Andaman and Nicobar Islands are referred as the last bastion of useful rattans. Natural calamities like tsunami, failure in natural regeneration, habitat destruction, low reproductive capacity, restricted distribution and lack of conservation measures put them at high level risk.

Research needs and priorities

Andaman and Nicobar Islands is remarkably rich in the genetic diversity of the rattans. Rattans are a much threatened group of tropical plants. As the world's demand for rattan and rattan products is on the increase, there is tremendous pressure on the wild population of these species. The potential resource of the country is fast depleting due to heavy biotic interference. The key areas for conservation of Indian rattans are Andaman and Nicobar Islands, Western Ghats, and North East India. Strict measures on the indiscriminate exploitation and habitat destruction are required to be enforced for the protection of these species.

Strategies for conservation

In order to protect these valuable species for posterity following conservation measures are proposed :

- i. Establishment of a canetum with representation of all the species growing in the islands.

- ii. Establishment of cane plantation of commercially important species in large scale for commercial purpose.
- iii. Understanding the biology and phenology of rattans, which is very important for the conservation of the species.
- iv. Control on the exploitation of wild populations.
- v. Check on the destruction of natural habitats.
- vi. Establishment of gene banks and seed orchards.
- vii. Introduction of rare and threatened species into Botanic gardens, arboreta and other protected areas.
- viii. Selection of specific pockets in the natural area of the occurrence of rattans for *in situ* conservation.
- ix. Evolving potentially useful methods for the propagation and improving the various existing methods.
- x. Exchange of germplasm among rattan growing countries.

CONCLUSIONS

The phytodiversity of rattans in Andaman & Nicobar Islands has been under great pressure due to various factors. The major causes leading to the loss of biodiversity includes over exploitation, competition between the species, natural calamities and lack of conservation measures. Hence, there is an urgent need for habitat preservation for *in situ* conservation. Ecosystem conservation together with large scale cultivation of rattans will guarantee the conservation of the species.

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Plate 1

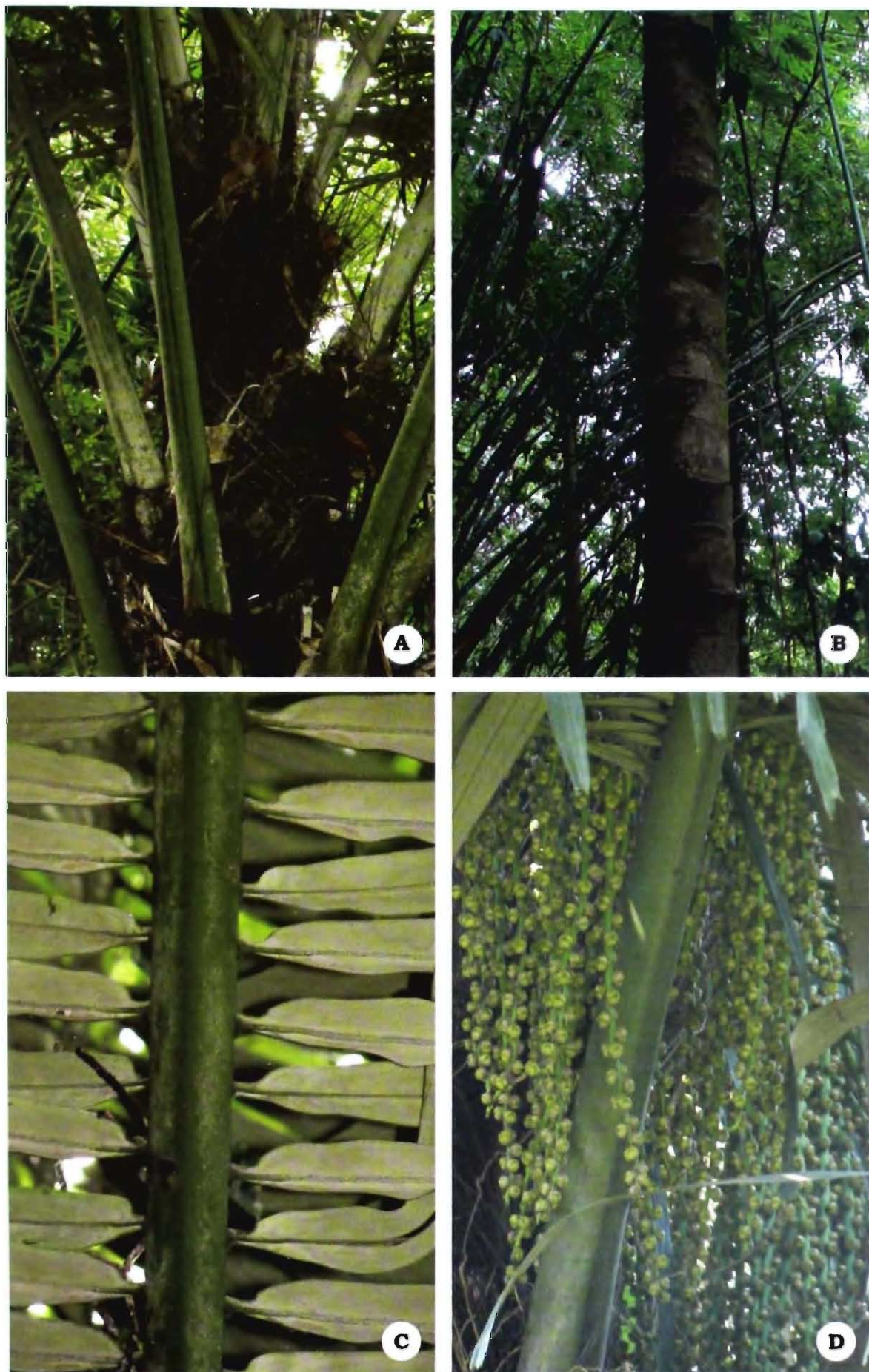


Fig. 1. *Arenga pinnata* (A. Leaf sheath fibers, B. Stem, C. A portion of leaf, D. Inflorescence).

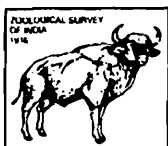
Plate 2



Fig. 2. A. *Phoenix andamanensis* Habit, B. *P. paludosa* habitat affected by tsunami, C. Coconut plantation affected by tsunami.

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GLIMPSES OF A FEW REMARKABLE WILD TREES FOR THE SURVIVAL OF ANIMAL SPECIES IN SOUTHERN WESTERN GHATS

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INTRODUCTION

Some of the wild trees in the Southern Western Ghats support entire ecosystems for pollinator birds and small animals. Butterflies and other insects, small birds and other animals depend on seeds, nectar and pollen for their food supply and life support system (Ambrose 2005). Unfortunately our forest is experiencing the increasing degraded forest area (Annamalai 2004). The present study emphasizes the identification of wild tree plant species in the order of preference by the pollinators and seed dispersers. The present study focuses on the families like Myrtaceae, Bombacaceae, Combretaceae, Elaeocarpaceae and Papilionaceae. Since they attract more pollinator birds and small animals, they are considered as "Keystone mutualists" among the other family members of the Southern Western Ghats study area. The outcome of the study recommends some of the tree species for afforestation programme to conserve forest ecosystem.

MATERIALS AND METHODS

Southern Western Ghats has selected as a study area to locate remarkable wild tree

species which attracts more animal visitors and also commonly visited by a few endemic and endangered animals. Vegetation sampling was done by quadrat method comprising one hectare sample plots starting from the foot hill to the higher elevations of the study area. One year study was made between 2007 and 2008 to identify a few tree species belonging to the five remarkable families namely Myrtaceae, Bombacaceae, Combretaceae, Elaeocarpaceae and Papilionaceae which invite more animal visitors. In the sample plot, only the flowering and fruiting trees which attracted more animal visitors were tagged as focal plant species as they are supposed to support the survival of endangered animals. The Plant-animal interaction identification was confirmed by taking digital photographs of the plant species and animal visitors. A small sample of plant twig from the focal plant species were collected (Yoganarasimhan 2000) and a herbarium is maintained in the Bat Research laboratory Sarah Tucker College, Tirunelveli. The identification of the plant species was confirmed by Dr. Chelladurai, (Rtd) Botanist, Govt. Siddha Medical College, Palayamkottai and Dr. Gopalan, (Rtd) Scientist, Botanical survey of India Coimbatore.

Animal visitors abundance in focal plant species was estimated by line transect method within the selected sample plot (quadrant) of one hectare. Animal visitors were counted 20m on either side of the 1Km walk of constant speed near the location of focal plant species. Direct observation on focal plant species was carried out to record various visitors and their activity for one hour. The anthophilous insect community (Melittophily, Phalaenophily, cantharophily and Myophily) was confirmed by observing 8 min per flower stand after this observation the flowers were swept with a net for 2 minutes to collect all remaining insect visitors on them (Kato *et al.* 1993, Kato 2000, Yamazaki and Kato 2003). Extended watch was done on the focal plant species both during day and night hours. Bird visitor's activity was recorded between 07.00 to 08.00 hours. Observations were made from the focal plant using binoculars (Howe 1977, Howe and Van de Kerckhove, Lambert 1989). Bat visitors activity was documented by mist netting below and above canopy near the fruiting and flowering tree between 18.30 and 20.30 hrs

RESULT AND DISCUSSION

The Western Ghats, one of the 25 megabiodiversity hot spots of the world (Myers *et al.* 2000) covers 5% of India's land area yet contains more than 4000 or 27% of the country's total plant species. Of these, 1500 species are endemic (Mackinnon *et al.* 1986). Nearly 63% of India's arborescent evergreen taxa are endemic to Western Ghats (Ramesh *et al.* 1997). In the Agasthyarmalai region, the pattern of high endemism and diversity is well illustrated by plant taxa. This region has about 150 localized plant endemics and a rich reservoir for a large number of wild relatives of cultivated plants such as cardamom, mango, banana, rice, jackfruit and turmeric (Henry *et al.* 1984). Few fruit tree species belonging to various forest types act as a life sustaining unit for these rare animals by way of providing dietary resources and habitat (Bagla and Menon 2000, Kanjilal 1982, Johnsingh 2001). The present study reveals majority of the life

sustaining trees (provide nectar and fruits) belongs to the family Bombacaceae(3), Combretaceae (6) Elaeocarpaceae (3), Myrtaceae (7), Papilionaceae (10) are tagged as focal trees.

Location and Phenology details of focal plant species which attracts more animal visitors are given in (Table 1). The Figure 1 represents the observed plant animal mutualistic interaction with the focal member of the five remarkable families. The comparative studies of plant-animal interaction between the members of the families are represented in Table 2, Figure 2 and 3. The following interpretations are derived from results of the present investigation.

The present investigation reveals that eight members of family Myrtaceae and twelve members of Papilionaceae have distribution - starts from lower to higher elevations. In addition, six focal plant species of Combretaceae have distribution from below 2000 feet elevation and three focal plant members of Bombacaceae and Elaeocarpaceae have distribution above 1000 feet to very high elevations.

The family members of Myrtaceae, are distributed in all the forest types. Collectively, Myrtaceae family attracts large number of animals. The number of animals visit per tree calculations reveal that Myrtaceae members are the mostly attracted family among the five families. *Syzygium* spp., *Bombax* spp., *Terminalia* spp., *Elaeocarpus* spp. and *Erythrina* spp. are commonly visited by rare animals. Quite a few members like *Syzygium* spp., *Eugenia Calacadensis*, *Psidium guajava* showed higher interaction both during flowering and fruiting season with pollinators and seed dispersers. They are also known to support endemic, endangered fruit bats, primates and variety of frugivorous and nectarivorous birds. It is noteworthy to highlight *Syzygium* spp. because they attract the lower grade insects to higher grade mammals like primates, bats, sloth bear, deer and nectarivorous and frugivorous avian fauna. Thus helps to sustain diversity in all the forest types.

Table 1. Location and Phenology details of Focal plant species which attract more animal visitors

Bombaceae			Flower	Fruit
<i>Bombax malabaricum</i> (Rare)	Moist Mixed Deciduous Forests, Southern Hilltop Evergreen Forests, Tropical Wet Evergreen Forest	Ele:3412ft N:8°31.974' E:77°27.256' Ele:3220ft N:8°11.271' E:77°27.569'	April	August
<i>Cullenia exarillata</i> (Rare)	Southern Hilltop Evergreen Forests, Tropical Wet Evergreen Forest	Ele:2421ft N:8°32.211' E:77°27.111' Ele:2447ft N:8°38.678' E:77°25.424' Ele:2145ft N:8°38.684' E:77°25.424' Ele:2444ft N:8°32.170' E:77°27.536'	July	September
<i>Eriodendron pentandrum</i>	Southern Dry Mixed Deciduous Forests, Moist Mixed Deciduous Forests, Southern Hilltop Evergreen Forests, Tropical Wet Evergreen Forest	Ele:2417ft N:8°32.211' E:77°27.111' Ele:2047ft N:8°38.688' E:77°25.426' Ele:2125ft N:8°38.684' E:77°25.424' Ele:2588ft N:8°32.170' E:77°27.536' Ele:2444ft N:8°32.170' E:77°27.536'	April	June
Combretaceae			Flower	Fruit
<i>Anogeissus latifolia</i> (Rare)	Southern Dry Mixed Deciduous Forests, Moist Mixed Deciduous Forests, Semi Evergreen Forest	Ele:2889ft N:8°32.170' E:77°27.537' Ele:2913ft N:8°32.211' E:77°27.126'	June	August
<i>Terminalia paniculata</i> (Rare)	Evergreen Forest	Ele:1493ft N:8°25.344' E:77°24.142'	October	December
<i>Terminalia chebula</i>	Moist Mixed Deciduous Forests, Semi Evergreen Forest	Ele:1755ft N:8°15.818' E:77°92.102'	March	November
<i>Terminalia arjuna</i>	Tropical Riparian Fringe Forests	Ele:300ft N:8°40.590' E:77°23.206'	June	August
<i>Terminalia bellerica</i> (Rare)	Moist Mixed Deciduous Forests, Semi Evergreen Forest	Ele:985ft N:8°31.621' E:77°29.004'	January	March
<i>Terminalia catappa</i>	Tropical Plain	Ele:163ft N:9°41.959' E:77°44.427'	May	July
Elaeocarpaceae			Flower	Fruit
<i>Elaeocarpus serratus</i>	Semi Evergreen Forest, Southern Hilltop Evergreen Forests, Montane Evergreen forest	Ele:1108ft N:9°41.589' E:77°18.887' Ele:1758ft N:8°15.847' E:77°92.102' Ele:1755ft N:8°15.844' E:77°92.174' Ele:5151ft N:9°38.248' E:77°21.799'	February	April

Table 1. Contd.

Elaeocarpaceae			Flower	Fruit
<i>Elaeocarpus munroii</i>	Semi Evergreen Forest, Southern Hilltop Evergreen Forests	Ele:3100ft N:8°31.874' E:77°27.256' Ele:3412ft N:8°31.974' E:77°27.256' Ele:3001ft N:8°12.256' E:77°27.234' Ele:4498ft N:8°30.431' E:77°27.190' Ele:4942ft N:9°36.787' E:77°18.451'	April	August
<i>Elaeocarpus tuberculatus</i> (Rare)	Southern Hilltop Evergreen Forests, Tropical Wet Evergreen Forest, Southern Montane Wet Temperate Forests and Subtropical Montane Forests	Ele:3478ft N:8°34.847' E:77°27.279' Ele:3124ft N:8°31.974' E:77°27.256' Ele:3124ft N:8°12.254' E:77°27.231' Ele:4214ft N:8°30.431' E:77°27.177'	April	August
Myrtaceae			Flower	Fruit
<i>Eugenia calacadensis</i> (Endemic Vulnerable, Rare)	Semi Evergreen Forest, Southern Hilltop Evergreen Forests	Ele:1144ft N: 9°41.544' E:77°18.111' Ele:1478ft N: 8°15.818' E:77°92.107' Ele:1769ft N: 8°15.818' E:77°92.108'	August	October
<i>Syzygium Jambos</i>	Southern Hilltop Evergreen Forests, Tropical Wet Evergreen Forest	Ele:2445ft N:8°32.277' E:77°27.101' Ele:2789ft N:8°38.671' E:77°25.412' Ele:2214ft N:8°38.684' E:77°25.424' Ele:2410ft N:8°32.111' E:77°27.547'	October	November
<i>Syzygium mundagam</i> (Endemic Vulnerable, Rare)	Southern Hilltop Evergreen Forests, Tropical Wet Evergreen Forest, Southern Montane Wet Temperate Forests and Subtropical Montane Forests	Ele:3145ft N:8°31.877' E:77°27.256' Ele:3478ft N:8°31.948' E:77°27.256' Ele:3011ft N:8°12.254' E:77°27.234' Ele:4789ft N:8°30.431' E:77°27.194'	October	November
<i>Syzygium rubicundam</i>	Southern Hilltop Evergreen Forests, Tropical Wet Evergreen Forest, Southern Montane Wet Temperate Forests and Subtropical Montane Forests	Ele:3100ft N:8°31.874' E:77°27.256' Ele:3412ft N:8°31.974' E:77°27.256' Ele:3001ft N:8°12.256' E:77°27.234' Ele:4498ft N:8°30.431' E:77°27.190'	November	January
<i>Syzygium cumini</i>	Tropical Plain, Southern Hilltop Evergreen Forests, Dry, Moist Mixed Deciduous Forests	Ele:161ft N:9°41.958' E:77°44.421' Ele:844ft N:8°41.587' E:77°18.887' Ele:349ft N:8°40.594' E:77°23.206' Ele:924ft N:8°31.821' E:77°28'926' Ele:3757ft N:9°34.638' E:77°32.340'	June	August

Table 1. Contd.

Myrtaceae			Flower	Fruit
<i>Eucalyptus globosa</i>	Tropical Plain, Southern Hilltop Evergreen Forests, Dry and Moist Mixed Deciduous Forests	Ele:163ft N:9°41.959' E:77°44.427'	July	September
<i>Psidium guajava</i>	Tropical Plain	Ele:164ft N:9°41.959' E:77°44.427' Ele:811ft N:8°41.521' E:77°18.814' Ele:311ft N:8°40.590' E:77°23.206' Ele:921ft N:8°31.821' E:77°28.926'	May	July
Papilionaceae			Flower	Fruit
<i>Dalbergia latifolia</i> (Rare)	Semi Evergreen Forest, Southern Hilltop Evergreen Forests	Ele:1755ft N:8°15.818' E:77°92.102'	July	October
<i>Dalbergia paniculata</i> (Rare)	Southern Dry Mixed Deciduous Forests, Tropical Plain	Ele:803ft N:9°22.258' E:77°22.496' Ele:845ft N:8°41.564' E:77°17.827'	November	January
<i>Dalbergia sissoo</i>	Moist Mixed Deciduous Forests	Ele:643ft N:9°21.999' E:77°23.795'	July	September
<i>Erythrina indica</i>	Semi Evergreen Forest, Southern Hilltop Evergreen Forests	Ele:1758ft N:8°15.818' E:77°92.101' Ele:1751ft N:8°15.111' E:77°92.144'	May	July
<i>Pterocarpus santalinus</i>	Micro Desert Forest	Ele:217ft N:9°47.573' E:77°1.021'	June	August
<i>Erythrina variegata</i> (Rare)	Southern Hilltop Evergreen Forests, Tropical Wet Evergreen Forest, Southern Montane Wet Temperate Forests and Subtropical Montane Forests	Ele:3241ft N:8°41.457' E:77°27.274' Ele:3789ft N:8°31.411' E:77°27.122' Ele:3141ft N:8°12.256' E:77°27.144' Ele:3211ft N:8°30.414' E:77°27.187'	April	July
<i>Pterocarpus marsupium</i> (Rare)	Southern Hilltop Evergreen Forests, Tropical Wet Evergreen Forest	Ele:3132ft N:8°11.271' E:77°27.569'	August	October
<i>Ormosia travancotica</i>	Southern Hilltop Evergreen Forests, Tropical Wet Evergreen Forest, Southern Montane Wet Temperate Forests and Subtropical Montane Forests	Ele:2961ft N:8°31.936' E:77°26.978'	September	November
<i>Mundulea sericea</i>	Moist Mixed Deciduous Forests, Semi Evergreen Forest	Ele: 855ft N:8°41.586' E:77°18.887'	June	August

Terminalia species bear fragrant flowers borne in clusters between April to July, invite large number of nectarivores during the dry season (Bagla and Menon 2000). Among the six members of *Terminalia*, *Terminalia arjuna* in the riverine forest provides "tree roost" for thousands of *Pteropus giganteus* (fruit bats) and the fruits of *Terminalia bellerica* attract the Indian giant squirrels (*Ratufa indica*), primates, ungulate animals. The *Terminalia Catappa* totally depends on fruit bats of the foothill for their faraway dispersal. In addition most of the species of *Terminalia* harbor large number of birds like Ardeidae (birds-halting and nesting), Alcedinidae (halting place for predation) and Accipitridae (halting place for vultures).

In Papilionaceae, most of the members are distributed below 2000 feet. They attract nectarivores during flowering season by their nectar. Almost all the members of Papilionaceae provide habitat (nesting and halting) for many animals. The *Erythrina*, *Dalbergia*, *Pterocarpus* spp. are distributed lower to higher elevations. The members of this family are noteworthy because they are visited by the common nectarivorous birds like *Nectarinia asiatica* (Sun bird) and the rare bat species *Eonycteris spelaea*.

In Combretaceae, majority of the members are represented below 1000 feet elevation. All six members attract the insect population, nectarivorous birds by their strong honey scent. Comparatively, Combretaceae members are preferred by habitat users.

In Bombacaceae, all the three members show higher interaction with the animal community

especially during flowering season. The *Bombax* spp. provides thick, big, clustered flowers with sweet nectar, bloom between February and April are beneficial to the dependent animals during dry season with food resource (Heithaus et al. 1975, Lopez et al. 1997). The red silk cotton tree (*Bombax malabaricum*) attracts birds to quite an extent. The constant chatter of bird voices from different location of forest area denote the flowering season of *B. malabaricum*. The flowers attract insects and birds during day time and fruit bats during night. The flower and tender fruit of *Eriodendron pentandrum* serve as best food resource for pollinators and frugivores.

Cullenia exarillata the noteworthy representative of this family is endemic to Agasthyarmalai Biosphere Reserve and the flowers attract greatly *L. salimalii*, *Rousettus leschenaultia* and *Cynopterus brachyotis* fruit bat species during flowering season and the fruits are favourite food for lion-tailed macaque (*Macaca silenus*). The belt of *Cullenia* tree plays a prime role in restricting the distribution of lion tailed macaque and Salimali's fruit bat, the endemic, endangered animals of southern Western Ghats.

The white raceme inflorescence with lacinate petals of family Elaeocarpaceae attracts insect population during flowering season. All the three members of the family *Elaeocarpus tuberculatus*, *E. serratus* and *E. munronii* provide the favourite fruits with exocarp and mesocarp which are preferred by fruit bat species *L. salimalii* and *C. brachyotis* (Vanitharani 2005a b,

Table 2. Average animal visitor to each family

Sl. No.	Family & No. of Focal trees observed	Total animal visitors to the focal plants of the Family				Total Animal visitors during the study	Average animal visitor per tree
		Nectarivores	Frugivores	Habitat Users	Insectivores		
1	Bombacaceae (3)	310	105	50	73	538	180
2	Combretaceae (6)	112	20	386	40	558	93
3	Elaeocarpaceae (3)	144	33	81	53	311	104
4	Myrtaceae (7)	965	223	166	224	1578	225
5	Papilionaceae (10)	776	45	201	207	1229	123

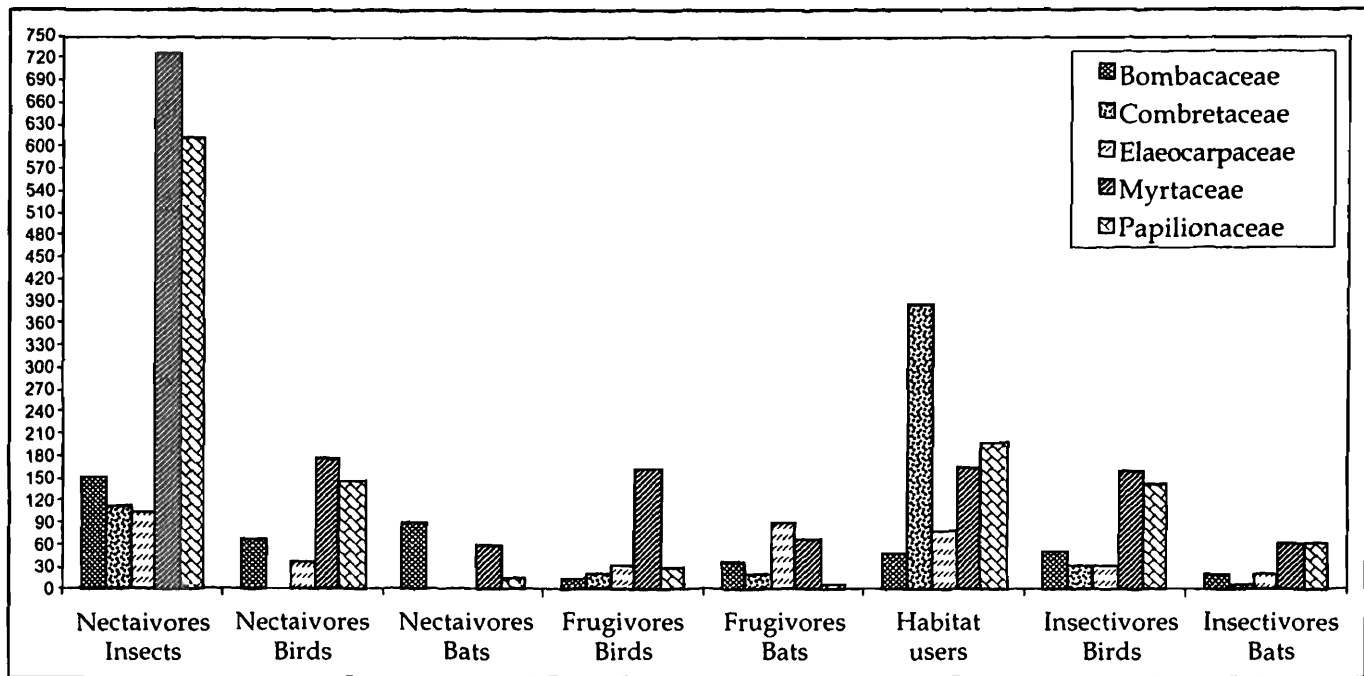


Fig. 1. The graphic representation of the plant-animal mutualistic interaction with focal member of the five Remarkable families during the extended watch

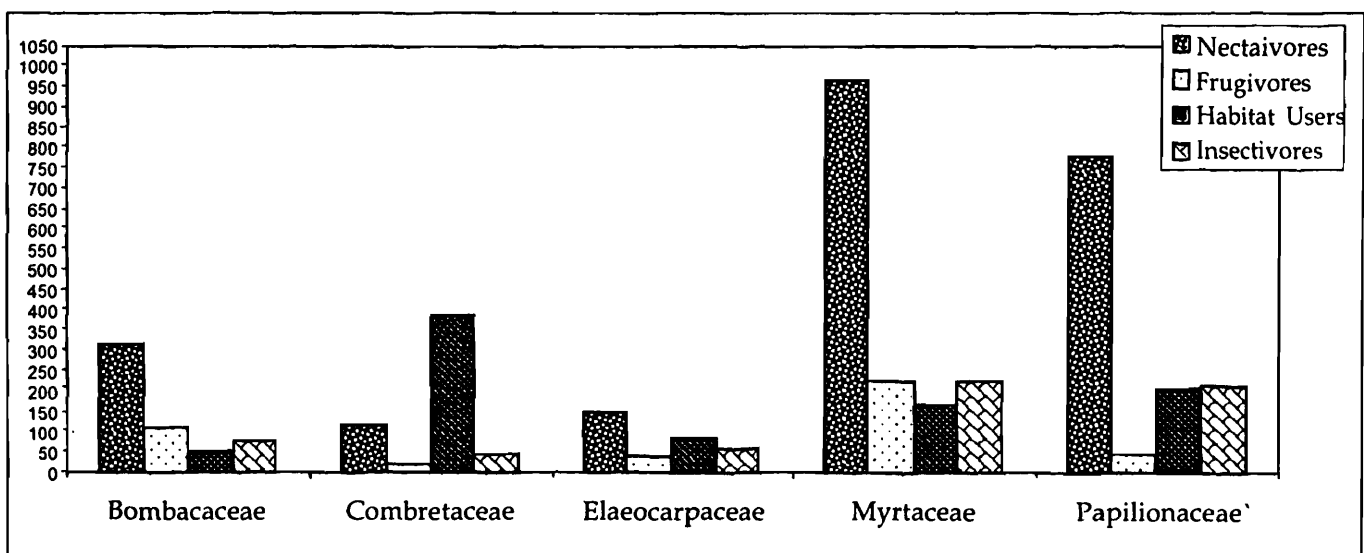


Fig. 2. Comparison of 'Plant-Animal Interaction' among the selected family members

2007a b) and Great horn bill (*Buceros bicornis*) of the evergreen forest. All the members of this family totally depend on bats for seed dispersal. All the members are distributed above 1000ft.elevation.

Interaction of Pollinators and seed dispersers to each of the plant species are important because they are the group responsible for genetic variation like change of phenology and reproductive calendar and thereby lead to diverse vegetation of forest ecosystem (Krishnaswamy *et al.* 2004).

The results confirm the studied tree members belongs to the families Myrtaceae Papilionaceae Bombacaceae Combretaceae Elaeocarpaceae are important and their contribution to maintain a forest community is enormous and they are the potential members for biodiversity conservation and sustain life of several endemic and endangered animals. Howe and Smallwood (1982) studies also confirmed these zoochorous tree species make up the bulk in the tropical flora. Vertebrate seed dispersal is a key process in the dynamics

of natural vegetation and vegetation recovery. Plant-frugivore interactions are important components of complex forest communities. Planting of these important fruiting trees in corridors, plantations or clearings will improve the forest by attracting pollinators and seed dispersers and thereby biodiversity conservation.

ACKNOWLEDGMENTS

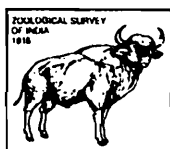
We thank the Chief Wildlife Warden for granting permission to carry out bat research work from 2000 onwards. I wish to express my gratitude to the Conservator and Field Director

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POTENTIAL DIVERSITY OF UNDER UTILIZED FRUITS IN ANDAMAN AND NICOBAR ISLANDS

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INTRODUCTION

According to the International Plant Genetic Resources Institute (IPGRI) based in Rome, Italy, at least 7,000 plant species could be cultivated for food, but only 150 crops are grown commercially. People have relied increasingly on select few plants for food, with about half of the world's calorie intake coming from just three crops *viz.*, rice, wheat and maize. But the remaining 6850 plant species are harvested from the wild or cultivated in a small area for food. These plant species are commonly described as under utilized, under developed, neglected, minor, promising, orphan or relict crops or species and life support species. These species represent enormous wealth of agro biodiversity with potential to contribute to improved incomes, food security and nutrition, combating the 'hidden hunger' caused by micronutrient (vitamin and mineral) deficiencies, occupy important niches, adapted to the risky and fragile conditions of rural communities. They have been selected to withstand stress conditions and contribute to sustainable production with low cost, contribute to the diversity and hence provide the stability of agro ecosystems, especially fragile ecosystems such

as mountains, steppes and tropical forests. The success of the breeding programs of any crop has depended by and large on the amount of genetic diversity present in the collected germplasm. These neglected and underutilized species play a crucial role in the agricultural biodiversity. Lack of attention has meant that their potential value is under-estimated and under-exploited. It also places them in danger of continued genetic erosion and disappearance of significant species. This would further restrict development options. Andaman and Nicobar Islands represent one of the richest repositories of biodiversity in the whole of south and south East Asia. Situated between two major biodiversity hotspots, namely the Indian subcontinent and the Malaysian-Indonesian region, it is hardly surprising that the Islands manifest biodiversity of extraordinary range within a limited geographical area. Andaman and Nicobar Islands are having a vast variety and diversity in under utilized wild tropical fruits, many of them are of evolutionary climate in specific niche. Most of these fruits, trees have remained semi-domesticated while many species have become rare and endangered due to large scale urbanization. With so much diverse species especially species of minor fruits in these islands there will be a need for making use of this biodiversity to its full potential.

Plant diversity of Andaman and Nicobar Islands

The unique positioning of these islands between the two major biodiversity areas namely the Indian subcontinent and the Malaysian-Indonesian region it endows with an unmatched distribution of plants with representatives of the Indian, Myanmarese, Thai, Malaysian and Indonesian floras. The flora of the Andaman group of islands shows closer affinity to the Indo-Myanmarese-Thai flora, while the Nicobar groups of islands are closer to the flora of Malaysia-Indonesia (Balakrishnan and Ellis, 1996). Nearly 2100 species of Angiosperms have been reported from the islands, of which 11 per cent are strictly endemic to the islands (Balakrishnan and Ellis, 1996). The diversity of plant forms have been documented, initially in around 52 species are being used by the sub aboriginal groups. Out of over 2500 angiospermous species so far known from these islands about 246 are endemic.

Diversity of minor fruits in Andaman and Nicobar Islands

The islands have vast variety of tropical under utilized fruit plants with good potential for commercial and environmental exploitation. Some of the identified indigenous fruits in Andaman and Nicobar Islands which are rich in nutrients and economic importance are alligator apple (*Annona glabra*), Governor's plum (*Flacourtia ramomtchi*), Khatta phal (*Bauccaria vamiflora*), Bethphal (*Calamus andamanica*), Khariphall (*Ardisia solanaceae*), Madhuphal (*Salacia chinensis*), custard apple (*Annona squamosa*), Soursop (*Annona reticulata*), Wild passion fruit (*Passiflora foetida*), *Pandanus lerum*, *Pandanus andamanensium*, *Pandanus tectorius*, Wild jamun (*Syzyium claviflorum*), Bullock heart (*Annona reticulata*), Wild mangoes like *Mangifera griffithi*, *M. andamanica* and *M.camptosperma*, Jambose (*Syzyium jambos*), Rambutan (*Nephelium lappaceaum*), Rose apple (*Syzyium aqueum*), Velvet apple (*Diospyrous discolour*), Mangosteen (*Garcinia mangostana*), Chalta (*Dillinea indica*), Sapida (*Bauccaria sapida*), Wild amra (*Dracontomelon dao*), Bread fruit

(*Artocarpus* sp.), Kendu (*Diospyrus* sp.), *Morinda trimera*, Bread fruit, Bael, Imli, Kadam, Kaw phal, West Indian Cherry, Passion fruit, *Morinda* sp., Khoonphal, Star gooseberry.

Morinda citrifolia, commonly called noni, has a long history as a potential minor fruit as well as medicinal plant and its use as a botanical dietary supplement has grown tremendously in recent years. The genus *Morinda* comprises approximately 80 species distributed all over tropical regions of the world (Singh *et al.*, 2002, 2007). There are 4 taxa of *Morinda* viz., *Morinda citrifolia*, *Morinda citrifolia* var. *bracteata*, *Morinda trimera* and one unidentified species are distributed throughout Andaman and Nicobar Islands. These fruits have a close association with local beliefs and rituals and are used in rich ethnic life of local people.

Potential uses of minor fruits

Many underutilized species are nutritionally rich and are suitable for low input agriculture. It can be grown successfully even under adverse agro-climatic conditions. These underutilized species are naturally occurs wild or under cultivation in harsh environmental conditions. In many instances these species are the only crops that can manage such difficult environments unfit for other major crops like tsunami affected lands in Andaman and Nicobar Islands, where they can provide sustainable productions with least risk. In this way, they contribute significantly to maintain diversity rich and hence more stable agro-ecosystems.

The fruits have both restorative and curative principles. These could be aromatic, cooling, digestive, stomachic, stimulant, useful in seasoning, maturation and fermentation of culinary, processed food and drinks. Some others have chemical principles responsible for astringent and emollient properties. There are few others which possess specific properties such as diuretic, diaphoretic, sedative or stimulant to nerves, improver of peristaltic movement of intestine and liver ailment, cardio tonic, relieving cough, cold, bronchitis, asthmatic spasm, blood pressure etc., some

minor fruits possess essential oils in peels or foliage, roots have carminative and germicidal property.

In addition to the therapeutical value they provide nutrition, strength and vigour to our body and restore loss of minerals, amino acids and thus protect against many nutritional deficiencies and diseases. They reported that the level of carotinoids varied from 7.71 to 1485.00µg/100g which was recorded in *Artocarpus integrifolia* followed by *A. lakoocha*, *Carissa carandus*, *Spondias cythera*, *Spondias pinnata*, *Syzygium claviflorum*, *Gnetum gnemon*. West Indian cherry (*Maliphigia glabra*) contains such an exceptionally high content of ascorbic acid of 3000-4000mg/100g. Some of the other minor fruits found in A and N Islands have shown good amount of ascorbic acid ranges from 12.12 to 176.0 mg/100gm. The highest content was recorded in *Artocarpus* sp., *Muntigia calabura* and *Mangifera andamanica*. The rich sources of calcium were also recorded in tamarind, karonda, bael and wood apple.

Noni fruit is one of the important minor fruit and reported for antibacterial, antiviral, antifungal, antitumor, antihelminthic, analgesic, hypotensive, anti-inflammatory and immune enhancing effects. This plant has also been popular for the source of red, yellow and purple dyes. Noni juice has become increasingly popular in recent years as a health food drink in western and Asian countries where there appears to be substantial market. Over 200 companies came in the market with different products such beverages (fruit juice, juice drinks), fruit powders (for manufacture of reconstituted juice or juice drink products made from dried ripe or unripe fruits), toiletries (lotions and soaps), oil (from seeds), leaf powders (for encapsulation or pills), biopesticides etc. estimated at more than \$5 billion annually. A market boom has led to a proliferation of noni enterprises and is of increasing importance in India.

The loss of these species can have immediate consequences on the nutritional status and food security of the poor.

Future strategies

The existence of underutilized fruit species may be threatened by their relative neglect by science and development, and by the increase in area under production to higher yielding and better researched crops. For future development and appropriate exploitation of underutilized fruit species, four major strategies might be addressed are knowledge generation, communication, capacity building, policy improvement and market development.

Conservation of Biodiversity : In-situ and Ex-situ

In-situ conservation

Conservation of a species is best done by protecting its habitat along with all the other species that live in it in nature. This is known as *in-situ* conservation. Species cannot be protected individually as they are all inter dependent on each other. Thus the whole ecosystem must be protected. The biologists view point deals with areas that are relatively species rich, or those where rare, threatened or endangered species are found, or those with 'endemic' species which are not found elsewhere. As rare endemic species are found only in a small area these easily become extinct due to human activity. Such areas must be given an added importance as their biodiversity is a special feature of the region.

Ex-situ conservation

Protecting the particular species in a carefully controlled situation, outside the natural habitat such as a botanical garden where there is expertise to multiply the species under artificially managed conditions. These breeding programs for rare plants are more expensive than managing a Protected Area.

Gene Bank

There is also another form of preserving a plant by preserving its germ plasm in a *gene bank* so that it can be used if needed in future. This is even more expensive.

Consortia approach

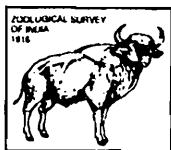
Because of the complexities involved in developing the potential of underutilized plant species, clear concepts for action need to be formulated, and consortia of complementary partners need to be formed. The roles of the diverse partners must be clarified and coordinated. Such partners include international and national agricultural and horticultural research organisations, advanced research institutions, non-governmental organizations (NGOs), community based organisations (CBOs), private companies, national governments, regional and

international organisations, donors and funding agencies. Regular discussion with the relevant desk officers in such funding agencies is recommended to raise awareness of underutilized plants value, and to devise new research paths jointly.

The poor status of underutilized and neglected species conservation severely hinders their successful improvement and promotion. Efforts need to be directed towards the better maintenance of their resource base, both through *ex-situ* and *in-situ* conservation methods, to ensure their development and their sustainable use by present and future generations.

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EFFECT OF POLLUTION ON THE BACTERIAL FLORA OF *CRASSOSTREA MADRASENSIS* ALONG TAMIL NADU COAST

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INTRODUCTION

The oyster are scientifically the best known marine animals in the world *Crassostrea* Species are the common oysters that are found along the Indian coast line. Oysters are rich in Zinc, Iron, Calcium and Vitamin A *Crassostrea. madrasensis* is a species of good demand in the coastline of Tamil Nadu. The filter feeding nature predisposes oyster to accumulate pathogenic bacteria and heavy metal which are polluted with sewage water rendering the oyster unfit for consumption. The organisms are vulnerable to toxic effect resulting from absorption or oral intake of contaminants form the immediate environment.

There has been extensive research on the contamination of bivalve molluscs by faecal bacteria but less is known about the bacterial content of these shell fish. in their natural environment (Colwell and Liston, 1960; Erkenbrecher, 1981; Sagita *et al.*, 1981). Some heterotrophic bacteria may be implicated in cases of gastroenteritis and non-specific illness in man after the consumption of oysters free from the better known intestinal pathogens (Rutala *et al.*, 1982). The bacteria responsible for the early stage of spoilage in bivalve shell fish are thought to be derived mainly form their natural flora. (Jay, 1978) The mechanism of

uptake of coli form bacteria by various bivalves is well established but the effect of environmental factors and physiological activity of the shell fish to retain aquatic microorganism is not known (Cabelli and Heffernan, 1970). Colwell and Liston (1960) first suggested the existence of a defined commensal flora in oyster.

Hence an attempt was made to study the nature of bacterial flora associated with *Crassostrea madrasensis* from Ennore Estuary and from Pulicat backwater (lake) in Tamil Nadu coast. These places are famous for the extensive oyster bed. The present study was done to understand effect of pollution on the bacterial flora of oyster by studying the coli form organisms.

MATERIALS AND METHODS

Crassostrea madrasensis were collected from the water. The water samples were also collected in sterile container. Both the shellfish and water samples were stored in ice pack and examined within 4 hours after collection.

Examination of Shell Fish

12 to 15 oysters were collected, cleaned and prepared for the examination of whole molluscs, shell, liquor was discarded and tissues pooled

and weighed. An equal volume of water from lake or estuary is added and the mixture was then homogenized for 40S at 17000 rev/min and 10S at 23000 rev/min. The homogenates were filtered through sterile steel gauze (mesh size 0.65 mm) and further dilutions were made for inoculation of the media.

For the examination of different tissues 12 oysters were opened and mantle, fluid, gills and adductor muscles were removed aseptically. The mantle cavity and gill surface of each oyster were flushed with sterile water from the source. Each oyster was drained thoroughly before the stomach contents, crystalline style, digestive diverticulum and lower intestine were removed aseptically and placed in a sterile glass bottle of known weight. To each sample, 10ml of water diluents from the source was added and the mixture was homogenized at 17000 rev/min for 20S and 23000 rev/min for 10S.

Enumeration of Bacteria

Heterotrophic count of shell fish and seawater were obtained by the spread plate method using a 2 B medium containing (g/l in aged sea water) Bactopeptone 1.0 Bacto-yeast extract 1.0, Bacto beef extract 1.0, Fe PO₄ 0.1, Bacto agar 18 at pH 7.3 duplicate plates were incubated at 25°C for 48 hours for the enumeration of bacteria that can grow under anaerobic conditions, glucose (0.5 per cent) and sodium thioglycollate (0.1 per cent) were added

to the 2B medium. After inoculation the plates were incubated at 25°C for 5 days under anaerobic conditions.

For coliform organisms the most probable number method with set of five Macconkey broth tubes were used. Tubes showing acid and gas were counted after incubation at 35°C for 48 hr *Escherichia coli* and other lactose fermentors were confirmed on Macconkey agar, Eosin MethyleneBlue agar Plates and by Gram staining. *Salmonella* sp. were enumerated by plating samples on Wilson and Blair modified Bismuth sulphite agar.

Isolation and Identification

Individual colonies from 2B agar plates were randomly selected and subcultured. After purification the organisms were test for Grams reaction, motility & type of flagella (Leifson *et al.*, 1964). Oxidative or fermentative metabolism was determined with methods of Hugh and Leifson (1953). The fermentation of sucrose, lactose and mannitol was done by a standard method. (Martin and Washington, 1980) The organisms were identified to generic or group level according to Bergey's manual (Buchanan. and Gibbons, 1974)

RESULTS

The quantitative results suggest that the number of bacteria were usually greater in *Crassostrea madrasensis* then in the source water Table 1.

Table 1.

Sample	CFU on Plates Incubated aerobically	CFU Anaerobes	Most probable number of Presumptive coli form	Salmonella sp.
<i>Crassostrea madrasensis</i> [wa]- Pulicat lake	1.1×10^5	2.1×10^3	6.8×10^2	0
<i>Crassostrea madrasensis</i> [wa]- Ennore Estuary	1.4×10^4	7.0×10^1	3.3×10^1	1.1×10^0
Water-Pulicat lake	1.6×10^3	5.0×10^1	8.3×10^1	2.0×10^0
Water-Ennore estuary	1.0×10^3	4.8×10^1	2.8×10^1	1.8×10^0

Aerobic count of both water and samples were two to three times higher than the anaerobic count.

In general, coliform count in the oyster resembled that to the water. *Salmonella* sp. were not detected in oyster and only infrequently in the oyster tissues.

Analysis of MPN coli form and aerobic bacterial count of the whole animal digestive tract and different individual digestive tract part showed the given values (Table 2)

Identification of Bacteria

A total of 202 bacterial strains belonging to

11 groups were isolated from *Crassostrea madrasensis* from Ennore and Pulicat lake. More than 25% of the total isolates were *Pseudomonas* sp. followed by *Vibrio* sp., *Acinetobacter* sp., Coliform organism and *Aeromonas* sp. *Alcaligenes* sp., accounted for 7 to 3 per cent respectively of the isolated strains (Table 3).

DISCUSSION

Oyster generally filters particulate matter, including bacterial cells. This bacterial flora has been shown to differ from those of the water, which suggest that commensal flora occurs in them. Microbial commensalisms assume the

Table 2. Coli form & Aerobic Bacterial count in the digestive tract

Samples	No. of samples	Bacterial concentration in tissue (per g)	
		Presumptive coliform (MPN)	Aerobic plate count CFU
Whole animal digestive tract	5	6.8×10^2	1.3×10^5
Stomach	5	3.0×10^2	3.4×10^6
Crystalline	5	3.5×10^2	1.8×10^5
Digestive diverticulum	5	6.1×10^0	3.1×10^4
Lower intestine	5	1.1×10^2	2.8×10^7

MPN-Most probable number CFU - Colony forming units

Table 3. Bacterial strains isolated form the digestive tract of *Crassostrea madrasensis*

	Whole animal	Oyster digestive tract				No. of strains
		Stomach	Crystalline style	Digestive diverticulum	Lower intestine	
<i>Pseudomonas</i>	37	9	0	8	1	55
<i>Vibrio</i>	10	3	10	15	12	50
<i>Acinetobacter</i>	7	4	8	4	9	32
Coliform	2	1	9	2	1	15
<i>Flavobacterium</i>	7	7	0	1	0	15
<i>Aeromonas</i>	0	5	5	1	5	16
<i>Coryneforms</i>	4	1	0	1	1	07
<i>Alcaligenes</i>	3	1	2	1	1	08
<i>Micrococcus</i>	2	0	0	0	1	03
<i>Spirillum</i>	0	0	0	0	0	0
<i>Bacillus</i>	0	0	0	0	1	01
Total						202

selection of certain groups adapting to the physicochemical conditions within a particular host. In oysters (bivalves) these conditions denote a higher organic level, lower oxygen tension (Purchon, 1977)

The bivalves also support a greater number of facultative anaerobic & fermentative stains of *Vibrio* and *Aeromonas* sp. but fewer *Micrococci* and *Coryneforms* which are common soil bacteria. Among the marine animals only the gut flora of fish and some crustacean shell fish have been extensively studied (Serae *et al.*, 1974; Yasuda and Kitao, 1980) The result of the present study suggest that despite its large size, the diverticulum accounts for only a small portion of the total bacterial population of the

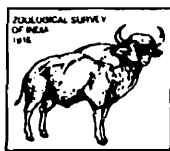
oyster. Intracellular and extracellular digestion occurring in the diverticulum and as well as the presence of lysozymes may account for the drastic reduction (Birbeck and McHenery, 1982)

The predominance of *Vibrio* and *Aeromonas* sp. in the digestive tract of oyster has also been observed in fish (Okuzumi and Horie 1968; Sera *et al.*, 1974). If these edible oysters are consumed raw or if not properly cooked, it is possible that *Aeromonas* sp. *Vibrio* sp. and other species of bacteria as observed in this study, could cause gastroenteritis and other infections in human beings. Further a detailed study of the bacterial pathogens in the oyster *Crassostrea madrasensis* may help to understand more about the present study.

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MANGROVE BIODIVERSITY CONSERVATION STRATEGIES

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INTRODUCTION

Thou madest him to have dominion over the works of thy hands; thou hast put all things under his feet: All sheep and oxen, yea, and the beasts of the field; the fowl of the air, and the fish of the sea, and whatsoever passeth through the paths of the seas. O LORD our Lord, how excellent is thy name in all the earth! Psalms 8 : 5-9. Hence, it is our inherent responsibility to rule over the earth with dignity.

Sustaining diverse habitats associated with marine environment such as beach, sand dune, mudflat, estuary, lagoon, backwater, salt swamp, mangroves, coral reef, marine algae, sea grass bed and coastal saline dry lands is highly essential to preserve the ecological balance. Mangroves are amazing tropical plants that are adopted to survive along the border of the sea reaching up to the edges of the river to the point where the water is saline (Oswin and Kathiresan, 1994). The total area of mangrove vegetation in India is 4,639 km² which accounts for about 5 percent of world's mangrove vegetation. Of the total vegetation, dense patch comprises 1,405 km² (30.29 percent of mangrove cover), moderately dense vegetation is 1,659 km² (35.76 percent), and open mangrove cover is 1,575 km² (33.95 percent) (FSI, 2009). Of this, 60 percent of mangroves are found along the east coast, 27 percent along the west coast and

remaining 13 percent in the Andaman and Nicobar Islands. Mangroves are able to sequester around 1.5 tonnes of carbon per hectare per year (Gong and Ong, 1990 and Ong, 1993). The present day Indian mangroves are efficient in sequestering 6,66,750 tonnes of carbon annually. Each hectare of managed mangrove system produces as much as \$11,300 (= INR 580000) a year (Primavera, 1991). The population depending on the coastal and fishery resources in the country directly or indirectly are 250 million; around 20 per cent of the population are living within a distance of 50 km of the shoreline, the population density of coastal areas (432 persons per square kilometer) is significantly higher than that of the country as a whole (256 persons per km²) (Sharma and Debabrata De, 2008).

Both the natural and man made causes induce reduction of mangrove area and India experiences some 16 common threat factors in different maritime states. The most significant threat is the increasing human pressure on mangrove-resources, and frequent natural calamities like cyclone, storms, surges and floods (Kathiresan, 2002). In the past 25 years, 3.6 million hectares of mangroves, have disappeared from the Earth's surface, indicating that the current mangrove area worldwide has fallen below 15 million hectares, from 19.8 million ha in 1980 (FAO, 2004). Conservative

estimates indicate that on global scale, mangrove vegetation decline by 1,000 km² annually. The rate of net loss of mangroves however show a decreasing propensity, from 1.03 per cent loss per annum in 1980 to 0.67 per cent annual loss during 2000-2005 period. This is attributed to increased awareness among the people about the value of mangrove ecosystems, which has led, in turn, to the preparation of new legislation, better protection and management and, in some countries, to an expansion of mangrove areas through active planting or natural regeneration (FAO, 2007). Eleventh Five Year Plan 2007-2012 of Government of India on islands, coral reefs, mangroves and wetlands has decided to extend 100% central assistance to the State/UT government to afforest or plant all possible degraded areas and open mud flat of country.

The success rate of mangrove afforestation projects in many countries, including India, if analyzed would bring a gloomy data. The success of mangrove afforestation all over the globe underscores the misunderstanding about the mangrove ecosystem functions and autecology of species. Most of the attempts were not based on well understood principles and well defined aims (Bosire *et al.*, 2008). Many mangrove rehabilitation projects fail due to the inability or unwillingness to apply basic ecological engineering principles (Lewis, 2000, 2005) and others (Turner and Lewis, 1997). Therefore, this article intend to explain the process of mangrove ecosystem functioning with case studies which would help conservationists to decide the appropriate site specific conservation strategy for better mangrove management.

MATERIALS AND METHODS

Mangrove management plans and practices focusing on Indian perspective are portrayed. Different case studies would indicate the present management approaches of mangrove rehabilitation programs and limitations experienced for attaining success. This paper concentrates on different possible site and problem specific strategies. Suggestions are

proposed to undertake studies and relevant steps to understand mangrove forest ecosystem structure, growth and function; to provide training and fellowships, increasing awareness and empowering skills of various stakeholders. Solutions are recommended to address limitations in social, ecological and management processes dealing with mangrove rehabilitation programs.

RESULTS AND DISCUSSION

When the species or ecosystem enters the threshold of extinction is the time when often the decision of preservation or conservation of our natural wealth is taken into account. However, it should start even before this point. Preservation of mangroves defined as prevent mangrove forests from further degradation through protection and considerable restriction from open usage. Conservation of mangroves defined as the act of protection, preservation and careful management of the mangrove forests resources under the custodianship of stakeholders. However, in the case of mangrove ecosystem attentions are paid towards mangrove plantation, however the reasons for large-scale degradation or denudation are not addressed.

Mangroves are specifically a complicated ecosystem to be restored to its original configuration. Only when the original hydrology is altered the ecosystem starts degrading. Unless the hydrology and topography is restored there is no way restoring the ecosystem by planting more seedlings. No two mangrove ecosystem is similar to replicate restoration efforts or rehabilitation methods. The ecosystem functions should be understood to its fullest extent to conserve the mangroves.

Every site needs to be understood for the reasons of degradation, pressures in existence, hydrology and tidal implications, substratum and species preference. Reason for the destruction or stunted-ness may vary from different categories of pressures such as free grazing, lopping, cutting, improper inundation, hyper salinity, industries, urbanization, etc.

Plantation process is needed only to facilitate or hasten the process or if the site has seed limitation. However, if the hydrology is restored in reference to the natural mangrove forest occurring adjacent to the site, natural pioneer species colonization and biodiversity succession would subsequently succeed. The initial strategy to restore an ecosystem is to conserve the existing mangrove patches and if necessary and feasible concentrate facilitating new establishments.

Community Mangrove Plantations in an Indian Perspective

In the Indian perspective of mangrove restoration there are several social, ecological and managerial factors which restrict the success of the mangrove restoration projects. Various visible limiting factors are presented for common understanding, technical and managerial rectification.

Social Limitations and Strategies :

As Labors

Involving the community is a good strategy. However, in most of the community based mangrove rehabilitation projects the local user community is involved only as laborers and generally know that they will be paid wages for a particular job or period. However the understanding of importance of the project and future protection of the natural resource are very little. Designing rational understanding of the community and solutions to bring out 'genuine participation' of local users is the major social strategy for the long term success of the mangrove rehabilitation program.

Low Wages

The pattern of project implementation or the finance flow in majority cases is not made transparent to the community and the wages paid to them are less than the regular payment. Though it is supposed to be the community managed system, but generally it happens to be the other way due to misunderstanding of the objective by the parties, the community and implementing agencies. There, many a times

the plantation process is disrupted as the community laborers prefer to work for other agencies in the field who would pay better wages. Integrity of managerial top level players and implementers is another social strategy suggested for successful mangrove rehabilitation.

Lack of Social Tuning and Existing Pay-Plant-Go Model

Most of the community mangrove projects in India and in most developing Asian countries lack social tuning. It is just the pay-plant-go model existing at present. Nowadays, implementing organizations is coordinating labor for different activities like collecting seeds, developing nursery, planting and write reports. All the social meetings were targeted to mobilize labor and the long term future of the forests or their sustenance attached with ecosystems are hardly explained. For instance, in the ICEF funded project in Gujarat the cattle and camel grazing issue, even after the duration of 6 years was not solved as the strategy at social fencing was not achieved. Till date grazing in plantation area is a common scene. Therefore, in future before starting the plantation scheme it is suggested that strategy of addressing the pressures and providing alternative sources of fuel or fodder in many cases would better solve the problem of degradation, destruction or overexploitation.

Returns from the Ecosystem

The reason for failure in genuine social participation is basically due to lack of immediate visible returns from mangroves. Labor is the only visible benefit which is less attractive for the community to protect or conserve the developed forest or the natural stands. In this view implementing organizations should strengthen the social workers in tune to be able to mould the community to perform better in reality. It is recommended that people with technical know-how should be involved with the social workers to evolve with strategies based on sites to fine tune the community mind set towards genuine participation.

Survival of community developed mangrove establishment

Survival proportions of the community mangrove establishments are highly skeptical. There are defending arguments from the implementing agencies from India stating that 'even if 5 to 10 percent survival in a long term basis as a success' However the quantum of money and efforts spent on developing the meager percent success is exorbitant and if that amount is spend on other greenery development would be more rational. There would be more than 30 per cent natural forest increase, if the community could just protect without intervening in plantation activity and supporting the natural forest stand to regenerate on its own. Plantation activity just adds more pressure on the weak natural stand by extraction of seeds hampering the natural settlement. So the programs with a success rate of 5 to 10 per cent survival in a long run are unjustifiable. The major failure of such projects is mere misunderstanding of the mangrove ecosystem functioning. It is suggested to adopt ecological mangrove restoration strategies (Lewis 2005) to achieve 100 per cent success of establishment.

Six (6) Steps to Successful Mangrove Restoration (Lewis 2005)

1. Understand both the autecology (individual species ecology) and community ecology of mangrove species at the site, paying special emphasis on patterns of reproduction, propagule distribution, and successful seedling establishment;
2. Understand the normal hydrologic patterns that control the distribution successful establishment and growth of targeted mangrove species;
3. Assess modifications of the previous mangrove environment that currently prevent natural secondary succession;
4. Select an appropriate mangrove restoration site through application of Steps 1-3, above, that is both technically likely to succeed in rehabilitating a

healthy mangrove ecosystem, and also takes into consideration resolution of land ownership/use issues necessary for ensuring long-term access to and conservation of sites;

5. Design restoration programs at appropriate sites selected in Step 4, above and initially restore the optimum hydrology and take advantage of natural volunteer recruitment of mangrove propagules for plant establishment;
6. Utilize actual planting of propagules, collected seedlings, or cultivated seedlings only after determining through Steps 1-5, above, that natural recruitment will not provide the quantity of successfully established seedlings, rate of stabilization, or rate of growth of saplings established as quantitative goals for the restoration project.

Community and Mangrove Conservation

Except the mangrove restoration project is fishermen based, the entire community or the entire village population generally fails to become the long term protecting force of mangrove establishments because of their little dependency or lack of direct benefit extraction. The instinct of natural resource conservation and coastal protection is high among fishermen than any other contemporary stakeholders as fishers have understood the leverage of livelihoods on marine biodiversity and related ecosystems. In order to address the issue of little involvement and ultimate failure of the project, strategies are to be drawn to incorporate the diverse community in mangrove development or to disengage the community participation wherever the dependency level is less. Experiences from various community based mangrove plantation programs denote that diverse community group (In Indian context, local caste systems) is quiet sensitive for being together in long term management and protection of mangroves. In such areas where the site is potential but the community is diverse or little mangrove dependent, the best strategy is that the Forest

and Environment department perhaps to carry out the mangrove rehabilitation effort without community participation in the management level.

Few other mangrove rehabilitation strategies evolved by different researchers in the field are as follows :

- An understanding of the many aspects of human influences on biological diversity and their underlying driving forces is of crucial importance in setting priorities and directing conservation and sustainable use measures (UNEP, 1995).
- Prioritizing and categorizing species inhabiting mangrove ecosystems for immediate conservation measures is one of the strategies suggested by Kathiresan (2002). He states that in India twenty mangrove species are either endangered or rare or endemic.
- Formulation of a Generic Code of conduct for sustainable management of mangrove forest ecosystems based on existing knowledge, experience and concepts is suggested by Macintosh and Ashton, (2002).
- Resource estimation, adequate database and ground verification is vitally important for policy making, planning and management (Macintosh and Ashton, 2002). Economic valuation of mangroves is also one of the approaches that validate the data base.
- Considering the activities in the upland water catchments area and linking related habitats (e.g. water catchment-mangroves-seagrass-coral reefs) is suggested by Macintosh and Ashton, (2002).

Assigning special status and conservation from an ecological and biodiversity perspective as National parks, nature reserve, gazetted forest bio sphere reserve, Ramsar site at national level, or World heritage site at international level is also in global practice.

Ecological Limitations and Strategies

Selecting an inappropriate site, where mangroves cannot be accommodated like open mud flats, areas below mean sea level, highly elevated areas where tidal inundation is improper, heavily flooded or highly inundated areas where the hydrology is irreversibly altered; areas with high utilization pressures, misunderstanding of ecological functioning, converting ecosystems are the few ecological limitations for rehabilitating mangroves. Therefore, it is suggested to follow the basic principles of ecology and

- Choose the rehabilitation site as per the factual background information of the area and do not end up attempting conversion of mudflats and other coastal habitats.
- Obtain a comparison chart of the land elevation, sediment structure, species composition and hydrology of the chosen rehabilitation site prior to deciding the rehabilitation strategy
- If the history of mangrove in a particular area says it has vanished due to sea level rise, it is rational to leave for natural recovery in the suitable area as the earlier place where mangroves survived is already deep for mangroves to survive
- Create translocation area for its landward movement, however in most cases it is not possible as most of the shorelines are already occupied due to urbanization, agriculture or other developments
- Before entering mangrove plantation attempt, thorough observation of referral forests as well as mangrove rehabilitation site is an important strategy, as the referral forest is a standing evidence of natural selection process and represent a easy replicating model
- Decide strategies to replicate the adjacent referral natural mangroves into the selected rehabilitation site
- Act along with natural hydrology and ecosystem functioning

- The entire venture of eco engineering solutions should be designed with the integrated approach of the Geologists, Hydro-graphers, Dredging specialists and Biologists.

A strategy of canal plantation originated by Tamil Nadu Forest Department in Muthupet and practiced by M.S. Swaminathan Research Foundation is successful in the Lagoon mangroves of Muthupet, Tamil Nadu but not in Pichavaram, Andhra Pradesh or other states. Though the canal has narrow measure and shallow canal area, this strategy worked well in Muthupet due to the historical customary practice of annual sediment clearing in narrow canals and traditional prawn fishing using local gears and crafts like Pari and Sar. This fishing method revived the canal annually and kept the hydrological system alive. The custom of owning canals by families and offering as dowry to the daughters to fish for her family's subsistence is still in practice.

Bismi Prawn Farms (P) Ltd located in Perunthottam, Sirkali coast is the pioneer model of integrated mangrove shrimp fisheries in India (Oswin and Ali-Hussain, 2001). Mangrove integration with shrimp farming was initiated during the year 1995. Mangroves are planted along the borders of outlet canals, inlet canals, sediments tanks and effluent treatment plants and mangroves, filtered excess nutrient discharge in the out let canals as equal to the inlet water quality (Oswin and Rahaman, 1997). Bismi has diversified its technologies and the candidate species from shell to fin fishes. Recently these efforts have been recognized by the Indian Council for Agricultural Research (ICAR), Government of India and bestowed with National Excellence Award.

Ecological mangrove rehabilitation programme called mangreen, by OMCAR Foundation on the coast of Thanjavur district in Tamil Nadu, India involves facilitation of natural water flow system in mangrove creeks and restoring degraded areas through nursery raised seedlings. Genuine participation of fishers has been succeeded by creating awareness among fishers regarding the use of

mangroves through sustainable fishery. Partial harvest of mangrove crabs is allowed to local fishers in limited intervals in the protected mangrove restoration areas. The progress of this approach in the coast is still in scrutiny through international university internship programme from Germany, Croatia and Australia.

In mangrove dependent areas like gulfs of Kachch and Khambhat, Gujarat, India alternative solutions for fuel and fodder would subsequently result considerable conservation of mangroves rather than plantation efforts. Ecological restoration strategy if practiced certainly would help rehabilitate mangroves in Gujarat coast (Oswin, 2005a). Many other mangrove restoration attempts in India by several organizations are in the gloomy direction. Especially the mangroves developed by industries and ports for obtaining environmental clearance are appalling.

In the Sri Lankan context many mangrove areas have been cut off from its original hydrology due to bund and road construction, courtesy post Tsunami fund flow and urgent construction activities without considering the mangrove ecosystems role in such low lying areas. Similar post Tsunami activities of converting coastal red soil ravines for the construction of Hospitals also is observed in Muttom-Kanyakumari coast of India; these coastal ravines are very important natural shelter ecosystem, which also helps drain rain water from the catchments to sea (Oswin, 2005b).

Management Strategies

In order to succeed any mangrove rehabilitation project, apart from ecological and social strategies, having a code of management strategies right from donors to implementing agency is imperative.

Design Change of the Project: Primary Requirement for Success

The failures of implementing agencies or community in developing successful mangrove establishments, monitoring systems and protection or conservation modules not only

lie with the efforts and integrity but mainly with the design of the project.

The project design should be based on the following

- Available suitable sites in the village
- Pressures exerted on mangroves
- Percentage of pressures on mangrove ecosystem
- Direct dependents
- Dependency pattern
- Stakeholder's dependency
- Diversity of the community
- Players of environment development of the area (To Avoid Repetition)
- Strength of the implementing organization in community mindset tuning (not labor organizing capacity)

Project Design should have the following phases

Phase I-Proposal

- List of pressures or issues on mangrove ecosystem
- Strategies to address pressures or issues
- Duration to address the pressures or issues (perhaps 2 to 3 years)
- In house Capacity and funds to address the same partially
- Community tuning strategies
- Risk Factors and Possible Solutions
- Scope of mangrove plantation or restoration

(Unless succeeded, going further for mangrove development is not recommended)

Phase II-Proposal

- Detail and Area of ecosystem development
- Site feasibility reports
- Suitable Technologies
- Technical Approaches for ecosystem management

- Risk Factors and Possible Solutions
- Performance Monitoring Systems
- Performance Indicators
- Long Term Protection and Conservation Strategies (Practicable)
- Compensation for project failures

Emerging Threat

The mangrove plantation activities themselves are becoming a major threat to the naturally prevailing mangroves. The reasons are as below :

- Larger Target Areas
- Seed Exploitation for continuous consecutive years from same stand
- Interference in natural forest regeneration and recruitment
- High percentage failures in artificial regeneration (seed wastage)
- Incorrect Performance Indicators (area coverage and density being indicators of mangrove development projects leaving behind the survival and recruitment capability)
- Benefit Extraction (compulsory fodder collection from undeveloped establishments if it happens to be a community based project)

Gathering the restoration practitioners, annually in one roof and bring one accord, regarding mangrove ecosystem functioning is one of the strategies suggested. This would widen knowledge among ecologists on restoration due to the exposure to different case studies, as well as help to evolve with more successful solutions.

CONCLUSION

Government of India in March, 2007 in its Eleventh Five Year Plan 2007-2012, has come out with a set of plan which is very appreciable and applicable; if implemented with the same magnitude would make a considerable positive impact. The success rate of community

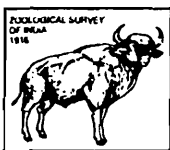
participation, the well accepted conservation strategy is directly proportional to the percentage of resource dependency. Thorough regional understanding of any particular mangrove ecosystem functions along with ecological and social interactions is the base to evolve with an effective code of conduct. Funding agency should develop a mode to fund for the right strategy through questionnaires and special short term studies to understand the ecosystem. Besides, implementing agency

also should be responsible for understanding the regional mangrove ecosystem and bring out the appropriate conservation strategy. Strategy should be designed based on mangrove conservation needs and not on financial fetch, which makes most of our mangrove development efforts with minimal returns in India. The strategy of linking ecological strength with and engineering techniques could also be a better solution for coastal protection in eroding coastlines.

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ON THE OCCURRENCE OF UNUSUAL FORAMINIFERA ASSEMBLAGE FROM OFFSHORE OF SOUTH ANDAMAN, ANDAMAN SEA

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INTRODUCION

Planktonic Foraminifera are the single celled floating animals, belong to the Order Foraminiferida, Class Rhizopodea and Phylum Protozoa. They are distributed in the pelagic waters, up to a depth less than 2,000 m. They are lack of locomotary organs and are distributed by ocean currents. Some time they carried by currents from thousands of kilometers and commonly die far away from their birth places. Globally 4,000 living species of foraminifera are estimated in the world oceans, out of these 45 species are planktonic forms (Hemleben *et al.*, 1989) and 29 species are common in the world ocean.

The exiting literature on the distribution of live planktonic foraminifera suggested that very few studies have been carried out on this aspect (Ganapati and Satyavati, 1958; Rao, 1972; Rao *et al.*, 1987). An overview studies on foraminiferal in nearshore regions of western and eastern coast of India, Laccadives, and Andaman and Nicobar Islands suggested that there is no specific study on live planktonic foraminifers distribution and diversity (Bhalla *et al.*, 2007; Khare *et al.*, 2007). Therefore, the

present study was carried to understand the distribution of live planktonic foraminifera in the nearshore waters of off Port Blair, Andaman.

STUDY AREA

The area selected for this study was in and around Port Blair, Off Wandoor area and Off Sisostris Bay (Fig.1). Since, these two areas were selected because to represent Bay of Bengal in the West and Andaman Sea in the East.

MATERIALS AND METHODS

The study was carried out in Sisostris Bay during December 2006 to March 2007 and December 2007 to March 2008 and in Wandoor during December 2007 to March 2008. The sampling was carried out in the evening 19.00 hours to 20.00 hours. The samples also collected from one or two day prior to the full moon as well as new moon day, depending upon the condition of the sea. The samples were collected from the study area by the horizontal deployment of planktonic net method, where the boat was allowed to run with the plankton net, which was immerse into the water surface

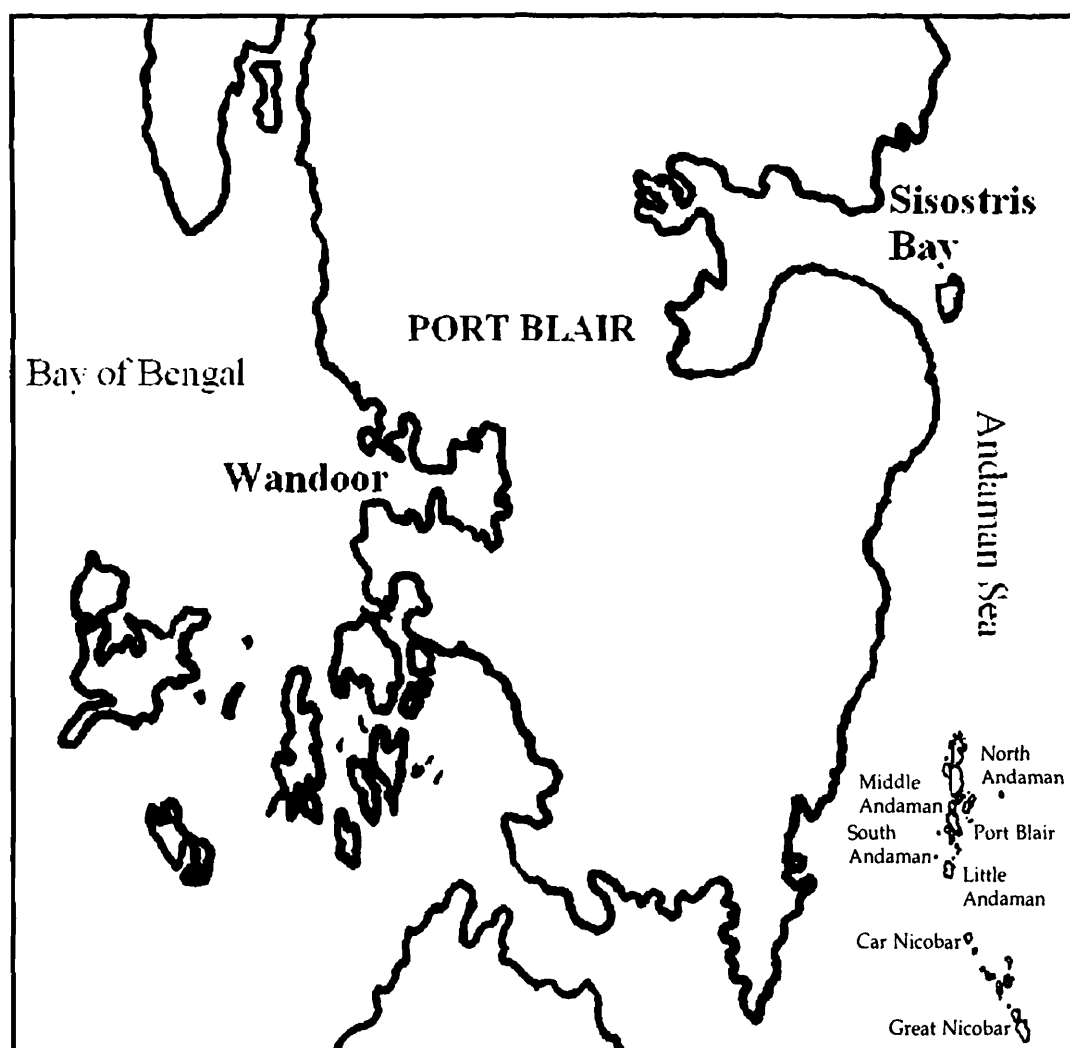


Fig. 1. Study area

and was dragged along for a period of 10 minutes. The samples were collected using the Plankton net (0.2mm). The net was hauled and the samples along with water were transferred into a 250 ml storage bottles. After sample collection, immediately 20ml of 10 per cent formaldehyde were added into the samples for preservation. The environmental data also collected using the Quanta Hydrolab probe.

The preserved samples were brought to the laboratory and washed over a sieve of 0.2mm. The sieved samples were poured into a petriplate and observed under a stereoscopic binocular microscope (Nikon-SMZ1500) where the zooplanktons and phytoplanktons were removed with the help of a needle and micropipette. The isolated forams were then stored in a screw tight bottles for further identification. The forams were then identified

under an inverted plankton microscope (Nikon -Eclipse TS100) and photographed by digital camera (Nikon-Cool Pix 8400). The identification was carried out using available literature on foraminifera.

RESULTS AND DISCUSSION

The collected zooplankton samples represent 47 species of foraminifera (Table 1) belonging to 18 genera, 6 subfamilies, 13 family and 8 super families (Plate 1-4). Out of these 47 species, only 12 species are belonging to planktonic form (Hemleben *et al.*, 1989). The remaining 35 species are identified under planktonic forms but which are originally belonging to benthic foraminifera as described in the existing literature (Murray, 1971; Haynes, 1981; Rao *et al.*, 1987; Loeblich and Tappan, 1992; Gupta, 1999; Bhalla *et al.*, 2007; Khare *et*

al., 2007). Out of these 47 species, 26 species are not matching with the any existing species characters and are described as follows :

Superfamily LITUOLACEA

Family TROCHAMMINIDAE

Trochammina sp. A

Plate 1. Agglutinated wall with particles attached to mineralised matrix. Planispirally coiled throughout. Peripherally located single aperture. Planispiral evolute; peripheral plain with keel on the edge. Chambers are even in size.

Trochammina sp. B

Plate 1. Agglutinated wall with particles attached to mineralised matrix. Planispirally coiled throughout. Peripherally located single aperture. Aperture is broad. Planispiral evolute; peripheral spiral; plain on the edge. Earlier chambers are smaller than latter.

Trochammina sp. C

Plate 3. Calcareous Agglutinated wall. Planispirally coiled and uncoiled in later part. Peripherally located single aperture. Planispiral evolute; peripheral spiral; uneven on the edge. Chambers size are not vary from earlier to latter stages. Bilamellar and outer layer has spines.

Trochammina sp. D

Plate 3. Calcareous Agglutinated wall. Planispirally coiled throughout. Peripherally located single aperture. Planispiral evolute. Aperture is broad. peripheral uneven and arcuate on the edge. Earlier chambers are smaller than latter. Juvenarium is present and secondary septum are not visible.

Trochammina sp. E

Plate 4. Calcareous agglutinated wall. Planispirally coiled throughout. Spiral suture are present. Single aperture peripherally located. Planispiral evolute. Aperture is broader than *Trochammina* sp. D. Arcuate on the edge. Earlier chambers are smaller than latter. However, comparing *Trochammina* sp. D, earlier chamber size is slightly larger.

Superfamily ROTALIACEA Ehrenberg, 1839

Family CALCARINIDAE

Calcarina sp. A

Plate 2. Test typically low trochospiral with numerous chambers; aperture basal, single; thickened lamellae with radial canals, tubular shaped chambers and usually spinose. Ten tubular chambers are radially arranged. Between the spines intra spaces are not even. Three intra spaces are broader than remaining spaces. Two spines are broader.

Calcarina sp. B

Plate 2. Test typically low trochospiral with numerous chambers; aperture basal, single; thickened lamellae with radial canals, tubular shaped chambers and usually spinose. Nine tubular chambers are radially arranged. Between the spines intra spaces are not even. One intra space is broader than remaining spaces. Two spines are broader.

Calcarina sp. C

Plate 3. Test typically low trochospiral with numerous chambers; aperture basal, single; thickened lamellae with radial canals, tubular shaped chambers and usually spinose. Eleven tubular chambers are radially arranged. Between the spines intra spaces are not even. Two intra spaces are broader than remaining spaces. Two spines are broader.

Calcarina sp. D

Plate 3. Test typically low trochospiral with numerous chambers; aperture basal, single; thickened lamellae with radial canals, tubular shaped chambers and usually spinose. Nine tubular chambers are radially arranged. Between the spines intra spaces are not even. Two intra spaces are broader than remaining spaces.

Calcarina sp. E

Plate 3. Test typically low trochospiral with numerous chambers; aperture basal, single; thickened lamellae with radial canals, tubular shaped chambers and usually spinose. Eight tubular chambers are radially arranged.

Between the spines intra spaces are not even. One intra space is broader than remaining spaces. Two spines are broader and bigger than the remaining chambers.

Calcarina sp. F

Plate 3. Test typically low trochospiral with numerous chambers; aperture basal, single; thickened lamellae with radial canals, tubular shaped chambers and usually spinose. Twelve tubular chambers are radially arranged. All intra spaces are nearly similar. Three spines are broader.

Calcarina sp. G

Plate 4. Test typically low trochospiral with numerous chambers; aperture basal, single; thickened lamellae with radial canals, tubular shaped chambers and usually spinose. Thirteen tubular chambers are radially arranged. All intra spaces are nearly similar. Two spines are smaller and broader. Two spines are larger and broader.

Calcarina sp. H

Plate 4. Test typically low trochospiral to planispiral with numerous chambers; aperture basal, single; thickened bilamellae with radial canals. Nine spines are radially arranged. Between the spines intra spaces are not even. Two intra spaces are broader than remaining spaces. Two spines are broader. Surface spinose.

Calcarina sp. I

Plate 4. Test typically low trochospiral with numerous chambers; aperture basal, single; thickened lamellae with radial canals, tubular shaped chambers and usually spinose. Nine tubular chambers are radially arranged. Between the spines intra spaces are not even. One intra space is broader than remaining spaces. Two spines are broader.

Superfamily BULIMINACEA Loeblich and Tappan, 1992

Family BULIMINIDAE

Bulimina sp. A

Plate 3. This species exhibit trochospiral test with uniserial. Aperture extending into

apertural face from basal suture, chambers is solid.

Bulimina sp. B

Plate 4. This species exhibit high trochospiral test. Chambers is biserial. Aperture is aerial with internal toothplate. Surface is smooth.

Superfamily GLOBIGERINACEA Carpenter, Parker and Jones, 1862

Family GLOBIGERINIDAE Carpenter, Parker and Jones, 1862

Subfamily GLOBIGERININAE Carpenter, Parker and Jones, 1862

Globigerina sp. A.

Plate 3. Low trochospiral, chambers semi-globular, surface spinose, aperture is basal; chamber are arranged in irregular with uneven size with trochospiral to planispiral. The last stages of chambers are arranged in circular pattern. More than twenty Chambers. Finely spinose surface sculpture. Primary aperture usually interiomarginal and secondary apertures sutural.

Globigerina sp. B

Plate 3. Semi-globular chambers; circular aperture, basal with umbilical placement; chamber are arranged with trochospiral to planispiral. The last stages of chambers are not arranged in spherical pattern. Less than ten Chambers. Spinose on chambers surface sculpture. Chambers are large in size.

Globigerina sp. C

Plate 3. Globular chambers; bilamellae, circular aperture, basal with umbilical placement; chamber are arranged in evenly with trochospiral to planispiral. The final stages of chambers are arranged in circular pattern. More than twenty Chambers. Finely spinose surface sculpture. Chambers are moderate in size.

Globigerina sp. D

Plate 3. Chambers are elongated, solid; circular aperture, basal with umbilical

placement; chamber are arranged in evenly with trochospiral to planispiral. Finely spinose surface sculpture. More than twenty five Chambers.

Globigerina sp. E

Plate 3. Chambers are semi-globular, broader; circular aperture, ventral basal with umbilical placement; chamber are arranged in uneven with trochospiral to planispiral. The very last stages of chambers are arranged in wide with circular pattern. More than twenty five Chambers. Finely spinose surface sculpture.

Superfamily DISCORBACEA

Family CYMBALOPORIDAE

Cymbaloporetta sp. A

Plate 3. Numerous chamber arranged in trochospiral in early part. Ventrally basal apertures, usually as large spinose on chambers. Chambers are uneven size with irregular, patchy arrangement pattern. More than twenty five chambers.

Superfamily NONIONACEA

Family NONIONIDAE

Nonionella sp. A

Plate 3. Test typically low planispiral with numerous chambers throughout or in early part. Aperture slit like or series of pore. Bilamellae, chambers are slightly elongate. Spinose on chambers.

Superfamily DISCORBACEA

Family ASTERIGERINIDAE

Asterigerina sp. A

Plate 4. Test typically low trochospiral with numerous chambers. Alternating with larger and smaller chamberlets in a stellate arrangement, aperture basal and ventral side. Sutural canal system and spinose on chambers.

Superfamily ROTALIACEA

Family ELPHIDIIDAE

Elphidium sp. A

Plate 4. Test typically low planispiral,

involute. Sutural canal system. Glassy appearance of walls. Broader aperture.

Superfamily NODOSARIACEA

Family VAGINULINIDAE

Lenticulina sp. A

Plate 4. Test of low Mg calcite. Wall monolamellar, perforate, multi chambered with serial chamber arrangement. Coiled throughout stages.

DISCUSSION

Total of 47 species of foraminifera were identified from the sample collected from the Sisostri Bay and Wandoor area (Table 1). The present study found only 12 species of planktonic foraminifera as described by the Hemleben *et al.* (1989). The remaining 35 species are from the benthic forms described by the earlier workers (Loeblich and Tappan, 1992) but which was found in the planktonic samples. These mixed populations availability may be due to three possibilities. The first one is due to the turbulence exerted by the mixing of water mass in the near shore area which leads to the floating of benthic foraminifera on the surface waters. The second is the species originally belongs to the planktonic forms which are identified as benthic forms by the exiting workers. The third is the younger stage of this species may undergo in the planktonic forms and in the adult stage it may reaches to the benthic life. The above inconsistency on the inference suggests that the lack of elaborate studies in this aspect of the live cycle of the foraminifera.

The identified 47 species are belongs to 18 genera, 6 subfamily, 13 family and 8 super family. Out of 47 species, only 10 species were identified from Sisostri Bay 2006-07 collection. Another 16 species were identified in Sisostri Bay 2007-08 collection and 21 species were found in Wandoor 2007-08. Based on the above distribution, there was no similar species recorded in the study area between the stations as well as among the stations. This is one of the interesting factors observed in this study.

Table 1. Distribution of foraminiferal species in the study area

Sl. No.	Sisostris 2006-07	Sisostris 2007-08	Wandoor 2007-08
1	* <i>Globigerinella adamsi</i>	+ <i>Cymbaloporella squamosa</i>	* <i>Globigerina</i> sp. A
2	* <i>Glabrotalia hirsuta</i>	+ <i>Cymbaloporella bradyi</i>	* <i>Globigerina</i> sp. B
3	* <i>Globigerinoides ruber</i>	* <i>Pulleniatina obliquiloculata</i>	* <i>Globigerina</i> sp. C
4	* <i>Globigerinoides sacculifer</i>	+ <i>Cyclogyra involvens</i>	* <i>Globigerina</i> sp. D
5	+ <i>Rosalina concinna</i>	* <i>Globigerinita glutinata</i>	* <i>Globigerina</i> sp. E
6	* <i>Globigerina bulloides</i>	+ <i>Trochammina nobensis</i>	+ <i>Cymbaloporella</i> sp. A
7	+ <i>Cibicides pseudoungerianus</i>	+ <i>Trochammina</i> sp. B	+ <i>Rosalina globularis</i>
8	+ <i>Elphidium rugulosum</i>	+ <i>Lagena striata</i>	+ <i>Nonionella</i> sp. A
9	+ <i>Nonionella auricular</i>	+ <i>Calcarina</i> sp. A	+ <i>Trochammina</i> sp. C
10	+ <i>Trochammina</i> sp. A	+ <i>Calcarina</i> sp. B	+ <i>Trochammina</i> sp. D
11	+ <i>Calcarina</i> sp. C	+ <i>Trochammina</i> sp. E	
12	+ <i>Calcarina</i> sp. D	+ <i>Asterigerina</i> sp. A	
13	+ <i>Calcarina</i> sp. E	+ <i>Elphidium jenseni</i>	
14	+ <i>Calcarina</i> sp. F	+ <i>Elphidium</i> sp. A	
15	+ <i>Elphidium crispum</i>	+ <i>Elphidium simplex</i>	
16	+ <i>Bulimina</i> sp. A	+ <i>Lenticulina</i> sp. A	
17		+ <i>Calcarina</i> sp. G	
18		+ <i>Calcarina</i> sp. H	
19		+ <i>Calcarina</i> sp. I	
20		+ <i>Calcarina calcar</i>	
21		+ <i>Bulimina</i> sp. B	

* Denotes planktonic stage of foraminifera

+ Denotes benthic foraminifera found in the planktonic stage

These variations among the stations as well as species may be due to the sensitiveness of the species with reference to the environmental condition or it may be due to the current patterns which drift the species continuously. However, it needs a detailed study in a wider area to understand the reality of this character.

When comparing the distribution of species in the Sisostris Bay and Wandoor stations suggested that the Sisostris Bay (Andaman Sea) has less number of species (16 species) but Wandoor (Bay of Bengal) has 26 species. The more number of species availability in the Wandoor station may be due to the coralline environment. Further, the present study enumerates 16 species in Wandoor and 9 species from Sisostris Bay as a first report in this water.

In addition, the *Trochammina* sp. is very much familiar in Japanese water which may be migrated to Andaman and Nicobar water by the way of natural current movements or by ship transportations, i.e. the ballistic waters or attachment with sediments carried over by the ship hull or it is an original species of this waters. A similar type of intrusions reported in Washington waters from Japan (Mary *et al.*, 2007).

Another finding in the study area has the highest species availability from *Calcarina* which consists of 10 species and followed by *Trochammina* and *Globigerina* which exhibit 6 species respectively and finally *Elphidium* shows 5 species. *Calcarina* shows the highest diversity in the Andaman Sea and *Globigerina* in Bay of Bengal.

Table 2. Environmental data for the study area

Sisostris Bay-2007-08

Sl. No.	Parameters	20/12/2007	07/01/2008	22/01/2008	06/02/2008
1.	Temperature ° C	27.95	28.17	28.1	28.42
2.	Salinity PSU	31.70	32.00	31.88	31.63
3.	Dissolved Oxygen ml/l	06.18	05.83	06.80	06.18
4.	pH	09.22	09.22	09.19	09.34
5.	Eh mvolt	112.75	108.45	124.75	115.20
6.	Turbidity NTU	10.00	00.00	09.50	40.35

Wandoor - 2007-08

Sl. No.	Parameters	23/12/2007	11/01/2008	27/01/2008	09/02/2008
1.	Temperature ° C	28.40	28.58	28.32	28.31
2.	Salinity PSU	32.07	31.94	32.03	32.07
3.	Dissolved Oxygen ml/l	05.86	06.84	06.40	06.04
4.	pH	09.14	09.40	09.32	09.37
5.	Eh mvolt	112.60	157.80	118.50	112.70
6.	Turbidity NTU	00.00	00.00	00.00	00.00

Over and above, the environmental data (Temperature, Salinity, Dissolved Oxygen, pH, Eh, Turbidity) collected during the time of foraminiferal collection (Table 2) suggested that there were changes in Bay of Bengal and Andaman Sea. In Bay Bengal it has been noticed that slightly high temperature (0.5°C) and Salinity (0.3 PSU) with low concentration in Dissolved Oxygen (0.3 ml/L) and nil turbidity make comparatively more divergent of foraminifera than in Andaman Sea.

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Plate 1



Globigerinella adamsi 20x



Globotrochalia hirsuta 40x



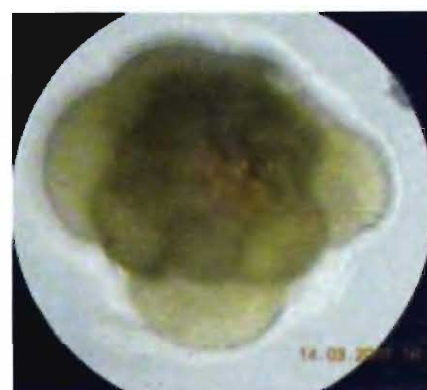
Globigerinoides ruber 20x



Globigerinoides sacculifer 20x



Rosalina concinna 40x



Globigerina bulloides 20x



Cibicides pseudoungerianus 40x



Elphidium rugulosum 40x



Nonionella auricula 40x



Trochammina sp.A 40x



Cymbaloporeta squamosa 10x



Cymbaloporeta bradyi 40x

Plate 2



Pulleniatina obliquiloculata 40x



Cyclogyra involvens 20x



Globigerinita glutinata 20x



Trochammina nobensis 20x



Trochomina sp.B 10x



Lagena striata 10x



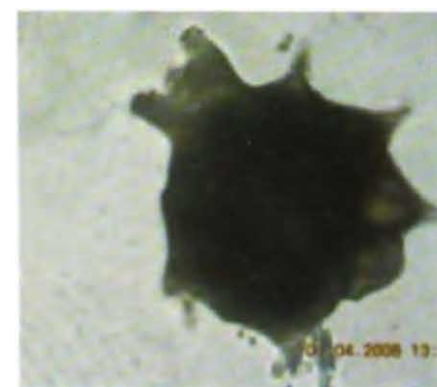
Calcarina sp.A 20x



Calcarina sp.B 20x



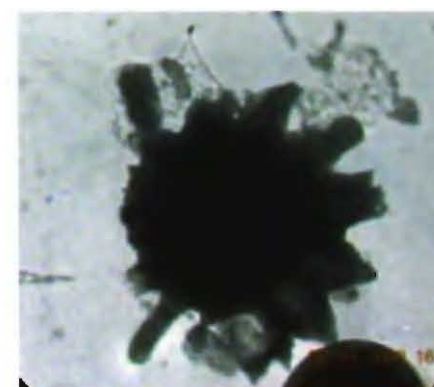
Calcarina sp.C 20x



Calcarina sp.D 20x



Calcarina sp.E 20x

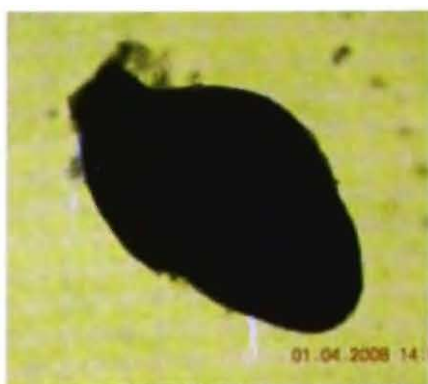


Calcarina sp.F 20x

Plate 3



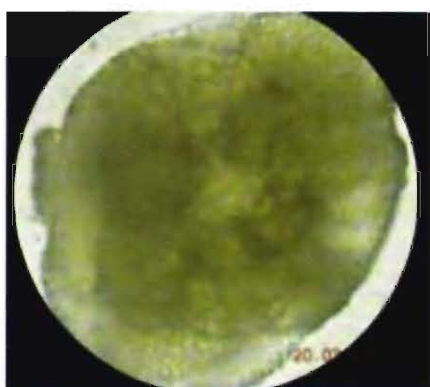
Elphidium crispum 20x



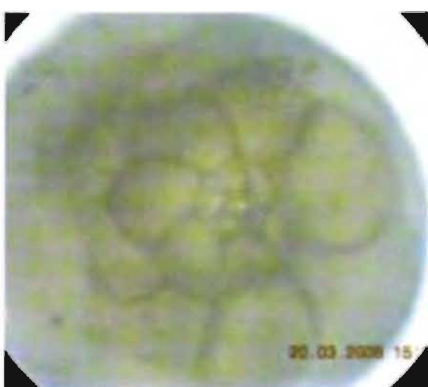
Bulimina sp.A 20x



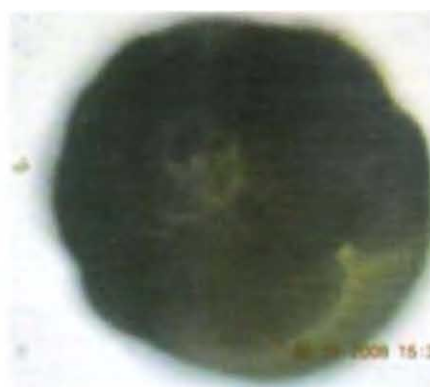
Globigerina sp.A 40x



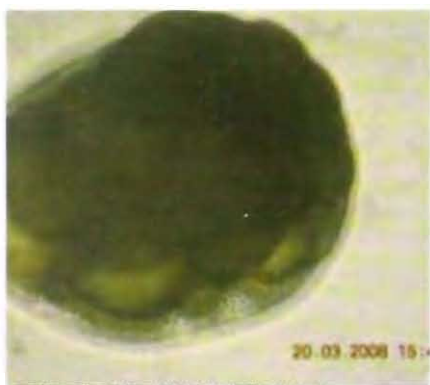
Globigerina sp.B 40x



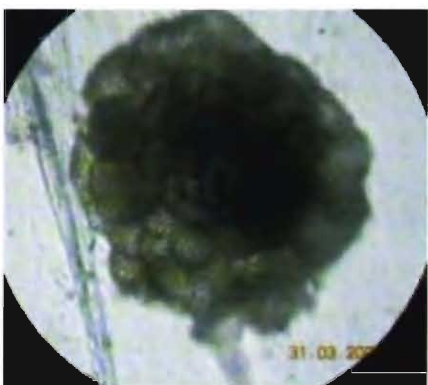
Globigerina sp.C 20x



Globigerina sp.D 20x



Globigerina sp.E 40x



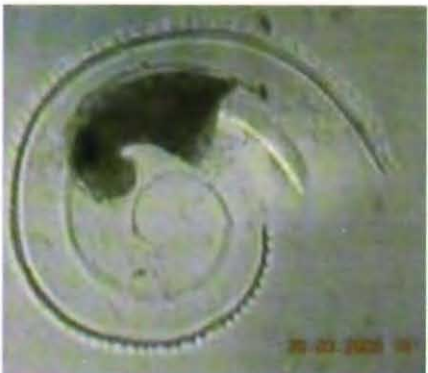
Cymbaloporeta sp.A 40x



Rosalina globularis 40x



Nonionella sp.A 20x



Trochammina sp.C 10x



Trochammina sp.D 20x

Plate 4



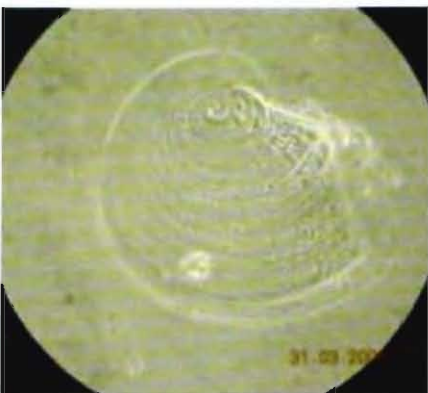
Trochammina sp.E 20x



Asterigerina sp.A 20x



Elphidium jenseni 10x



Elphidium sp.A 20x



Elphidium simplex 20x



Lenticulina sp.A 20x



Calcarina sp.G 10x



Calcarina sp.H 10x



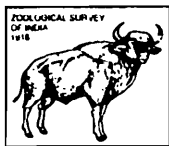
Calcarina sp.I 10x



Calcarina calcar 10x



Bulimina sp.B 20x



ROTIFER DIVERSITY IN A FEW LAKES OF ANDHRA PRADESH

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INTRODUCTION

Rotifers are pseudocoelomate and usually microscopic organisms with the size ranging from 40 to 250 μm . Studies on the rotifer fauna in Andhra Pradesh have been carried out by Dhanapathi (2000), Dhanapathi and Sarma (2000), Mohan and Rao (1976), Siddiqi and Chandrasekhar (1995, 2007 and 2008), Chandrasekhar and Siddiqi (2005), Ahsan (1980), Devi (1985), Chandrasekhar (1997) and Malathi *et al.* (2003). Of the 325 species reported from India, 91 species record during this study from Andhra Pradesh. There is no systematic documentation on the total Rotifer composition of the state, therefore a study has been undertaken and presented the paper that has reported 91 species belonging to 18 Families under three orders.

Andhra Pradesh (12°37'-19°54' N latitude and 76°46'-84°46' E longitude) is the fifth largest state in area-wise in India, with a total geographical area of 2,75,069 km^2 , out of which 5,26,457 ha. spread area of wetlands (natural wetlands with 1,00,457 and man-made of 4,25,892 ha.). Andhra Pradesh State is surrounded one side by Bay of Bengal and on other sides Tamil Nadu, Karnataka, Maharashtra, Madhya Pradesh, Chattishgarh and Orissa. There are about 1,193 wetlands, of

which 572 were natural are available in India. The Kolleru Lake has been designated as Ramsar site. Out of 18 wetlands in Andhra Pradesh, eight are of natural and the remaining man-made.

MATERIALS AND METHODS

This study is based on the plankton samples collected from different water bodies *viz.*, Kondakarla Lake, Kolleru Lake, Pocharam Lake, Wyra Lake Manjira Lake.

RESULTS AND DISCUSSION

India contains a great wealth of rotatorian diversity with 325 species in its wetlands and in its marine areas. Out of the 325, 95 per cent of the species are reported from freshwater habits and the rest are of marine or estuarine ones. Among the new species described from India, *Brachionus durgae* from Andhra Pradesh is known to be reported from Japan, South Africa and South America and this species can be considered as tropicopolitan. The monogonants constituted a major component of the rotifer fauna documented from Andhra Pradesh and their significant fraction was formed by the members of the families Lecanidae and Brachionidae. The qualitative predominance and common occurrence of the

species particularly of *Lecane* and *Brachionus* imparted broadly tropical character to the fauna of the state. The total rotatorian composition in Andhra Pradesh is present in (Table 1) and the new species (Table 2). Endemism among the rotifers is relatively low. Out of the 32 endemic rotatorian species available in India, seven are known from the state (Table 3).

ACKNOWLEDGEMENTS

The author is thankful to the Officer-in-Charge, Freshwater Biology Regional Centre, Zoological Survey of India, Hyderabad and to the Director, Zoological survey of India, Kolkata for providing facilities to carry out this study.

Table 1. List of Rotifer species recorded from Andhra Pradesh

Class ROTIFERA	23. <i>K. tropica</i> Apstein, 1907
Subclass MONOGONONTA	24. <i>K. Volga</i> (Ehrenberg, 1834)
Order PLOIMIDA	25. <i>Platijas quadricornis</i> Ehrenberg, 1832
Family EPIPHANIDAE	26. <i>Platijas qudricornis andhraensis</i> Dhanapathi, 1974
1. <i>Epiphanes clavulata</i> Ehrenberg, 1832	Family EUCHLANIDAE
Family : Brachionidae	27. <i>Euchlānis brahmae</i> Dhanapathi, 1976
2. <i>Anuraeopsis fissa</i> (Gosse, 1851)	28. <i>E. dialatata</i> Ehrenberg, 1832
3. <i>Brachionus angularis</i> Gosse, 1851	29. <i>E. oropha</i> Gosse, 1887
4. <i>B. caudatus</i> Barrois & Daday, 1894	30. <i>Dipleuchlanis propatulus</i> Gosse, 1886
5. <i>B. caudatus f. aculeatus</i> Haeur, 1937	31. <i>Tripleuchlanis plicata</i> (Levander, 1894)
6. <i>B. diversicornis</i> Daday, 1883	32. <i>Pseudoeuchlanis longipedis</i> Dhanapathi, 1978
7. <i>B. forficula f typicus-urawensis</i> Sudzuki,, 1955	33. <i>Beauchammpiella eudactylotum</i> Remane, 1929
8. <i>B. calyciflorus</i> Pallas, 1776	34. <i>Diplois devieseeae</i> Gosse, 1886
9. <i>B. calyciflorus</i> var.dorcas Gosse, 1851	Family MYTILINIDAE
10. <i>B. calyciflorus</i> var. <i>hymani</i> Dhanapathi, 1974	35. <i>Mytilina ventralis</i> Ehrenberg, 1832
11. <i>B. bidentata</i> Anderson, 1889	36. <i>M. ventralis brevispina</i> (Ehrenberg, 1832)
12. <i>B. durgae</i> Dhanapathi, 1974	37. <i>M. ventralis macrocantha</i> (Gosse, 1886)
13. <i>B. falcatus</i> Zacharias, 1898	Family TRICHOTRIDAE
14. <i>B. falcatus</i> var. <i>lyratus</i> Lammerman, 1908	37. <i>Trichotria tetractis</i> Ehrenberg, 1830
15. <i>B. quadridentatus</i> Hermann, 1783	38. <i>T. similis</i> (Stenroos, 1898)
16. <i>B. quadridentatus</i> var. <i>entzi</i> (France, 1894)	39. <i>Macrochaetus serica</i> Thorpe, 1893
17. <i>B. quadridentatus</i> var. <i>melhini</i> (Barrois & Daday, 1894)	Family COLURELLIDAE
18. <i>B. urceolaris</i> Muller 1773	40. <i>Lepadella ovalis</i> (O.F. Muller 1786)
19. <i>B. patulus</i> (Muller 1786)	Family LECANIDAE
20. <i>B. rubens</i> Ehrenberg, 1838	41. <i>Lecane bidentata</i> Dhanapathi, 1976
21. <i>Keratella cochlearis</i> Gosse, 1851	42. <i>L. curvicornis</i> (Murray, 1913)
22. <i>Keratella procurva</i> (Thorpe, 1891)	43. <i>L. donnerianus</i> Dhanapathi, 1976

Table 1. Contd.

44. <i>L. eswari</i> Dhanapathi, 1976	72. <i>A. intermedia</i> Hudson, 1886
45. <i>L. hornemanni</i> (Ehrenberg, 1881)	73. <i>Asplanchnopus bhimavaramensis</i> Dhanapathi, 1975
46. <i>L. laterborni</i> (Hauer, 1924)	74. <i>A. hyalinus</i> Harring, 1917
47. <i>L. leotina</i> (Turner, 1892)	Family SYNCHAETIDAE
48. <i>L. ludwgii</i> (Eckstein, 1883)	75. <i>Polyarthra vulgaris</i> Carliu, 1943
49. <i>L. luna</i> (Muller, 1776)	Family DICRANOPHORIDAE
50. <i>L. papuana</i> (Murray, 1913)	76. <i>Dicranophorus dolerus</i> Harring & Myers, 1927
51. <i>L. angulata</i> (Gosse, 1887)	77. <i>D. tegillus</i> Harring & Myers, 1927
52. <i>L. (Monostyla) bulla</i> (Gosse, 1851)	Order GNESIOTROCHA
53. <i>L. (M) closteroerca</i> (Schmarada, 1898)	Family FLOSCULARIDAE
54. <i>L. hamata</i> (Stokes, 1896)	78. <i>Floscularia ringens</i> (Linnaeus, 1758)
55. <i>L. (HM) inopinata</i> Harring & Myers, 1926	79. <i>Lacinularia flosculosa</i> (Muller, 1773)
56. <i>L. (M) obtuse</i> (Murray, 1913)	80. <i>Sinantherina spinosa</i> (Thorpe, 1853)
57. <i>L. (M) qudridentata</i> (Ehrenberg, 1832)	Family CONOCHILIDAE
58. <i>L. (M) stenroosi</i> (meissner, 1908)	81. <i>Conochiloides dissuarius</i> (Hudson, 1885)
59. <i>L. (M) styrax</i> Harring & Myers, 1926	Family HEXARTHRIDAE
60. <i>L. (M) tethis</i> Harring & Myers, 1926	82. <i>Hexarthra intermedia</i> Wizneiowski, 1929
Family NOTOMMATIDAE	83. <i>H. mira</i> (Hudson, 1871)
61. <i>Cephalodella forficula</i> (Ehrenberg, 1832)	Family FILINIDAE
62. <i>C. hiula</i> Myers, 1924	84. <i>Filinia longiseta</i> (Ehrenbeg, 1834)
63. <i>Esophora anthalis</i> Harring & Myers, 1921	85. <i>F. opoloensis</i> (Zacharias, 1898)
64. <i>E. najas</i> Ehrenberg, 1830	86. <i>F. pejleri</i> Hurchinson, 1964
65. <i>Notommata copeus</i> Ehrenberg, 1834	Family TESTUDINELLIDAE
66. <i>N. pseudocereberus</i> Beauchamp, 1908	87. <i>Testudinella mucronata</i> (Gosse, 1886)
67. <i>Taphrocampa selenura</i> Gosse, 1887	88. <i>T. patina</i> (Hermann, 1783)
Family SCARIDIDAE	Family TROCHOSPHAERIDAE
68. <i>Scaridium longicaudatum</i> (Muller, 1786)	89. <i>Horaella brehmi</i> Donner, 1949
Family LINDIDAE	Family COLLOTHECIDAE
69. <i>Lindia intermedia</i> Dhanapathi and Rama Sharma, 2000	90. <i>Cupellopagis vorax</i> (Leidy, 1957)
Family TRICHOCERCIDAE	Subclass BDELLOIDA
70. <i>Trichocerca rattus</i> (Muller, 1776)	Order BDELLOIDA
Family ASPLANCHNIDAE	Family PHILLODINIDE
71. <i>Asplanchna brightwelli</i> Gosse, 1850	91. <i>Rotaria neptunea</i> (Ehrenberg, 1832)

Table 2. List of new species/sub-species/ varieties/forms from Andhra Pradesh

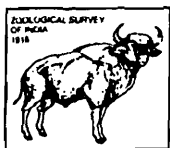
1. <i>Brachionus calyciflorus</i> var. <i>hymani</i> Dhanapathi, 1974
2. <i>B. durgae</i> Dhanapathi, 1974
3. <i>Platylabus quadricornis andhraensis</i> Dhanapathi, 1974
4. <i>Euchlanis brahmae</i> Dhanapathi, 1976
5. <i>Pseudoeuchlanis longipedis</i> Dhanapathi, 1978
6. <i>Lecane bidentata</i> Dhanapathi, 1976
7. <i>L. donnerianus</i> Dhanapathi, 1976
8. <i>L. eswari</i> Dhanapathi, 1976
9. <i>Lindia intermedia</i> Dhanapathi and Rama Sharma, 2000

Table 3. Endemic Rotifer Composition of Andhra Pradesh

1. <i>B. durgae</i> Dhanapathi, 1974
2. <i>Platylabus quadricornis andhraensis</i> Dhanapathi, 1974
3. <i>Euchlanis brahmae</i> Dhanapathi, 1976
4. <i>Pseudoeuchlanis longipedis</i> Dhanapathi, 1978
5. <i>Lecane bidentata</i> Dhanapathi, 1976
6. <i>L. donnerianus</i> Dhanapathi, 1976
7. <i>L. eswari</i> Dhanapathi, 1976

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SEASONAL VARIATION IN DIVERSITY, SPATIAL DISTRIBUTION AND SPECIES SUCCESSION OF PHYTOPLANKTON IN PORT BLAIR BAY, INDIA

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INTRODUCTION

Phytoplankton groups are primary producers of marine ecosystem. Due to their small size, short life span, rapid nutrient uptake, specific growth requirements phytoplankton is highly responsive to variation in environmental conditions (Reynolds 1984). This sensitivity, combined with their ability to rapidly proliferate in waters affected by anthropogenic (agricultural, urban, and industrial watershed activities) and natural (droughts and elevated rainfall events) disturbances, implies that phytoplankton can be useful indicators of environmental change in marine environments (Richardson, 1997). Characterization of phytoplankton has therefore become imperative in understanding the functionality and impediments occurring in marine ecosystems (Ariyadej *et al.*, 2004; Cermeno, 2008). Bay is a dynamic area where land based effluents undergo continuous change in ecological characteristics and the magnitude of change depends on season and quality of discharged waste (Shams-El-Din and Dorgham, 2007). Hence, the knowledge of

phytoplankton distribution, species diversity abundance and taxonomic composition will give a better insight on the undesirable disturbances occurring in marine bay ecosystems.

Port Blair Bay is located in the eastern side of the South Andaman Island. Major percentage of Andaman population is concentrated in the capital city, Port Blair. Hence, the ecological environment of this Bay is greatly influenced by human activity. In recent years there is a marked resurgence of interest in studying the biological diversity of the Port Blair Bay because of the sudden surge in the anthropogenic activity in this fragile Island city due to shipping, tourism, disposal of untreated sewage and devastation caused by the December 2004 M9 earthquake and tsunami (Sridar *et al.*, 2007).

There is paucity of information on the phytoplankton community structure of Port Blair Bay. The purpose of this work was to explore the spatial distribution, species diversity and species succession of phytoplankton during different seasons in 2006 (an year after the Tsunami). The results derived

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from this study will provide background information for future research in this fragile marine ecosystem.

MATERIALS AND METHODS

Description of study area

Port Blair Bay (Fig. 1) is located in the eastern side of the South Andaman Island. Seven sampling stations were chosen for the survey. The list of sampling stations and their GPS positions are given in Table 1. The exact

GPS position of different stations varied marginally during different seasons.

Station 1-Flat Bay zone (FB)

It is a shallow bay with many creeks extending deep inside the adjacent land. This Bay receives large amount of freshwater, sewage and municipal waste that influences the water quality dynamics of entire Port Blair Bay ecosystem. This Bay is fringed with dense mangroves.

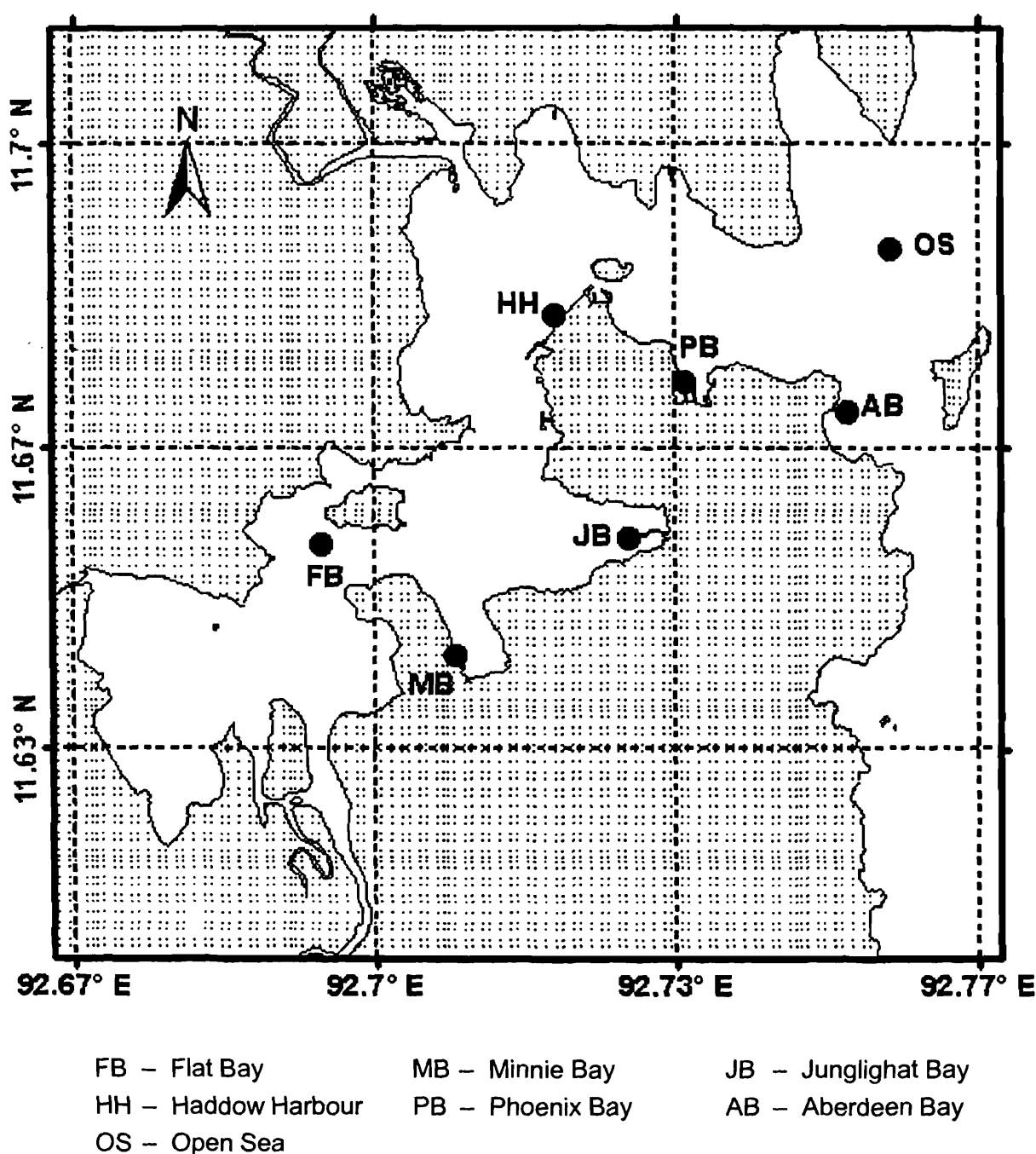


Fig. 1. Sampling stations in Port Blair Bay

Table 1. Locations of Stations in Port Blair Bay

Sl. No.	Station name	Station code	Latitude	Longitude
1.	Flat Bay	FB	11°39'21.9" N	92°41'39.5" E
2.	Minnie Bay	MB	11°38'40.4" N	92°42'27.9" E
3.	Junghlight Bay	JB	11°39'30.2" N	92°43'34.3" E
4.	Haddo Harbour	HH	11°40'58.3" N	92°43'04.5" E
5.	Phoenix Bay	PB	11°40'29.3" N	92°44'00.6" E
6.	Aberdeen Bay	AB	11°40'17.1" N	92°45'01.6" E
7.	Open Sea	OS	11°41'16.3" N	92°45'13.9" E

Station 2-Minnie Bay zone (MB)

Minnie Bay is located at the head of Port Blair Bay and it is approximately about 0.538 km² in area with an average depth of 3m. This Bay is also encircled with mangrove vegetation on its embankments. A residential complex of Indian Navy is situated in the southeast bank. The sewerage generated from these residential quarters is released into the head end of the Bay.

Station 3-Junghlight Bay Zone

Junghlight Bay area is situated towards northeast of Minnie Bay and is one of the major fish landing area of Port Blair. This Bay receives large amount of sewage discharge from the adjacent settlements.

Station 4-Haddo harbour zone (HH)

Haddo harbour area is the major harbour in A & N Islands. Mainland bound passenger vessels, cargo vessels, oil tankers, etc., berth in this port. The naval wharf is situated adjacent to the Haddo Harbour.

Station 5-Phoenix Bay zone (PB)

Phoenix Bay jetty is one of the important jetties for inter-island boat services. This Bay also receives large amount of anthropogenic wastes and sewage discharges.

Station 6-Aberdeen Bay zone (AB)

This zone is very broad and the average depth ranges between 10 and 20 m. Aberdeen Bay jetty is one of the important jetties for recreational boat services and receives large amount of sewerage discharges.

Station 7-Open Sea area

Open sea area is the mouth region for Port Blair Bay between the mouth of North Bay and Ross Island. This is the entry point for all ships coming into the Port Blair Bay.

Phytoplankton Sampling and Observations

Sampling was carried out during the four quarters of 2006. The sampling for first quarter representing the months of dry season (January-March) was done in February. The sampling for second quarter representing the summer season (April-June) was done in May. Sampling for third quarter representing the monsoon/rainy season (July-September) was done in August. For the fourth quarter representing the North east monsoon season (October-December) sampling was done in November. For enumerating phytoplankton cell count and taxonomy 5 liter water samples were collected from surface during low tide and high tide. The samples were fixed immediately in few drops of lugols iodine and preserved in 4% buffered formaldehyde and stored in a dark and cool place until analysis. Phytoplankton composition was determined using the sedimentation method by Utermöhl, (Utermöhl, 1958) and expressed as cells per liter. Phytoplankton cells were identified and counted using Nikon phase contrast microscope (Model Axioskop, Nikon Corporation, Japan) at 400x magnification. Phytoplankton identification was done using standard taxonomic keys (Venkatraman, 1939; Cupp, 1943; Subrahmanyam, 1946 and Tomas, 1997).

The diversity indices were calculated using the following formulae

1. Shannon -Weaver diversity index (Shannon - weaver, 1963)

$$H = -\sum_{i=1}^S p_i \ln(p_i)$$

2. Margalef diversity index d (Margalef, 1967) = $(S - 1)/\log_e N$
3. Simpson diversity index d' (Simpson 1949) = $1 - \sum (n_i/N)^2$
4. Dominance index (Y) (Sun *et al.*, 2004) = $(n_i/N) \times f_i$
5. Pielou evenness index (J) (Pielou, 1966) = $H / \log_2 S$

In the above formulae, H = diversity, $P_i = n_i/N$, where n_i is the number of individuals of species (I), N is the total number of individuals in the sample, S is the total no. of species and f_i is the individual frequency in the samples.

RESULTS

Phytoplankton species composition in Port Blair Bay

In 2006, during the four quarters a total of 170 species of phytoplankton were identified in the Port Blair Bay. Three major groups of phytoplankton were distinguished (Fig. 2).

Bacillariophyta (Diatoms), Pyrrophyta (Dinoflagellates) and Cyanophyta. Of these three major groups diatoms formed the largest community both in terms of abundance and species richness (49 genera and 129 taxa) accounting for 75.88 per cent of the overall species diversity. In the case of diatoms, the centric diatom species (66.67 per cent) outnumbered the pennate diatom species (33.33 per cent). Dinoflagellates were the second most abundant group with 11 genera and 40 taxa, constituting 23.53 per cent of the total community. Cyanophyta was the least abundant species with 1 genus and 1 species, contributing 0.59 per cent to the total phytoplankton community of Port Blair Bay. *Rhizosolenia* and *Chaetoceros* were the genus that contributed more number of species to Bacillariophyta (Diatoms). *Prorocentrum* and *Peridinium* were the most diversified genus of Pyrrophyta (Dinoflagellates). The dominant Bacillariophyta (Diatoms) encountered in Port Blair Bay are *Chaetoceros lorenzianus* Grunow, *Rhizosolenia alata* forma *gracillima* (Cleve) Gran, *Rhizosolenia imbricata* (Brightwell), *Chaetoceros curvisetus* (Cleve), *Nitzschia longissima* (Brébisson in Kützing) Ralfs, *Thalassiothrix longissima* Cleve & Grunow). The dominant Pyrrophyta (Dinoflagellates) observed in Port Blair Bay are *Noctiluca scintillans* (Mccartney), and *Certium tripos*.

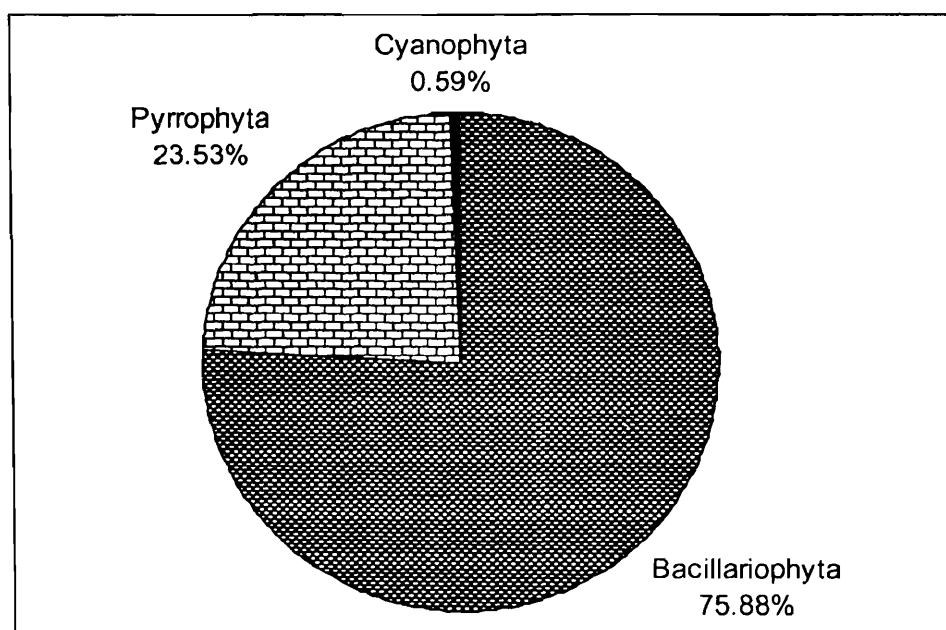


Fig. 2. Percentage contribution of different phylum of phytoplankton to species number in Port Blair Bay, Andaman Sea

Seasonal variation and spatial distribution of phytoplankton abundance

Fig. 3 portrays the phytoplankton cell density in different sampling stations during different seasons of the year. The cell density of phytoplankton varied from 0.805×10^3 cells/mL in rainy season to 32.645×10^3 cells/mL in summer. The spatial distribution of the phytoplankton density showed a definite trend. Generally the offshore open sea station had the lowest phytoplankton density when compared to near shore stations during all seasons. A single annual peak was observed during second quarter (summer).

During the dry season highest (5.950×10^3 cells/mL) phytoplankton density was found in the Haddo Harbour station of Port Blair Bay and the lowest was observed in Open sea station (2.415×10^3 cells/mL). During summer season highest (32.645×10^3 cells/mL) phytoplankton density was encountered in the Phoenix Bay station of Port Blair Bay and the lowest was found in Open sea station (8.405×10^3 cells/mL). Similarly during the rainy season

Phoenix Bay station of Port Blair Bay recorded the highest (2.58×10^3 cells/mL) phytoplankton cell density and open sea station recorded the lowest phytoplankton density (0.805×10^3 cells/mL). During North East monsoon season the highest (2.58×10^3 cells/mL) phytoplankton density was observed in Haddo Harbour station and the lowest (1.360×10^3 cells/mL) was observed in open sea station.

Dominant species

In 2006, the composition of dominant species in Port Blair Bay varied with season. Diatoms were the most dominant species. There was succession of species in different season; however some species like *Chaetoceros lorenzianus* existed through out the year. During I quarter, dry season the temperature was 28.65°C to 31.19°C , the fresh water runoff and rainfall inputs were minimal and dominant species during this season were *Chaetoceros lorenzianus* and *Rhizosolenia formosa* (Table 2). These two species contributed 45.14 per cent of the total phytoplankton abundance during this season.

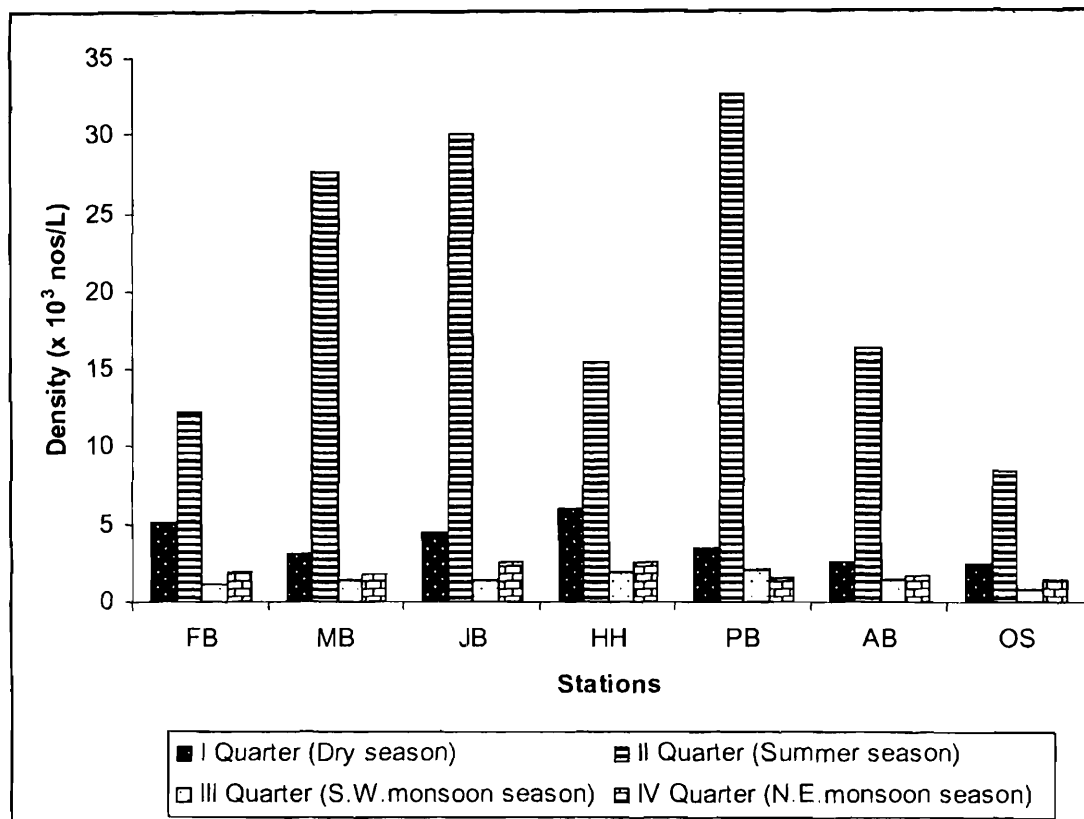


Fig. 3. Phytoplankton abundance in different sampling stations of Port Blair Bay

Table 2. Dominant species of phytoplankton in Port Blair Bay in 2006

Season	Dominant species	Total abundance (in %)	Dominant (Y)
I	<i>Chaetoceros lorenzianus</i> Grunow, 1863	28.818	0.288
	<i>Rhizosolenia formosa</i> H. Peragallo, 1890	16.326	0.128
	<i>Guinardia striata</i> (Stoleforth) Hasle, 1997	08.404	0.084
	<i>Rhizosolenia imbricata</i> Brightwell, 1856	06.636	0.066
	<i>Dactyliosolen tenuis</i> Cleve, 1886	06.176	0.044
II	<i>Chaetoceros lorenzianus</i> Grunow, 1863	34.980	0.300
	<i>Chaetoceros curvisetus</i> Cleve, 1889	19.606	0.128
	<i>Chaetoceros wighami</i> Brightwell, 1856	15.610	0.123
	<i>Skeletonema costatum</i> Cleve, 1873	13.072	0.131
	<i>Chaetoceros didymus</i> Ehrenberg, 1845	01.588	0.011
III	<i>Nitzschia longissima</i> (Brissson) Ralfs	12.610	0.126
	<i>Pleurosigma galapagense</i> Cleve	10.390	0.096
	<i>Chaetoceros lorenzianus</i> Grunow, 1863	06.330	0.050
	<i>Pleurosigma normanii</i> Ralfs, 1880	04.302	0.030
	<i>Leptocylindrus danicus</i> Cleve 1889	04.204	0.042
IV	<i>Rhizosolenia alata</i> Brightwell, 1858	12.892	0.129
	<i>Navicula septentrionalis</i> (Grunow) Gran, 1905	10.737	0.092
	<i>Rhizosolenia imbricata</i> Brightwell, 1856	10.473	0.097
	<i>Nitzschia seriata</i> P.T. Cleve, 1883	04.197	0.039
	<i>Fragilaria cylindrus</i> Grunow, 1882	03.894	0.033

During II quarter, summer bloom forming species like *Chaetoceros lorenzianus*, *Chaetoceros curvisetus*, *Chaetoceros wighami*, *Skeletonema costatum* were dominant. These four species contributed 83.27 per cent of the total phytoplankton abundance in Port Blair Bay during this season. This season was characterized by the abundance of few species. The temperature in summer was higher than in other seasons and ranged from 30.23°C to 30.90°C. In contrast, salinity during this period was lower and ranged from 32.53 to 34.99 psu. Thus environmental factors played a significant role in determining the dominant ecotypes and favouring the growth of species that exhibited tolerance to high temperature and lower salinity.

During the III quarter, rainy season (The total rainfall for Port Blair in August 2006 was 314 mm, Meteorological statistics, 2006), the

distribution of phytoplankton was closely related to the monsoon. The Southwest monsoon prevailed during this season and there was frequent occurrence of cyclones. The species like *Nitzschia longissima*, *Pleurosigma galapagense* were the dominant species during rainy season (Table 2). This season was characterized by the absence of few dominant species.

During the IV quarter, North east monsoon season the north east monsoon replaced the south west monsoon and there were frequent cyclones. The water temperature ranged from 29.70°C to 30.32°C. Salinity ranged from 31.77 to 33.07 psu and rainfall during this season rainfall was 79 mm. There was lack of single species domination. *Rhizosolenia alata*, *Navicula septentrionalis* and *Rhizosolenia imbricata* were the dominant species during this season.

Species diversity and evenness

Fig. 4 shows the values of three diversity indices *viz* Shannon-Weaver (H), Margalef (d) and Simpson (d') during different seasons of the year 2006 in the sampling stations of Port Blair Bay. Shannon weaver diversity index ranged from 1.65 in II quarter (summer) to 3.00 in IV quarter (winter). Margalef diversity index ranged from 2.22 in II quarter (summer) to 5.17 in IV quarter (North east monsoon). Simpson diversity index ranged from 0.69 in II quarter (summer) to 0.95 in IV quarter (North east monsoon). The highest values of the three diversity indices were observed in IV quarter North east monsoon in all the stations except the open sea station. In the Open Sea the highest value for Margalef and Simpson indices were observed in III quarter (Rainy season). Regardless of the stations the lowest value for all the three diversity indices was observed in summer (Fig. 4). During summer conditions of high temperature, high light intensity, heavy rainfall (The total rainfall for the month of May,

2006 for Port Blair was 403.8 mm, Meteorological statistics, 2006) favoured the growth of few species which are capable of tolerating these unfavourable conditions. These few species accounted for nearly 83.17 per cent of the total abundance during summer (Table 2). Hence, all the three diversity indices showed lowest value during summer. In the I quarter the highest value for all the three indices were observed in the Minnie Bay station but the lowest value for Shannon-Weaver and Simpson diversity index were observed in Haddo Harbour station and lowest Margalef diversity index was observed in Open Sea station. During the III quarter (rainy season) highest value for Shannon-Weaver and Simpson diversity index were observed in Haddo Harbour station and highest Margalef diversity index was observed in Open sea station. During the IV quarter highest Shannon Weaver and Simpson diversity index were observed in Minnie Bay station and the lowest was observed in Open Sea station. In the same period the highest values for

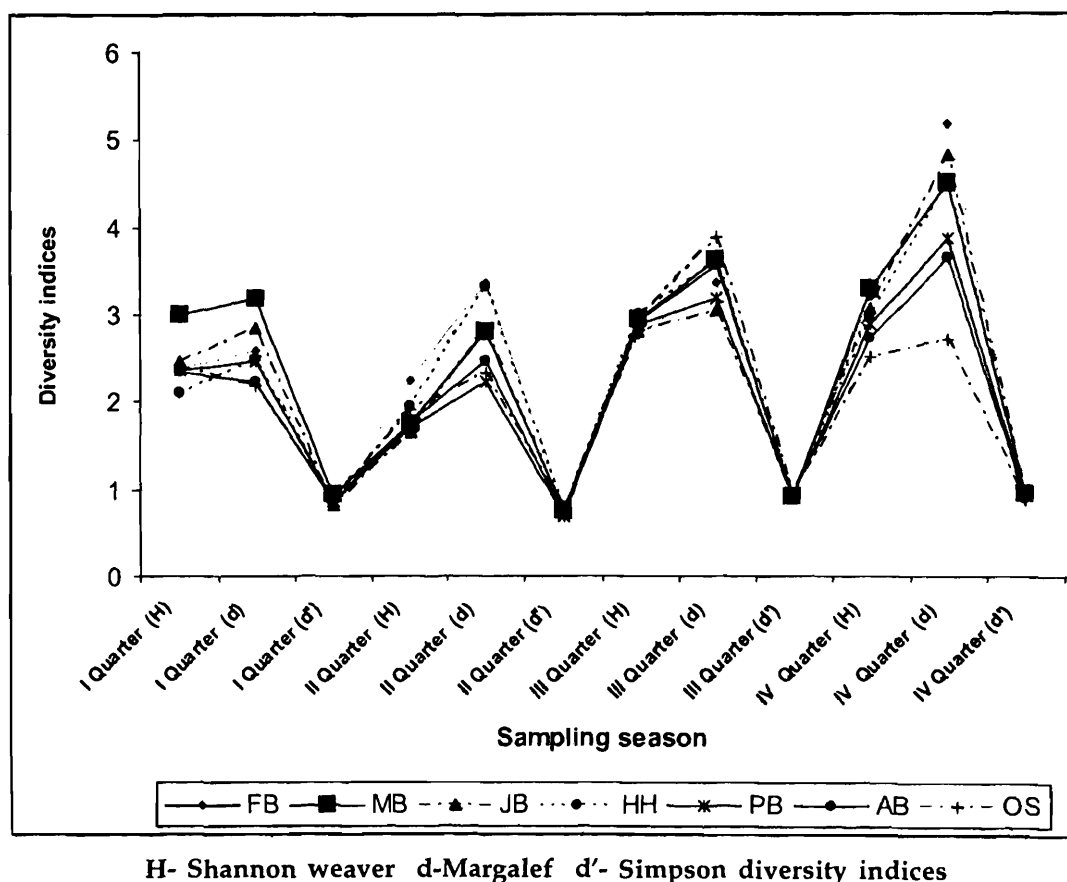


Fig. 4. Shannon-weaver, Margalef, Simpson diversity indices for the sampling stations of Port Blair Bay in different seasons

Margalef diversity index was observed in Flat Bay station and lowest was observed in Open Sea station.

Fig. 5 shows the evenness of Phytoplankton in Port Blair Bay in different sampling stations. The evenness index (J) ranged from 0.47 in II quarter (summer) to 0.93 in IV quarter (North East monsoon). In general the evenness index was low in summer when compared to other seasons. In I quarter highest value for evenness index was observed in Minnie Bay station and lowest was observed in Minnie Bay station and lowest was observed in Haddo Harbour station. During the II quarter the highest evenness index was observed in Flat Bay station and lowest was observed in Junghlighat station. During the III quarter Open sea station showed the highest evenness index and the lowest was observed in Flat Bay station. During the IV quarter Minnie Bay station had the highest evenness index and Open Sea station the lowest.

DISCUSSION

Relationship between phytoplankton species composition in Port Blair Bay and environmental factors

Diatoms formed the largest community both in terms of abundance and species richness (49

genera and 129 taxa) accounting for 75.88 per cent of the overall species diversity. Different phytoplankton groups have different requirements for dissolved nutrients such as nitrate, phosphate and silicate (Eppley *et al.*, 1969 and Guillard *et al.*, 1973). These varying nutrient requirements play a significant role in shaping the local phytoplankton community structure of different regions (Tilman, 1986). The dominance of diatom in Port Blair may be related to the concentration of silicate. Egge and Aksnes (1992) have found that in experiments diatoms were dominant irrespective of season if the silicate concentration exceeded approximately $2\mu\text{M}$. Concentrations of silicate in Port Blair Bay exceeded this value in major part of the year 2006 (Magesh *et al.*, unpublished). Burford *et al.* (1995) have reported diatoms as the dominant group in Albatross Bay, Australia. Similarly San Cuici *et al.* (2006) have also reported diatoms as the dominant group contributing 84 taxa to the phytoplankton community of Daya Bay, China. Furthermore diatoms have often been shown to be associated with high nutrient concentration typically associated with rain runoff (Tilman *et al.*, 1986). Hence it is not surprising diatoms are the dominant group in Port Blair Bay which received 3004.2mm rainfall in 146 days

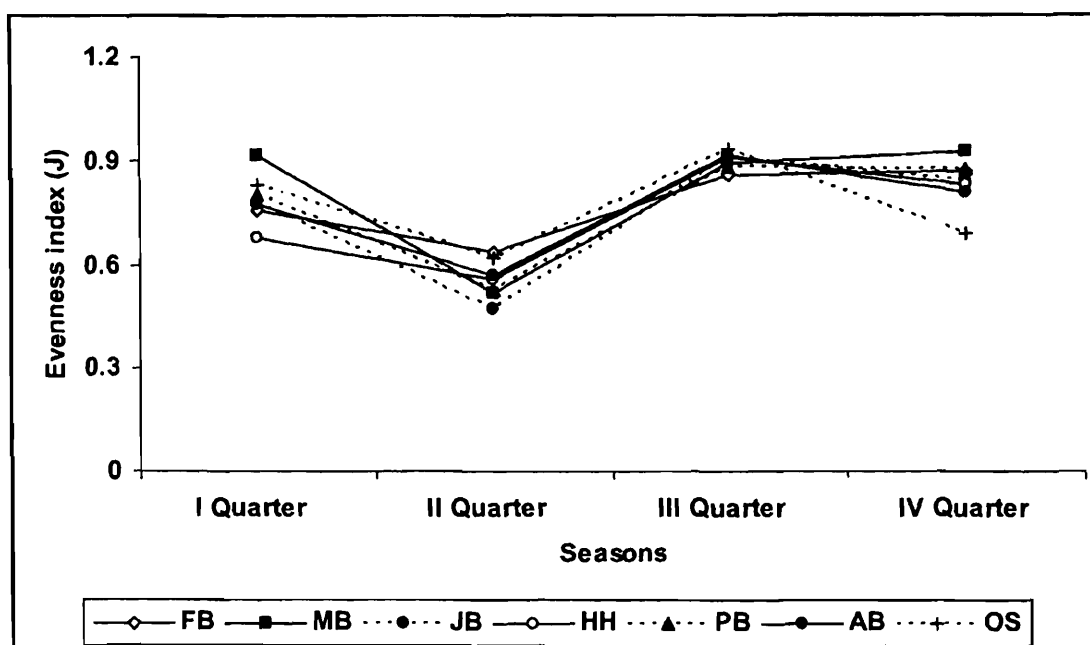


Fig. 5. Evenness index of Phytoplankton in Port Blair Bay

(Metrological statistics, 2006, IMD) of 2006. Several authors have speculated several reasons for the competitive superiority of diatoms. Furnas, 1990 reported a maximum in situ doubling rate of 2 and $4d^{-1}$ for diatoms and has postulated growth potential as the main reason for its dominance in costal waters. Thomas *et al.*, 1978 have hypothesized diatoms better ability to utilize low nitrogenous nutrient level as a reason for its success i.e. diatoms have a lower half saturation values (ks) for nitrate and ammonium uptake. The higher photosynthetic capacity observed in diatoms due to higher chlorophyll content is also believed to be responsible for the higher inherent growth rate observed in diatoms (Langdon, 1988)

Diatoms are one of the most prominent phytoplankton species with respect to abundance and photosynthetic capabilities within coastal waters and provide about twenty five percent of global net productivity (Lalli *et al.*, 1997). Hence it is not surprising that Port Blair Bay with a favourable temperature, salinity and nutrient concentration has diatoms as the dominant phytoplankton group. Growth rates of diatoms are very high, and can increase in abundance by several orders of magnitude under favorable conditions (Rynewson, 2003). Consequently, diatom blooms often compose more than ninety percent of phytoplankton biomass during blooms (Rynewson, 2003). Similarly in the present study during summer (II quarter) when phytoplankton peak was observed bloom forming Diatom species like *Chaetoceros lorenzianus*, *Chaetoceros curvisetus*, *Chaetoceros wighami* and *Skeletonema* contributed 83.27 per cent of the total phytoplankton.

Relationship between spatial distribution of phytoplankton abundance and environmental factors

The Port Blair Bay is situated in the eastern side of the South Andaman Island and has a climate characterized by wet and dry seasons. The yearly cycle of North East and South West Monsoon wind systems bring enormous amount of rainfall to this region. Hence, the phytoplankton community structure,

abundance and spatial distribution in Port Blair Bay were related to seasonal changes in precipitation and terrestrial input. It has been shown by several researchers that distributions of nutrients, development of dense blooms and phytoplankton community succession respond to seasonal fluctuations in freshwater discharges (Jordan *et al.*, 1991 and Harding, 1994). But the conversion efficiency of introduced nutrients into biomass and the structuring effect on phytoplankton communities depends on timing and ratios of supplied nutrients (Gallegos, 1992). For instance in the second quarter (summer) with a rainfall of 403.8 mm resulted in the phytoplankton abundance upto 32.645×10^3 cells/mL whereas a rainfall of 314 mm during the third quarter did not translate into high phytoplankton abundance. Regardless of the season density of phytoplankton was lowest in the offshore open sea station. Similar observation was made by San Cuici *et al.* (2006) in the Daya Bay, China.

Species Diversity

The different species diversity indices are considered as suitable indicators for water quality (Gharib and Dorgham, 2006). These indices have a direct relation with the degree of dominance, species richness and total standing crop (Gharib and Dorgham, 2006). Many researchers have found negative correlation between diversity and phytoplankton abundance (Sebastian *et al.*, 2001). Our own data offers further support to this generality. All the stations had the lowest value for all the three diversity indices during summer when the phytoplankton abundance was the maximum. Wetzel (1983) has reported lower diversity index values for eutrophic lakes when compared to oligotrophic lakes. Similarly the evenness index was also low during summer when compared to other seasons when bloom forming species like *Chaetoceros lorenzianus*, *Chaetoceros curvisetus*, *Chaetoceros wighami*, *Skeletonema costatum* were dominant (up to 83.27 per cent). Similar low species richness were reported by Macedo *et al.*, 2001 in Santo And e lagoon due to frequent overwhelming dominance of *Procentrum*

minimum (upto > 90 per cent cell count). Huston, 1979, 1994 has reported that species richness is maximized in Caribbean phytoplankton under intermediate conditions of disturbance and primary production. On one hand, low production reduces recovery from mortality and may therefore reduce species diversity. On the other hand, higher production may lead to lower diversity through competitive exclusion.

CONCLUSION

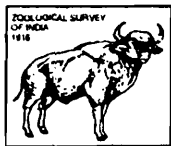
The species diversity in Port Blair Bay was high except during summer when few bloom forming species dominated the phytoplankton community. The spatial distribution of density and community structure of Port Blair Bay was influenced by the forces of monsoon, current, geographical characteristics and human activities.

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DISTRIBUTION AND BIODIVERSITY OF PHYTOPLANKTON IN THE COASTAL SEAWATERS OF ANDAMAN AND NICOBAR ISLANDS, INDIA

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INTRODUCTION

Andaman and Nicobar Islands (A & N) are typical tropical ecosystem, comprise of 572 islands, lying between 6°45' N and 13°45' N latitude and 92°12' E and 93°57' E longitude, spread over a distance of 1120 km with the coast line of about 1962 km. A & N Islands are situated on a Burma microplate in the junction of Indian plate, Sunda plate and Australian plate. The islands are situated on mountain tops which rose from the bottom of the sea from around 2000 meters depth. Hence the continental shelf is steep and very limited. There are numerous creeks and bays bordered with mangroves, coral reefs and rocks and sandy beaches. The influence of oceanic seawater is much pronounced close to the shore. The climate of these islands is typically tropical, with heavy gales, cyclones, and hot and humid conditions. The annual temperature ranges from 18°C to 36°C, with slight increase from Northern Andaman group of islands to Southern Nicobar group of islands. The relative

humidity of ambient atmosphere reaches about 80 per cent. The A & N Islands are covered with clouds during most of the months and rainfall is heavy with an average of about 3100 mm/y, which prolongs from May to December. Major rainfall occurs during late May to early October (southwest monsoon), while a weak spell of northeast monsoon brings rain during November to December. Since most of the islands are covered with dense tropical forests, the coastal waters are much influenced by the heavy rainwater released into the coastal areas. The coastal waters of A & N Islands are comparatively pristine since the seas around the islands are deep with clear water.

The biodiversity of these islands are documented in various studies (Ali and Uppal, 2002). There are scant reports available about the phytoplankton distribution and diversity of Andaman Sea but hydrographic features in western and eastern margins of Andaman and Nicobar Islands are characterized (Sen Gupta *et al.*, 1981). The extent of these variations in

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the Northern Andaman to the Southern Nicobar groups of Islands is not known. The climatic conditions between North and South Islands vary considerably and influence the planktonic diversity and distribution of nearshore and offshore waters. The physical oceanographic characteristics prevailing in Andaman Sea were observed and reported by Varkey *et al.*, 1996. The phytoplankton samples were collected from 8 stations based on the geographical nature, which includes 5 stations from Andaman Islands and 3 stations from Nicobar Islands during the months between January and March 2004. The Phytoplankton species diversity and abundance in region of Andaman Sea has been studied by Devassy and Bhattathiri, (1981); Sarojini and Sarma, (2001); Paul, *et al.*, (2007). This article deals with the species composition, density, distribution and the variations between the Andaman group of Islands and Nicobar group of Islands along with a comparison of phytoplankton distribution between the waters of Bay of Bengal and Andaman Sea.

MATERIALS AND METHODS

The phytoplankton samples were collected during June to March 2004 from Aerial Bay (Lat. 13°16'301"N and Long. 93°04'287"E), Mayabunder (Lat. 12°55'593" and Long. 92°53'692"), Rangat (Lat. 12°29'335" and Long. 92°57'281"), Havelock (Lat. 12°03'438" and Long. 92°56'931"), Hut Bay (Lat. 10°35'385" and Long. 92°33'532"), Kamorta (Lat. 08°02'081" and Long. 93°32'108"), Katchal (Lat. 07°58'536" and Long. 93°24'226") and Campbell Bay (Lat. 07°00'000" and Long. 93°55'931") (Fig. 1). Phytoplankton samples were collected from the nearshore (NS) and offshore (OS) areas of the sampling stations using the mechanized boats. The average distance between nearshore and offshore among eight stations were approximately 2 km. The GPS locations of the each station were marked using a hand held GPS (Garmin *eTrex*).

Phytoplankton analysis was carried out by following Utermohl's (1931) sedimentation technique. For this 5 liters of subsurface

seawater samples were collected using Niskin's water sampler and transferred to polyethylene container and preserved with 4 per cent formalin and Lugol's iodine. The 5 liters samples were allowed for settlement of phytoplankton in a measuring cylinder for a period of 24 hrs. The settled phytoplanktons were used for enumeration. The total volume of 5 liters of samples reduced to 5 mL and the subsample of 100 µl was taken in a glass slide with cover slip for identification and counting. The samples were observed under Nikon Eclipse E600 Optiphort microscope at 20 × for counting and 40 × for identification. The phytoplankton was identified up to species level and enumerated using keys (Venkataraman, 1939; Cupp, 1943; Subrahmanyam, 1946; Desikachary, 1986; Santhanam, 1998). Species diversity of phytoplankton was calculated using the Shannon-Wiener (Shannon, 1948) diversity index "H" along with species evenness by Pielou's (Pielou, 1966) evenness index "J"

RESULTS

The samples of eight stations revealed that the phytoplankton species were belonging to Families namely Coscinodisceae, Soleniae, Chaetocerae, Biddulphiae, Fragilarioideae, Naviculoideae and Peridiniaceae. The phytoplankton density of all stations were ranged from 4990 to 12800 Nos./L with an average of 6806.25 ± 2890.8 Nos./L in the nearshore waters, whereas in the offshore waters it ranged between 4000 and 10400 Nos./L with an average of 5937 ± 2746.4 Nos./L. The maximum phytoplankton densities 12800 and 10400 Nos./L were observed from the nearshore and offshore waters of Katchal Island respectively. Whereas, minimum density of 4990 and 4000 Nos./L was recorded from the nearshore and offshore waters of Havelock Island respectively. Species composition of Katchal Island was found to be maximum in relation to its high phytoplankton density. There were 39 species recorded from the nearshore waters and 38 species from the offshore waters of Katchal. The phytoplankton species diversity was found minimum in the

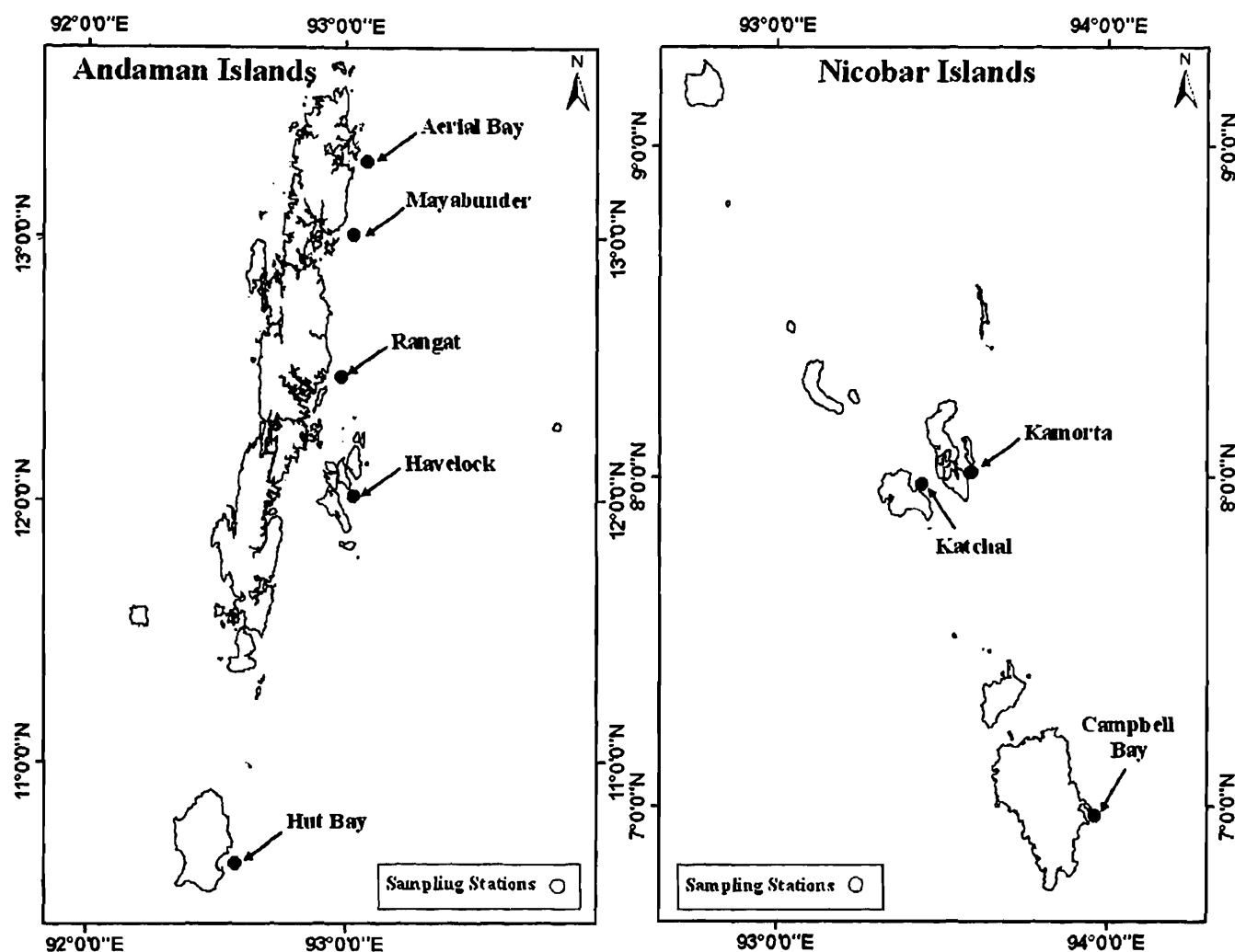


Fig. 1. Locations of the study area in A & N Islands

offshore waters of Hut Bay with 24 species. The diatoms were found to be the major group in this area. In Aerial Bay nearshore waters *Thalassionema nitzschioides* and *Thalassiothrix longissima* were dominating species composition with 350 Nos./L (6.48 per cent) and 300 Nos./L (5.56 per cent) respectively [$H=3.48(NS)$, $3.40(OS)$; $J=0.96(NS)$, $0.96(OS)$]. The total number of species in this area was 37. The total number of species found at offshore was 34 with *Thalassionema nitzschioides* with 250 Nos./L (6.02 per cent) and *Leptocylindrus danicus* with 200 Nos./L (40.82 per cent) were found dominating the phytoplankton diversity.

At Mayabunder Bay nearshore waters the dominating species were *Chaetoceros lorenzianus* with 390 Nos./L (7.59 per cent) and *Chaetoceros peruvianus* with 300 Nos./L (5.84 per cent). Total number of species recorded was 31. At offshore the dominating species were *Thalassiothrix*

longissima with 390 Nos./L (7.99 per cent) and *Bacteriastrum delicatum* with 400 Nos./L (8.20 per cent). The species composition was 34 in this area [$H=3.32(NS)$, $3.32(OS)$; $J=0.97(NS)$, $0.94(OS)$]. The phytoplankton population in the Rangat Bay nearshore waters found to be dominated by *Leptocylindrus minimus* with 390 Nos./L (6.98 per cent) and *Dactyliosolen phuketensis* with 200 Nos./L (3.58 per cent) with a total of 37 species. The offshore waters had dominated growth of *Bacteriastrum delicatum* with 400 Nos./L (9.09 per cent) and *Rhizosolenia imbricatum* with 200 Nos./L (4.55 per cent) with total number of 36 species [$H=3.53(NS)$, $3.45(OS)$; $J=0.98(NS)$, $0.96(OS)$]. *Thalassionema nitzschioides* and *Chaetoceros peruvianus* were dominating species in the nearshore waters of Havelock with 390 Nos./L (7.82 per cent) and 350 Nos./L (7.01 per cent) respectively. The total number of species at the area was 32.

Whereas, the dominating species at offshore waters were *Bacteriastrum delicatum* with 250 Nos./L (6.25 per cent) and *Navicula longissima* with 300 Nos./L (7.50 per cent) with the total of 36 species [$H=3.33(NS)$, 3.41(OS); $J=0.96(NS)$, 0.95(OS)].

The nearshore waters of Hut Bay showed that *Thalassiothrix longissima* was dominant species with 800 Nos./L (8.18 per cent) and *Ceratium furca* with 800 Nos./L (8.18 per cent) among the total of 30 species. However, in offshore waters *Leptocylindrus danicus* and *Rhizosolenia setigera* were dominating each with 800 Nos./L (7.78 per cent). The total number of species recorded was 24 [$H=3.22(NS)$, 3.03(OS); $J=0.95(NS)$, 0.95(OS)]. The nearshore waters of Kamorta *Bacteriastrum varians* with 300 Nos./L (5.36 per cent) and *Navicula longissima* with 300 Nos./L (5.36 per cent) were dominating among the total number of 37 species. Whereas, in the offshore waters of Kamorta *Rhizosolenia imbricatum* with 300 Nos./L (5.77 per cent) and *Coscinodiscus eccentricus* with 300 Nos./L (5.77 per cent) were dominating among the total number of 38 species [$H=3.52(NS)$, 3.48(OS); $J=0.96(NS)$, 0.96(OS)]. In the nearshore waters of Katchal *Rhizosolenia setigera* and *Pleurosigma normanii* with the same density of (800 Nos./L) and percentage composition of (6.25 per cent)

were dominating among total of 39 species. Whereas, in the offshore waters *Rhizosolenia imbricatum* with 600 Nos./L (5.77 per cent) and *Coscinodiscus eccentricus* with 600 Nos./L (5.77 per cent) were dominating among the total of 38 species [$H=3.50(NS)$, 3.48(OS); $J=0.97(NS)$, 0.96(OS)]. In the nearshore waters of Campbell Bay *Thalassiothrix longissima* and *Rhizosolenia styliiformis* with same density and species composition of 300 Nos./L (5.83 per cent) were dominating. In the offshore waters of Campbell Bay *Thalassiothrix longissima* with 390 Nos./L (9.31 per cent) and *Thalassionema javanicum* were dominated with 300 Nos./L (7.16 per cent). The total number of species at nearshore water was 33 and offshore water was 28 [$H=3.37(NS)$, 3.16(OS); $J=0.96(NS)$, 0.95(OS)].

DISCUSSION

Density of the phytoplankton from North to South showed consistency from Aerial Bay till Havelock with a sudden increase in Hut Bay and Katchal with Kamorta in between giving the low density result (Table 1, Figs. 2 and 3). Density and diversity of the phytoplankton in the present study being observed in the surface water which is often regarded as well illuminated and well mixed in terms of light and nutrient availability. The

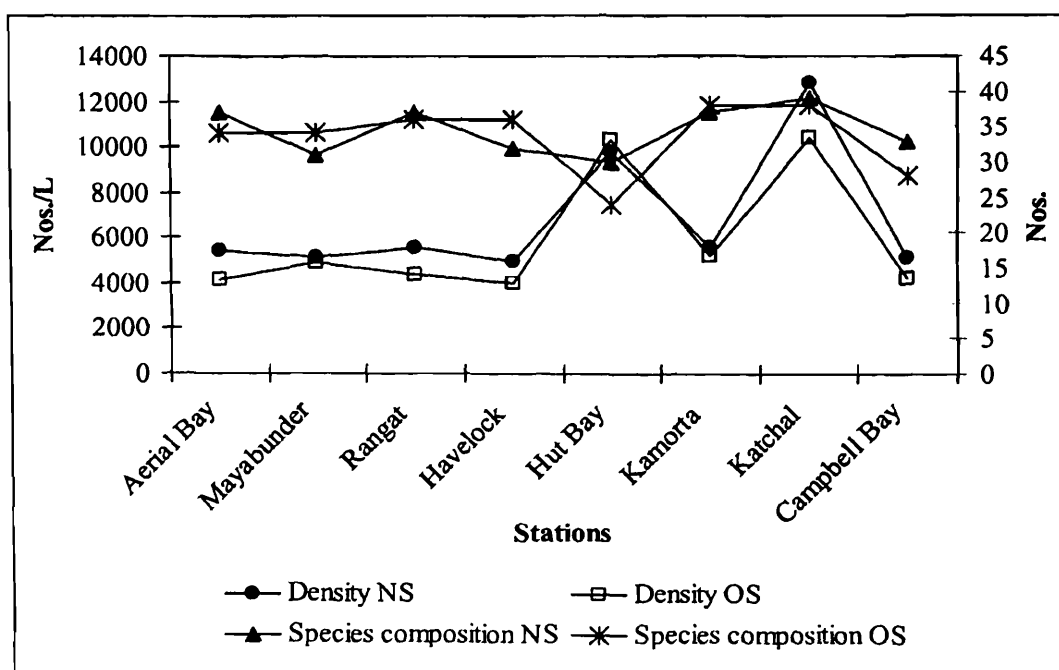


Fig. 2. Phytoplankton density (Nos./L) and total number of species (Nos.) in nearshore (NS) and offshore (OS) coastal waters of A&N Islands

Shannon diversity index $H' > 3$ and Evenness $J' > 0.94$ (Fig. 5) indicated high species diversity and evenness in the study area. The distribution of phytoplankton in the illuminated zone has been well studied by Gran and Braarud (1935). Campbell Bay showed decrease in total number of phytoplankton cells. The density in Hut Bay was higher but the species composition was lowest when compared with other stations. The nearshore area was dominated by dinoflagellate species such as *Ceratium furca*. Hut Bay was the only place where the dinoflagellates were found to be dominating. The dinoflagellate as the major primary producers under assessment of phytoplankton population of the Hut Bay (little Andaman) has been significantly noted by Devassy and Bhattathiri (1981). The species composition from North to South was almost consistent (Table 1, Fig. 2 and 4) with slightly lowest number of species were recorded from the Hut Bay offshore waters. The two families namely Solenidae and Chaetocerae appeared dominating in almost every station and followed by Fragilarioideae and Naviculoideae (Table 1, Fig. 3). The diatoms were abundant than dinoflagellates. Similar condition was reported in Bay of Bengal where diatoms accounted for more than 95 per cent of phytoplankton population (Shenoy *et al.*, 2006).

The dominating pattern of diatoms has been observed in the nearshore and offshore waters of Katchal Island with highest phytoplankton density as well as diversity. The growth of diatoms depends on the availability of silicate in water (Egge and Aksnes, 1992). The species dominating the nearshore waters of Katchal Island was *Pleurosigma normanii* and offshore water was *Bacteriastrum hyalinum*. The fertility of seawater can be related to the condition of diatoms dominating the phytoplankton composition in nutrient rich water and dinoflagellate in nutrient deficient oceanic water (Quasim and Kureishy, 1986).

A total of 44 species of phytoplankton were recorded from the surface waters of A&N Islands. The average phytoplankton density of the study area in nearshore and offshore water were 6806.25 and 5937.5 Nos./L respectively which is considered to be quite productive for the region. The difference in the phytoplankton densities of nearshore and offshore water was minimal. The whole region of the Katchal waters appeared to be productive that could be helpful to predict high fishery resource in the region. Throughout the period of study harmful dinoflagellates were not encountered. It is known that A & N Island's water masses

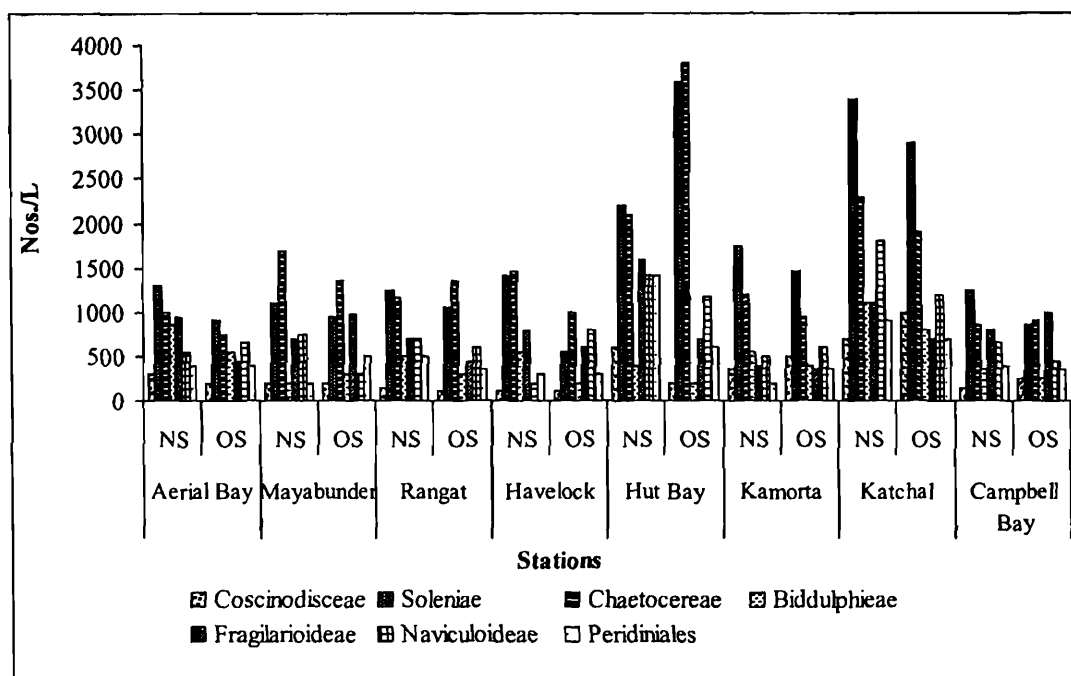


Fig. 3. Family wise phytoplankton density (Nos./L) in nearshore (NS) and offshore (OS) coastal waters of A&N Islands

have similar characteristic to depth of 1300 m (Sen Gupta *et al.*, 1981). At particular season, the availability of nutrients and sufficient light leads to even distribution of phytoplankton. This is well supported by the fact that rapid mixing of water due to various internal waves generated from tidal currents flowing through rough topography (Koushik *et al.*, 2007). Vertical mixing is very important in terms of

nutrient availability at the surface to have primary productivity. Fair degree of diversity of phytoplankton species in almost all the stations shows the strength of marine ecosystem in the water as experimented and reported by Tilman, 1999. Nearshore and offshore waters of Katchal and Hut Bay appeared as the phytoplankton rich stations in terms of density, where the dominating species were pinnate

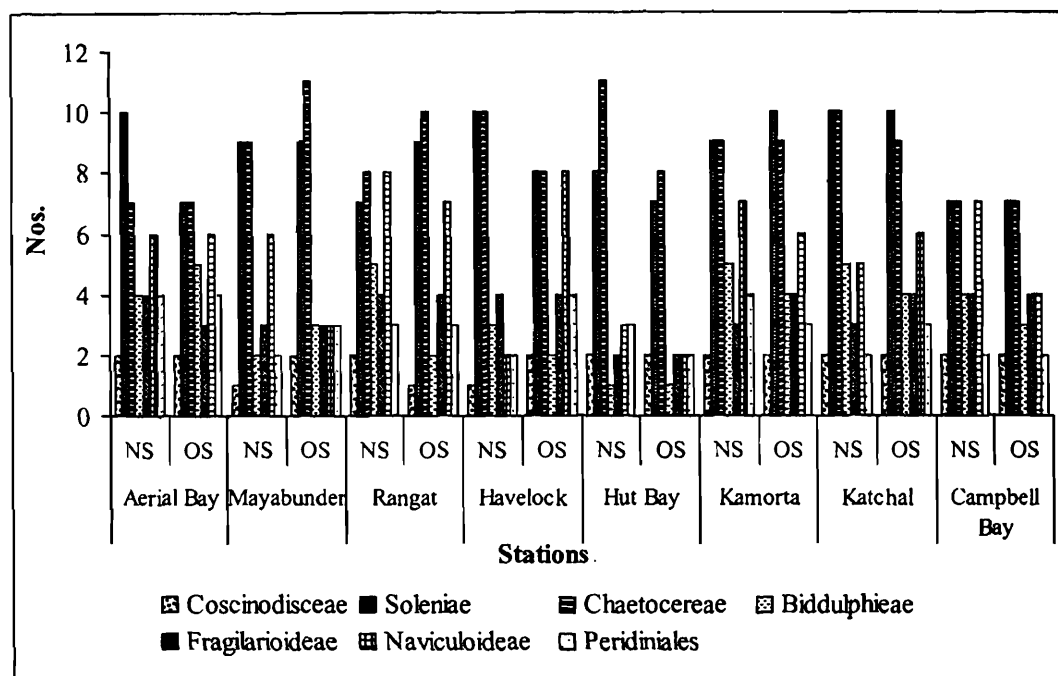


Fig. 4. Family wise phytoplankton total number of species (Nos.) in nearshore (NS) and offshore (OS) coastal waters of A&N Islands

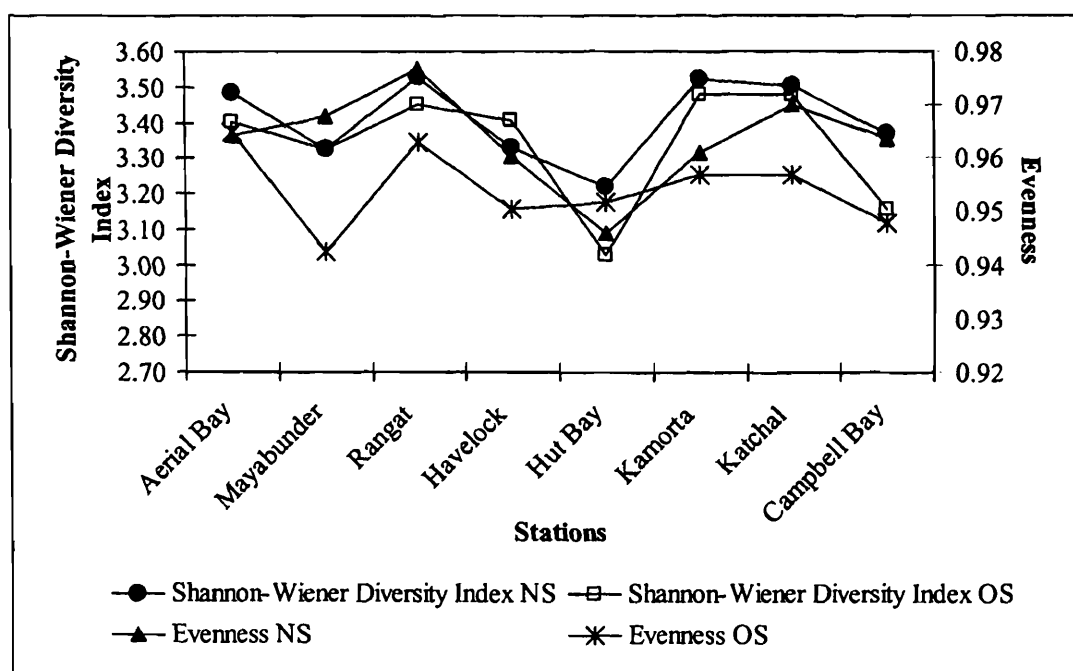


Fig. 5. Shannon-Wiener diversity (H) and Evenness (J) in nearshore (NS) and offshore (OS) coastal waters of A&N Islands

Table 1. Phytoplankton population density (Nos./L) and percentage composition (in parenthesis) in the nearshore (NS) and offshore (OS) coastal waters of A&N Islands

Name of the Family/species	Aerial Bay		Mayabunder		Rangat		Havelock		Hut Bay		Katchal		Kamorta		Campbell Bay	
	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS
Coscinodisceae																
<i>Coscinodiscus eccentricus</i>	200 (3.70)	150 (3.61)	200 (3.89)	100 (2.05)	50 (0.89)	100 (2.27)	100 (2.00)	50 (1.25)	200 (2.04)	100 (0.97)	400 (3.13)	600 (5.77)	250 (4.46)	300 (5.77)	100 (1.94)	200 (4.77)
<i>Skeletonema costatum</i>	100 (1.85)	50 (1.20)		100 (2.05)	100 (1.79)			50 (1.25)	400 (4.09)	100 (0.97)	300 (2.34)	400 (3.85)	100 (1.79)	200 (3.85)	50 (0.97)	50 (1.19)
Soleniae																
<i>Leptocylindrus danicus</i>	50 (0.93)	200 (4.82)	100 (1.95)	50 (1.02)		50 (1.14)	200 (4.01)	50 (1.25)	400 (4.09)	800 (7.78)		100 (0.96)	100 (1.79)	50 (0.96)	100 (1.94)	100 (2.39)
<i>Leptocylindrus mimimus</i>	100 (1.85)	50 (1.20)	200 (3.89)	100 (2.05)	390 (6.98)	100 (2.27)	100 (2.00)	50 (1.25)	200 (2.04)	600 (5.84)	600 (4.69)	100 (0.96)	200 (3.57)	50 (0.96)	200 (3.88)	
<i>Schroederella delicatula</i>	100 (1.85)	150 (3.61)	100 (1.95)	200 (4.10)	100 (1.79)	100 (2.27)	50 (1.00)	100 (2.50)	200 (2.04)		400 (3.13)	200 (1.92)	200 (3.57)	100 (1.92)	150 (2.91)	50 (1.19)
<i>Guinardia striata</i>	200 (3.70)		50 (0.97)	50 (1.02)		50 (1.14)	200 (4.01)	50 (1.25)	200 (2.04)		200 (1.56)	400 (3.85)	200 (3.57)	200 (3.85)		
<i>Dactyliosolen phuketensis</i>	200 (3.70)	100 (2.41)			200 (3.58)	100 (2.27)	100 (2.00)			400 (3.89)	100 (0.78)	500 (4.81)	100 (1.79)	250 (4.81)		
<i>Rhizosolenia imbricatum</i>	200 (3.70)	150 (3.61)	200 (3.89)	150 (3.07)	150 (2.68)	200 (4.55)	50 (1.00)	50 (1.25)	400 (4.09)		200 (1.56)	600 (5.77)	200 (3.57)	300 (5.77)	200 (3.88)	300 (7.16)
<i>Rhizosolenia setigera</i>	150 (2.78)	200 (4.82)	100 (1.95)	100 (2.05)	100 (1.79)	200 (4.55)	150 (3.01)	50 (1.25)	200 (2.04)	800 (7.78)	800 (6.25)	400 (3.85)	200 (3.57)	200 (3.85)	100 (1.94)	100 (2.39)
<i>Rhizosolenia alata</i>	50 (0.93)		200 (3.89)	50 (1.02)	100 (1.79)	100 (2.27)	200 (4.01)	100 (2.50)	400 (4.09)	400 (3.89)	400 (3.13)	200 (1.92)	200 (3.57)	100 (1.92)	200 (3.88)	100 (2.39)
<i>Rhizosolenia cochlea</i>	100 (1.85)		50 (0.97)	50 (1.02)			200 (4.01)			200 (1.95)	400 (3.13)	100 (0.96)	200 (3.57)	50 (0.96)		
<i>Rhizosolenia styliiformis</i>	150 (2.78)	50 (1.20)	100 (1.95)	200 (4.10)	200 (3.58)	150 (3.41)	150 (3.01)	100 (2.50)	200 (2.04)	400 (3.89)	300 (2.34)	300 (2.88)	150 (2.68)	150 (2.88)	300 (5.83)	200 (4.77)

Table 1. Contd.

Name of the Family/species	Aerial Bay		Mayabunder		Rangat		Havelock		Hut Bay		Katchal		Kamorta		Campbell Bay	
	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS
Chaetocereae																
<i>Chaetoceros curvisetus</i>	250 (4.63)	200 (4.82)	200 (3.89)	50 (1.02)	200 (3.58)	100 (2.27)	100 (2.00)	50 (1.25)	100 (1.02)	600 (5.84)	300 (2.34)	400 (3.85)	150 (2.68)	200 (3.85)	200 (3.88)	250 (5.97)
<i>Chaetoceros lorenzianus</i>	150 (2.78)	100 (2.41)	390 (7.59)	50 (1.02)	150 (2.68)	50 (1.14)	50 (1.00)	50 (1.25)	100 (1.02)	800 (7.78)	100 (0.78)	300 (2.88)	50 (0.89)	150 (2.88)	100 (1.94)	100 (2.39)
<i>Chaetoceros wighamii</i>	100 (1.85)		200 (3.89)	100 (2.05)	100 (1.79)	100 (2.27)	50 (1.00)	100 (2.50)	200 (2.04)	700 (6.81)		200 (1.92)	50 (0.89)	100 (1.92)	50 (0.97)	100 (2.39)
<i>Chaetoceros aequatorialis</i>		50 (1.20)	100 (1.95)	100 (2.05)	200 (3.58)	50 (1.14)	50 (1.00)		400 (4.09)	400 (3.89)		100 (0.96)		50 (0.96)	50 (0.97)	50 (1.19)
<i>Chaetoceros tenuissimus</i>	150 (2.78)		100 (1.95)	100 (2.05)		100 (2.27)	100 (2.00)		100 (1.02)		200 (1.56)	200 (1.92)	100 (1.79)	100 (1.92)	200 (3.88)	200 (4.77)
<i>Chaetoceros diversus</i>	150 (2.78)	200 (4.82)		200 (4.10)	200 (3.58)	200 (4.55)	200 (4.01)	100 (2.50)	400 (4.09)	600 (5.84)	400 (3.13)	200 (1.92)	200 (3.57)	100 (1.92)	50 (0.97)	100 (2.39)
<i>Chaetoceros danicus</i>		50 (1.20)	200 (3.89)	200 (4.10)	100 (1.79)	100 (2.27)	250 (5.01)	50 (1.25)	100 (1.02)	200 (1.95)	200 (1.56)	100 (0.96)	100 (1.79)	50 (0.96)		
<i>Chaetoceros peruvianus</i>			300 (5.84)	50 (1.02)		150 (3.41)	350 (7.01)	200 (5.00)	100 (1.02)		100 (0.78)		50 0.89		200 3.88	100 2.39
<i>Bacteriastrum delicatum</i>	100 (1.85)		200 (3.89)	400 (8.20)	200 (3.58)	400 (9.09)	200 (4.01)	250 (6.25)	400 (4.09)	400 (3.89)	400 (3.13)	400 (3.85)	200 3.57	200 3.85		
<i>Bacteriastrum varians</i>	100 (1.85)	150 (3.61)		100 (2.05)		100 (2.27)	100 (2.00)	200 (5.00)	200 (2.04)	100 (0.97)	600 (4.69)		300 5.36			
<i>Bacteriastrum hyalinum</i>		50 (1.20)	100 (1.95)	100 (2.05)	100 (1.79)				100 (1.02)		400 (3.13)	600 (5.77)	200 3.57	300 5.77		
Biddulphiaeae																
<i>Ditylum brightwellii</i>	200 (3.70)	150 (3.61)	100 (1.95)	50 (1.02)	100 (1.79)		200 (4.01)	50 (1.25)			400 (3.130)	100 (0.96)	200 (3.57)	50 (0.96)	50 (0.97)	50 (1.19)
<i>Eucampia zodiacus</i>	350 (6.48)	200 (4.82)		200 (4.10)	50 (0.89)	200 (4.55)	250 (5.01)	150 (3.75)	400 (4.09)	200 (1.95)	400 (3.13)	400 (3.85)	200 (3.57)	200 (3.85)	200 (3.88)	150 (3.58)

Table 1. Contd.

Name of the Family/species	Aerial Bay		Mayabunder		Rangat		Havelock		Hut Bay		Katchal		Kamorta		Campbell Bay	
	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS
<i>Triceratium reticulatum</i>	100 (1.85)	50 (1.20)			100 (1.79)		100 (2.00)				100 (0.78)	200 (1.92)	50 (0.89)	100 (1.92)	50 (1.97)	50 (1.19)
<i>Hemiaulus indicus</i>		50 (1.20)			50 (0.89)						100 (0.78)	100 (0.96)	50 (0.89)	50 (0.96)		
<i>Hemiaulus sinensis</i>	200 (3.70)	100 (2.41)	100 (1.95)	50 (1.02)	200 (3.58)	100 (2.27)					100 (0.78)		50 (0.89)		50 (0.97)	
Fragilarioideae																
<i>Thalassiothrix frauenfeldii</i>	200 (3.70)	100 (2.41)	200 (3.89)	200 (4.10)	150 (2.68)	200 (4.55)	100 (2.00)	50 (1.25)			400 (3.13)	300 (2.88)	200 (3.57)	150 (2.88)	200 (3.88)	200 (4.77)
<i>Thalassionema nitzschioides</i>	350 (6.48)	250 (6.02)	200 (3.89)	390 (7.99)	200 (3.58)	100 (2.27)	390 (7.82)	200 (5.00)	780 (7.98)	500 (4.86)	400 (3.13)	200 (1.92)	100 (1.79)	100 (1.92)	100 (1.94)	100 (2.39)
<i>Thalassiothrix longissima</i>	300 (5.56)	100 (2.41)	300 (5.84)	390 (7.99)	200 (3.58)	100 (2.27)	200 (4.01)	150 (3.75)	800 (8.18)	200 (1.95)	300 (2.34)	100 (0.96)	100 (1.79)	50 (0.96)	300 (5.83)	390 (9.31)
<i>Thalassionema javanicum</i>	100 (1.85)				150 (2.68)	50 (1.14)	100 (2.00)	200 (5.00)				100 (0.96)		50 (0.96)	200 (3.88)	300 (7.16)
Naviculoideae																
<i>Navicula longissima</i>	50 (0.93)	200 (4.82)	200 (3.89)	200 (4.10)	200 (3.58)	100 (2.27)	200 (4.01)	300 (7.50)			600 (4.69)	300 (2.88)	300 (5.36)	150 (2.88)	300 (5.83)	100 (2.39)
<i>Navicula granii</i>					200 (3.58)	100 (2.27)		100 (2.50)			200 (1.56)				200 3.88	
<i>Trachyneis antillarum</i>					150 (2.68)			50 (1.25)			300 (2.34)	300 (2.88)	150 (2.68)	150 (2.88)	200 (3.88)	50 (1.19)
<i>Navicula directa</i>	100 (1.85)	200 (4.82)	200 (3.89)	100 (2.05)	100 (1.79)	50 (1.14)		200 (5.00)	400 (4.09)	780 (7.59)	300 (2.34)	400 (3.85)	150 (2.68)	200 (3.85)	200 (3.88)	150 (3.58)
<i>Pleurosigma angulatum</i>	100 1.85	150 3.61	100 (1.95)		200 (3.58)	200 (4.55)	200 (4.01)	200 (5.00)								
<i>Pleurosigma normanii</i>	100 (1.85)	50 (1.20)	50 (0.97)		150 (2.68)	150 (3.41)		100 (2.50)	400 (4.09)		800 (6.25)	100 (0.96)		50 (0.96)	100 (1.94)	

Table 1. Contd.

Name of the Family/species	Aerial Bay		Mayabunder		Rangat		Havelock		Hut Bay		Katchal		Kamorta		Campbell Bay	
	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS	NS	OS
<i>Gyrosigma balticum</i>	50 (0.93)	100 (2.41)	200 (3.89)		100 (1.79)	100 (2.27)		100 (2.50)			300 (2.34)	300 (2.88)	150 (2.68)	150 (2.88)	150 (2.91)	
<i>Nitzschia seriata</i>	200 (3.70)	150 (3.61)	200 (3.89)	200 (4.10)	150 (2.68)	100 (2.27)		200 (5.00)	600 (6.13)	400 (3.89)	400 (3.13)	400 (3.85)	200 (3.57)	200 (3.85)	200 (3.88)	300 (7.16)
Peridinales																
<i>Ceratium extensum</i>	150 (2.78)	150 (3.61)		200 (4.10)	150 (2.68)	200 (4.55)	100 (2.00)	100 (2.50)	400 (4.09)	300 (2.92)	200 (1.56)	200 (1.92)	100 (1.79)	100 (1.92)	200 (3.88)	200 (4.77)
<i>Ceratium horridum</i>	50 (0.93)	50 (1.20)	200 (3.89)	200 (4.10)	150 (2.68)			50 (1.25)			400 (3.13)					
<i>Ceratium furca</i>	100 (1.85)	100 (2.41)		100 (2.05)	200 (3.58)	100 (2.27)	200 (4.01)	100 (2.50)	800 (8.18)	300 (2.92)	200 (1.56)	400 (3.85)	100 (1.79)	200 (3.85)	200 (3.88)	150 (3.58)
<i>Odontella mobilensis</i>	100 (1.85)	100 (2.41)				50 (1.14)		50 (1.25)	200 (2.04)		100 (0.78)	100 (0.96)		50 (0.96)		
Total	5400	4150	5140	4880	5590	4400	4990	4000	9780	10,280	12,800	10,400	5600	5200	5150	4190
Total number of species	37	34	31	34	37	36	32	36	30	24	37	38	39	38	33	28

diatoms. Similar trend of pinnate diatoms abundance was observed in almost all the stations. Centric diatoms population was comparatively less in composition. The composition of phytoplankton shows the overall good diversity in the A & N Islands. Recent threats on marine environment such as bio-invasion, rising global temperatures and pollution have a direct relation between biodiversity and ecosystem stability in nearshore and offshore water. Ecosystem functioning and biodiversity relation is valuable as reported by Seshagiri and Anil, 2003. The present investigation shows that the phytoplankton diversity, abundance and evenness in the A & N coastal waters are quite higher compared to phytoplankton in the open waters Bay of Bengal (Choudhury and Pal, 2009), although the waters of the region is influenced by the low nutrients oligotrophic waters of Bay of Bengal (Prasanna *et al.*, 2007; Sarupria and Bhargava, 1998; Madhupratap *et*

al., 2003). Increased coastal phytoplankton density and diversity may be attributed to influx of nutrients through land run-off during eight months of rain during in a year at A & N Islands. The coastal waters of A & N Islands appeared to be highly productive with less difference in coastal nearshore and offshore waters. The present study on phytoplankton species density and diversity reveals the existence of healthy marine ecosystem in the coastal waters of A & N Islands.

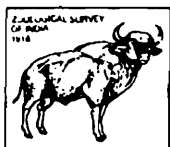
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SPATIAL DISTRIBUTION PATTERN OF PHYTOPLANKTON IN RELATION TO NUTRIENTS AVAILABILITY IN THE OFFSHORE WATERS OF ANDAMAN SEA, INDIA

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INTRODUCTION

The Andaman and Nicobar (A&N) Islands group is an archipelago of 572 islands lying in North-South direction between 6° and 14° North Latitude and 92° and 94° East Longitude in the Bay of Bengal. The total population of 3,79,944 in A & N Islands directly or indirectly depends on coastal marine environment, (Census of India publication, 2011). Andaman Sea is subjected to varied climatic changes due to monsoon and weather disturbances in Bay of Bengal, which in turn influence the nutrient availability and thus, abundance and diversity of phytoplankton. Diatoms and dinoflagellate are two important groups that dominate the world net phytoplankton (Nybakken, 1997). Diatoms account for approximately 40 per cent of primary productivity in ocean and 50 per cent of organic carbon accumulation in marine sediments (Falkowski *et al.*, 2004). They have great role as a biological carbon pump (Treguer and Pondaven, 2000) and influence atmospheric CO₂ level (Falkowski *et al.*, 2000). The role of

phytoplankton in uptake of CO₂ in the ocean is important as it reduces the rate of change in the global warming by greenhouse effect caused by the increased atmospheric carbon dioxide due to burning of fossil fuel (Houghton *et al.*, 1992; Woods and Barkmann, 1993). Dinoflagellate on the other hand has the ability to survive at the oligotrophic water and with various nutritional strategies to dominate the diatom population. The nitrogen fixing cyanobacterium "*Trichodesmium*" producing bloom in the Indian Ocean is a common occurrence (Agawin *et al.*, 2000; Devassy *et al.*, 1987). These ecologically important and chiefly autotrophic unicellular algae are extremely sensitive and highly dependable on the nutrient and physical state of the environment they survive. Any change in the environment may be good or bad would be reflecting the abundance and diversity of phytoplankton community. This article deals with the phytoplankton abundance and diversification pattern which is compared with the nutrient availability of the study area.

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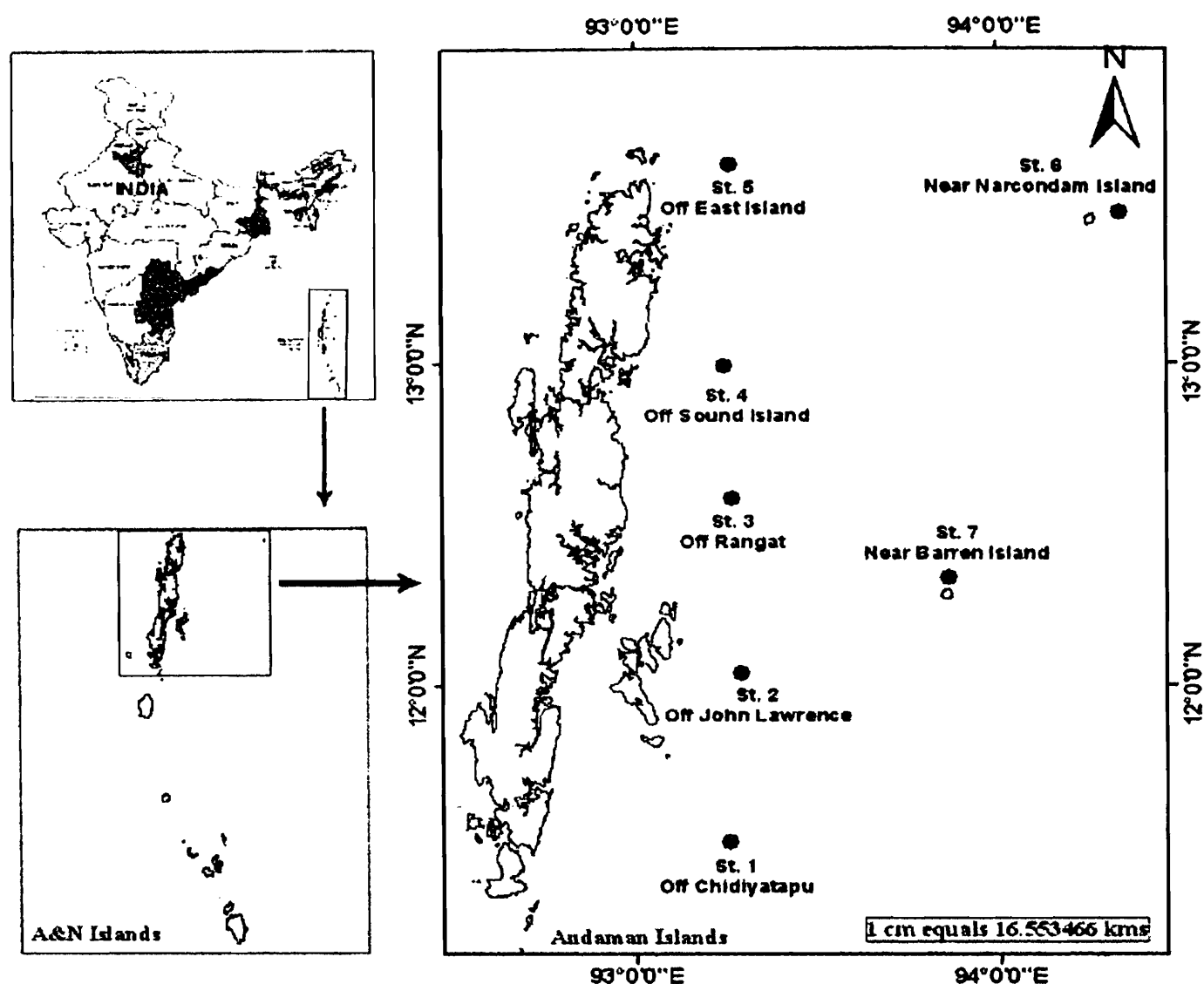


Fig. 1. Sampling Locations in the Andaman Sea

MATERIALS AND METHODS

The study was carried out during oceanographic cruise conducted between 4th and 24th September 2008 with ORV *Sagar Manjusha* of National Institute of Ocean Technology. Samples were collected from seven locations at Andaman Sea from South Andaman to North Andaman (Lat. 11° 30' 55.1" N, Long. 93°15'32.0" E and Lat. 13°37'04.2" N, Long. 93°15'52.3" E) (Fig. 1), for qualitative and quantitative analysis of phytoplankton and for nutrient analysis such as phosphate, nitrate, nitrite and silicate. The locations and other details of the study area are given in the Table 1. For the study of phytoplankton 5 liters of

surface seawater samples were collected using Niskin water sampler and transferred to polyethylene container and preserved with 4 per cent formalin and Lugol's iodine. Utermohl's sedimentation technique (1931) was followed for phytoplankton analysis. The samples were kept in dark for 48 hours without any disturbances and then reduced to 1 liter by slowly siphoning the top water through a tube. The 1 Litre of samples with phytoplankton was allowed to settle in a glass measuring cylinder for a period of 24 hours. After 24 hours period the sample again reduced to 500 mL and finally to a volume of 5 mL. The settled phytoplankton was enumerated and identified up to species level following the methods of

Utermohl's, 1931; Santhanam, *et al.*, 1987. For this a subsample of 100 µl from 5 mL volume was taken in a glass slide with cover slip and identified using the keys of Venkataraman, 1939; Cupp, 1943; Subrahmanyam, 1946; Desikachary, 1986; Santhanam, 1998. The samples were observed under Nikon Eclipse E600 Optiphort microscope at 20 X for counting and 40 X for identification. Replication of counting was also done to minimize the counting error. For analysis of nutrients the seawater samples were collected using Niskin samplers, transferred to clean polyethylene containers and immediately analysed at onboard water quality laboratory using standard methods described (Grasshoff *et al.*, 1999). Species diversity amongst the phytoplankton was calculated using the Shannon-Wiener (Shannon, 1948) diversity index "H" along with species evenness by Pielou's Evenness index "J" (Pielou, 1966) with following formulas.

Shannon-Weiner Diversity Index

$$H_s = - \sum (P_i) (\ln P_i), \text{ where } i = 1$$

H_s-symbol for the diversity in a sample of S species or kinds

S-the number of species in the sample

P_i- relative abundance of *i*th species or kinds measures, = n_i/N

N-total number of individuals of all kinds

n_i -number of individuals of *i*th species

ln-natural log

Pielou's evenness index

$$J' = \frac{H'}{H'_{\max}}$$

$$J' = \frac{H'}{\log_2 S}$$

RESULTS

The samples collected at the end of the monsoon season (4th to 24th September 2008)

from seven locations at Andaman Sea from South to North Andaman revealed interesting features. The species recorded were belonging to families Asterolampraceae, Bacillariaceae, Biddulphiaceae, Ceratiaceae, Chaetocereae, Coscinodiscaeae, Cyanophyceae, Fragilaroideae, Hemiaulaceae, Naviculaeae, Oxytoxaceae, Peridiniaceae, Prorocentriaceae and Solenaceae. A total of 105 species were recorded from seven different stations. The phytoplankton density (Nos./L) recorded during the period of study ranged from 613.64 to 19825.24 Nos./L. The maximum density of phytoplankton was recorded from off the Sound Island (St. 4) whereas, the minimum density was recorded near Barren Island (St. 7). The total number of phytoplankton species recorded ranged from 28 to 61. Off the John Lawrence Island (St. 2) and off the Sound Island (St. 4) shows highest Phytoplankton diversity whereas Barren Island (St. 7) shows the minimum diversity of 28 species.

The density of phytoplankton off the Chidiyatapu (St. 1) was 1009 Nos./L with a total number of 39 species. *Trichodesmium* sp. belonging to Cyanophyceae was the dominating family in this water with density of 269 Nos./L and composition of 26.61 per cent. The density off the John Lawrence station was 3367 Nos./L with *Trichodesmium* sp. being dominant. The total number of phytoplankton species in this station was 61. The diversity of phytoplankton belonging to different families was found to be highest in this station. The composition of *Trichodesmium* sp. was 11.21 per cent. Phytoplankton density in off the Rangat waters were 2637 Nos./L and the total number of species were 44. *Nitzschia seriata* was the dominant species representing with a composition of 16.73 per cent. The maximum phytoplankton density of 19825 Nos./L was recorded from off the Sound Island (St. 4). *Nitzschia seriata* was the dominating species in the water with a composition of 35.55 per cent. The species diversity of this station was higher with 61 species.

The phytoplankton density in the off the East Island (St. 5) was 1408 No./L with *Nitzschia*

seriata dominating the total phytoplankton composition (15.89 per cent). The total number of species found in this water was 33. The phytoplankton density in off the Narcondam Island was lower with 902 Nos./L. *Navicula directa* was dominating in this station with the composition of 15.38 per cent. The total number of species encountered in this station was 32 which were higher when compared to the density of the same station. The density of phytoplankton in off the Barren Island (St. 7) was found to be the lowest (614 Nos./L) and *Trichodesmium* sp. was found to be dominating the water with the composition of 20.37 per cent. This survey station is located near the volcanic island (Table 2 and Fig. 2).

Shannon-Wiener diversity index (H) and Evenness (J) were calculated and results are presented in Table. 3 indicated that the off the Sound Island (St. 4) had minimum Shannon diversity, maximum abundance with lowest evenness. However, Barren Island (St. 7) showed minimum abundance with Shannon diversity of 3.00 and evenness of 0.90. The species evenness (Fig. 6) in this area showed that species living in that are evenly distributed. The Shannon diversity (Fig. 6) index (H) within

the stations was ranging from 2.7 to 3.6 and species evenness (J) was ranged between 0.67 and 0.90.

Nutrients of surface water column showed considerable variation among the stations. Silicate concentration in the surface seawater was ranging from 0 to 0.20 $\mu\text{mol/L}$. Silicate was also found below detectable level in the stations such as off the Chidiyatapu (St. 1), off the Sound Island (St. 4), off the East Island (St. 5) and Barren Island (St. 7). Maximum concentration was recorded from off the Rangat (St. 3). Nitrite concentration was observed between 0 and 0.30 $\mu\text{mol/L}$ with below detectable concentration in off the Sound Island (St. 4) and maximum concentration in waters off the East Island (St. 5). Nitrate concentration was found to be in the range between 0.05 and 1.43 $\mu\text{mol/L}$ with minimum concentration in waters off the Rangat (St. 3) and maximum concentration in off the John Lawrence Island (St. 2). Phosphate was ranging from 0 to 0.45 $\mu\text{mol/L}$ with below detectable level in off the Rangat (St. 3), Narcondam Island (St. 6) and maximum concentration in off the Chidiyatapu (St. 2) (Table 1 and Fig. 3).

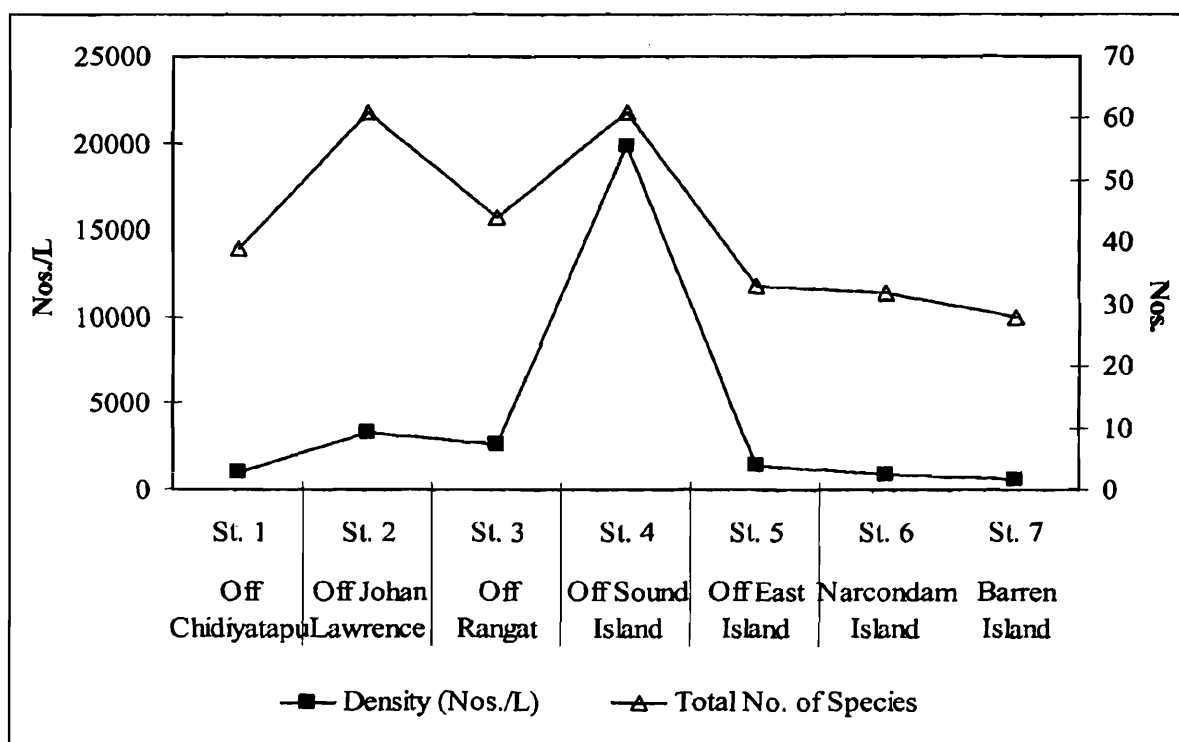


Fig. 2. Density (Nos./L) and total number of phytoplankton species (Nos.) in the study area of Andaman Sea

DISCUSSION

The present study deals with phytoplankton density and diversity in relation to nutrient availability in the surface water of the seven locations East of Andaman Islands in the Andaman Sea. The supply and availability of nutrients are very important as the macronutrients influx leads to crucial changes in the aquatic ecosystem structure and function including species abundance and diversity. Nitrate, the most abundant nitrogen source in ocean, varies in concentration depending on habitat. Its availability drives primary production and influence ecosystem dynamics.

In general the offshore surface water contains low nitrate concentrations because of algal uptake, hence their accumulation is always higher below the photic zone. Nitrite is an unstable nitrogen ion, is also a source of nutrient for phytoplankton. Similarly phosphate is essential for the growth of phytoplankton. Ketchum and Redfield (1949) have experimented and noticed that the growth of *Nitzschia closterium* limited by concentration of phosphate in illuminated condition. Phosphorus is being utilized for photosynthetic activity by marine phytoplankton in highly effective ways (Goldberg *et al.*, 1951; Tett *et al.*,

1975; Fuiis 1969). The highest phytoplankton population was encountered at off the Sound Island (St. 4). The high density of phytoplankton showed inverse relationship, when compared with the availability of the silicate, nitrate, nitrite and phosphate concentrations (Fig. 2 and 3). Similar relationship between low nutrients availability and high phytoplankton density have been observed and recorded by Choudhury and Pal (2009) in Bay of Bengal and Carvalho *et al.* (2008) in continental shelf of Southeast Brazil. Low concentration of nutrients was observed in the surface water of St. 4, indicating that almost all the dissolved nutrients were consumed by the phytoplankton (Fig. 3). The silicate and nitrite values were below detectable limit (BDL) at this station and nitrate and phosphate concentration were also found to be low (Table 1). The family Bacillariaceae (Fig. 4) was found dominating in this area with *Nitzschia seriata* with 35.55 per cent leading, followed by *N. closterium* and *N. sigma* with 5.29 per cent and 1.47 per cent respectively.

At off the John Lawrence Island (St. 2) the phytoplankton density was showing increment when compared to the St. 1 and St. 2. The concentration of nitrate and phosphate were

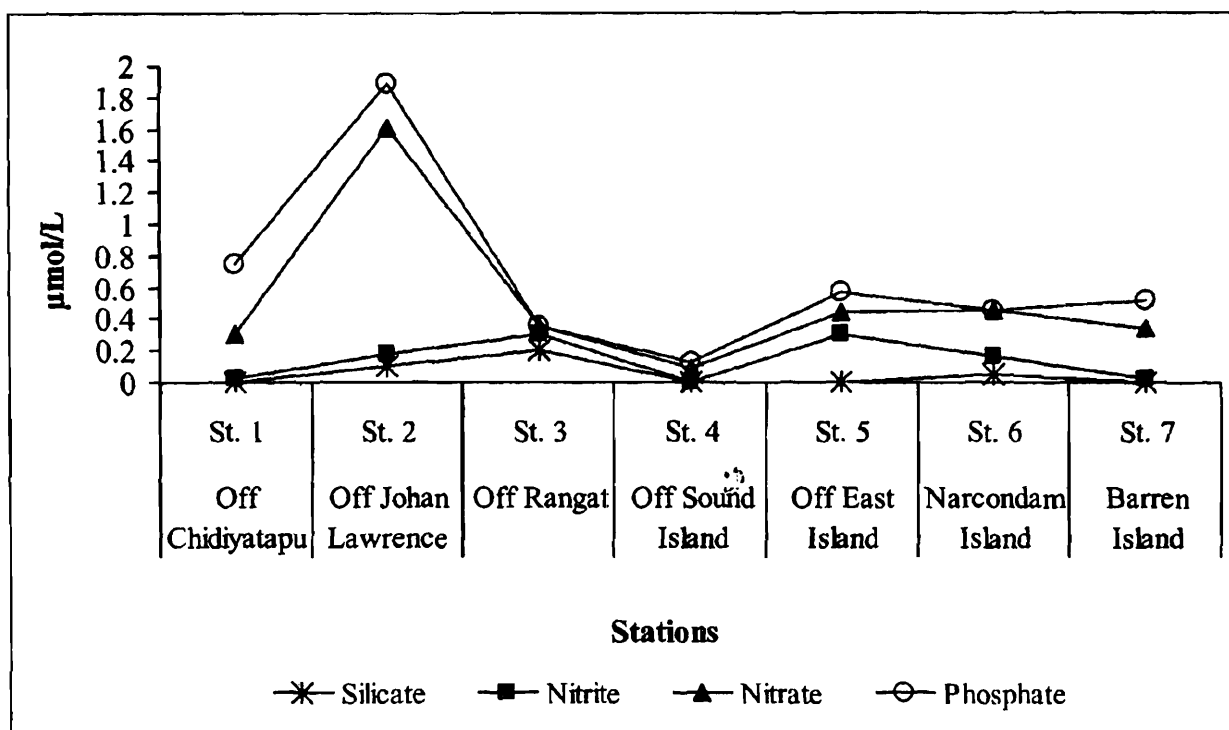


Fig. 3. Nutrient profile of surface water in the study area of Andaman Sea

Table 1. Details of station name, locations at Andaman Sea along with Physical parameters, Phytoplankton density, Number of species and Nutrient concentrations in the surface waters

Station Name/Code/ details	Off the Chidiyatapu	Off the Johan Lawrence	Off the Rangat	Off the Sound Island	Off the East Island	Off the Narcondam Island	Off the Barren Islands
	(St. 1)	(St. 2)	(St. 3)	(St. 4)	(St. 5)	(St. 6)	(St. 7)
Latitude (N)	11° 30' 55.1"	12° 02' 22.5"	12° 34' 50.4"	12° 59' 40.5"	13° 37' 04.2"	13° 28' 17.1"	12° 20' 04.5"
Longitude (E)	93° 15' 32.0"	93° 16' 78.2"	93° 16' 04.4"	93° 14' 55.2"	93° 15' 52.3"	94° 20' 30.7"	93° 51' 50.3"
Depth (m)	1460	760	460	595	750	795	1764
Distance from Land (km)	58.06	25.60	33.54	25.75	21.79	7.66	3.6
Atm. Temp.	25°C	27.5°C	25.5°C	28.0°C	29.8°C	28.0°C	26.5°C
Surface Seawater Temp.	28°C	28°C	28.6°C	28.4°C	29.2°C	28.4°C	28.4°C
Time of Sampling	19:45	8:00	16:30	6:15	14:00	14:45	6:50
Phytoplankton details							
Phytoplankton Density (Nos./L)	1009.26	3367.35	2637.25	19825.24	1407.89	901.73	613.64
Total No of Species (Nos.)	39	61	44	61	33	32	28
Nutrient details							
Silicate (µmol/L)	0	0.1	0.2	0	0	0.05	0
Nitrite (µmol/L)	0.02	0.08	0.1	0	0.3	0.12	0.02
Nitrate (µmol/L)	0.28	1.43	0.05	0.09	0.14	0.28	0.32
Phosphate (µmol/L)	0.45	0.27	0	0.04	0.13	0	0.18

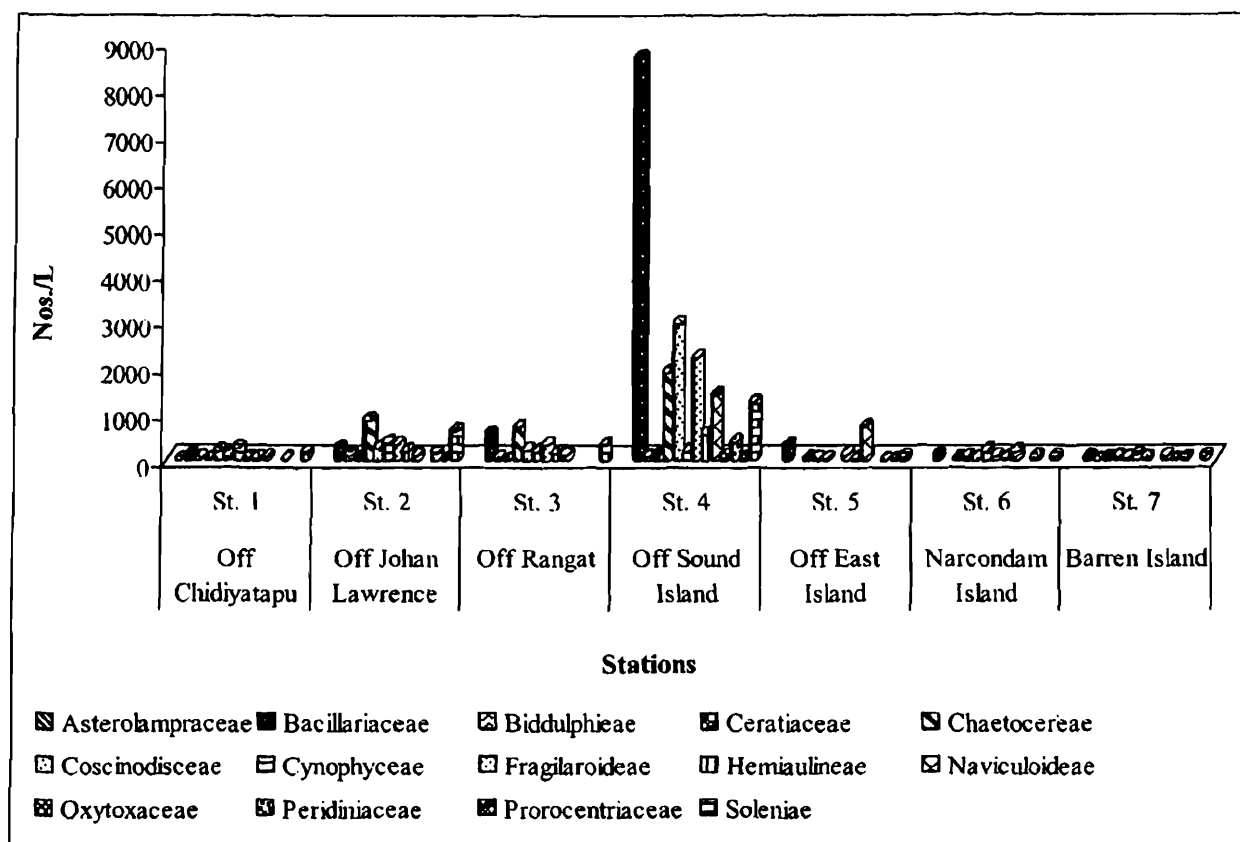


Fig. 4. Family-wise phytoplankton density (Nos./L) trend in the study area of Andaman Sea

higher whereas, the silicate and nitrite concentration were lower. This may be explained for the abundance of *Trichodesmium* sp. (11.21 per cent) in the area. The concentration of surface water nitrate in the area was $1.43 \mu\text{mol/L}$, found to be the highest value amongst all other stations. *Trichodesmium* sp. indicates important input of new nitrogen fixation in the euphotic zone (Carvalho *et al.*, 2008; Capone and Carpenter 1982; Zehr *et al.*, 2001; Lugomela *et al.*, 2002; Capone *et al.*, 2005). At the same time they have the ability to remove the inorganic phosphate radical from organically bound phosphate (Yentsch *et al.*, 1972). A total of 61 species recorded from St. 2 which was equal to St. 4.

In general the centric diatoms were more in the study area when compared to pinnate, at the same time dinoflagellate were also present in considerable numbers and diversity. Although the phytoplankton density of the study area was lower the diversity reached to its maximum level. The number of representative species was higher from Chaetoceraceae family in all the stations (Fig.

5). Fragilaroideae, Naviculoideae and Peridiniaceae were the next to have showed high diversity. This may be attributed to the pulsed nutrient supply in the area at different interval because of frequent rains and rapid vertical mixing of lower high nutrient water (Koushik *et al.*, 2007). The fluctuation and periodicity of nutrient supply have the effect in maintaining the phytoplankton diversity and co-existence of different species (Tamiji and Gen, 2004). The previous study done in Andaman Sea had recorded the *Navicula* sp. and *Peridinium* sp. dominating the phytoplankton composition (Bhattathiri and Devassy, 1981). Dinoflagellate *Peridinium* sp. was recorded in moderate numbers in almost all the stations could be attributed to their ability to survive in oligotrophic waters (Devassy and Bhattathiri, 1981). The concentration of silicate was found to be lower in the waters of most of the stations indicating the abundance of diatoms and its utilization, at the same time the regeneration of silicate is often very slow in the water column (Egge and Aksnes, 1992).

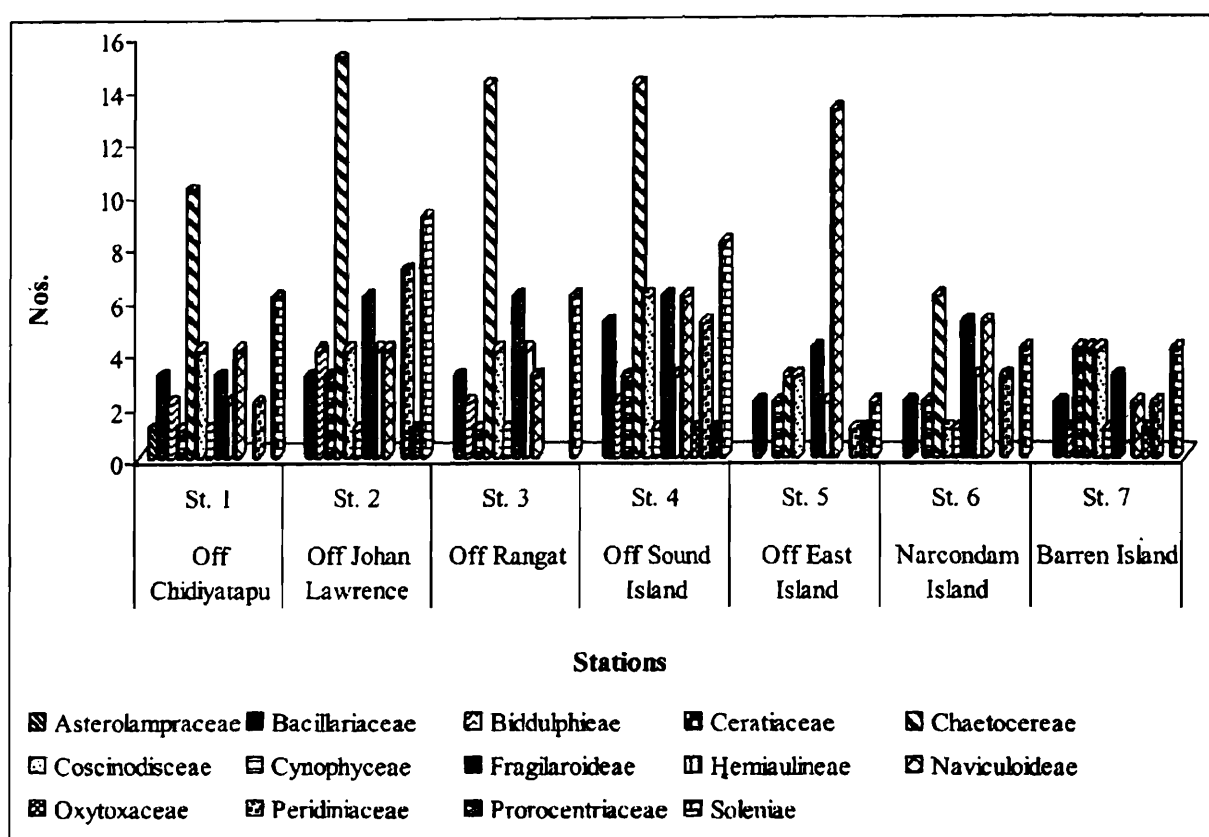


Fig. 5. Family wise species composition (Nos.) in the study area of Andaman Sea

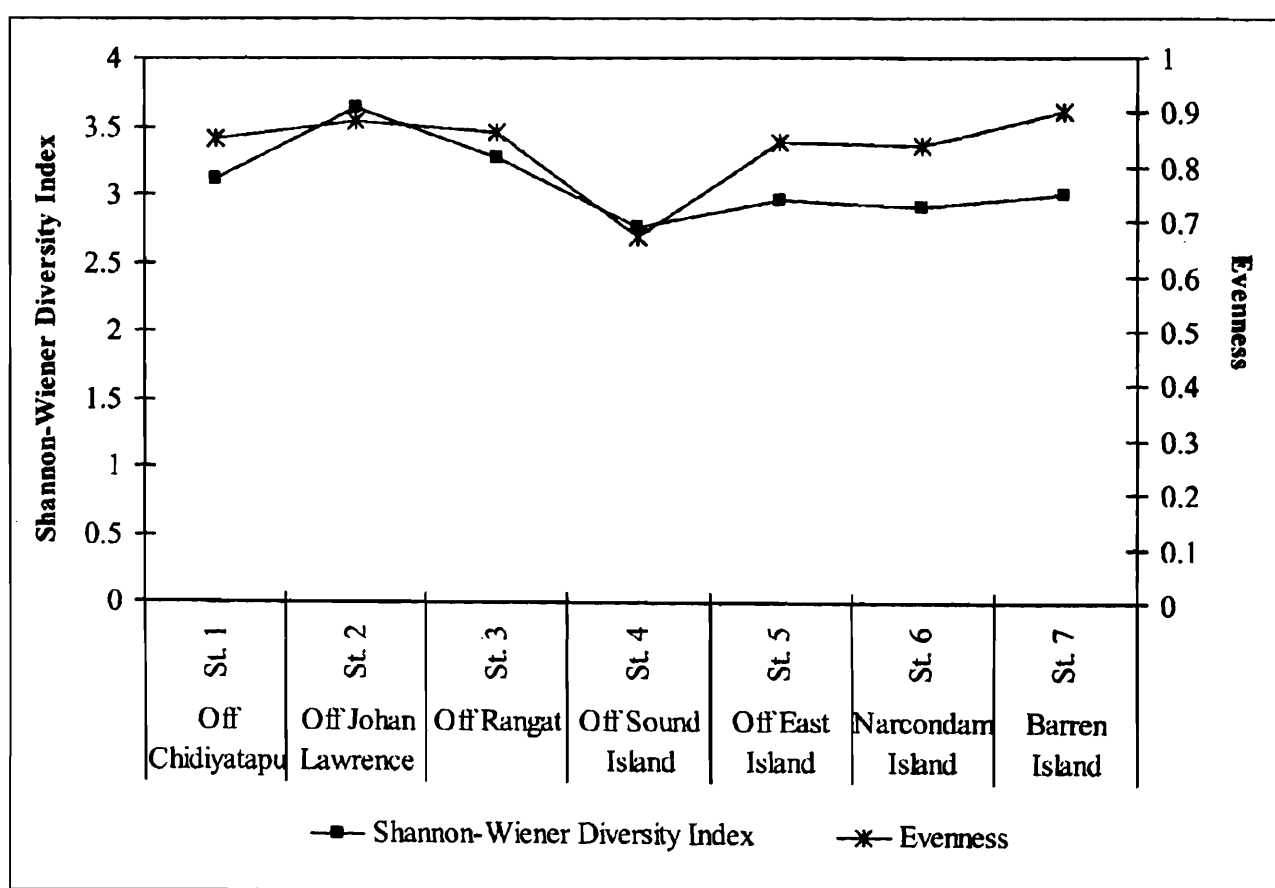


Fig. 6. Shannon-Wiener Diversity Index and Evenness in the study area of Andaman Sea

Table 2. Phytoplankton Density (Nos./L), species composition and percentage composition (in parenthesis) in the seven stations of Andaman Sea

Name of the Families/species	Station Name / Code						
	Off the Chidiyatapu	Off the Johan Lawrence	Off the Rangat	Off the Sound Island	Off the East Island	Off the Narcondam Island	Off the Barren Islands
	(St. 1)	(St. 2)	(St. 3)	(St. 4)	(St. 5)	(St. 6)	(St. 7)
Asterolampraceae							
<i>Asteromphalus</i> sp.	9 (0.92)						
Bacillariaceae							
<i>Nitzschia closterium</i>	19 (1.83)	41 (1.21)	29 (1.12)	1049 (5.29)	105 (7.48)	58 (6.41)	
<i>Nitzschia delicatissima</i>	28 (2.75)	31 (0.91)	98 (3.72)	252 (1.27)			
<i>Nitzschia pungens</i>				39 (0.20)			
<i>Nitzschia seriata</i>	46 (4.59)	194 (5.76)	441 (16.73)	7049 (35.55)	224 (15.89)	69 (7.69)	45 (7.41)
<i>Nitzschia sigma</i>				291 (1.47)			11 (1.85)
Biddulphiaeae							
<i>Biddulphia mobilensis</i>							11 (1.85)
<i>Ditylium brightwilli</i>	9 (0.92)	10 (0.30)	20 (0.74)				
<i>Eucampia cornuta</i>	9 (0.92)	20 (0.61)		58 (0.29)			
<i>Eucampia groenlandica</i>				19 (0.10)			
<i>Eucampia zodiacus</i>		41 (1.21)	20 (0.74)				

Table 2. Contd.

Name of the Families/species	Station Name / Code						
	Off the Chidiyatapu	Off the Johan Lawrence	Off the Rangat	Off the Sound Island	Off the East Island	Off the Narcondam Island	Off the Barren Islands
	(St. 1)	(St. 2)	(St. 3)	(St. 4)	(St. 5)	(St. 6)	(St. 7)
<i>Lithodesmium undulatum</i>		31 (0.91)					
Ceratiaceae							
<i>Ceratium furca</i>	9 (0.92)	20 (0.61)	10 (0.37)	78 (0.39)	13 (0.93)	23 (1.28)	11 (1.85)
<i>Ceratium extensum</i>				39 (0.20)	13 (0.93)	12 (2.56)	11 (1.85)
<i>Ceratium fusus</i>				19 (0.10)			
<i>Ceratium macroceros</i>		20 (0.61)					11 (1.85)
<i>Ceratium tripos</i>		10 (0.30)					11 (1.85)
Chaetocereae							
<i>Bacteriastrum furcatum</i>	19 (1.83)	102 (3.03)	69 (2.60)	194 (0.98)			23 (3.70)
<i>Bacteriastrum hyalinum</i>	9 (0.92)	51 (1.52)	10 (0.37)	19 (0.10)			
<i>Chaetoceros affinis</i>			29 (1.12)				
<i>Chaetoceros borealis</i>	9 (0.92)		39 (1.49)				
<i>Chaetoceros compressus</i>		41 (1.21)	20 (0.74)	19 (0.10)			
<i>Chaetoceros constrictus</i>		31 (0.91)					

Table 2. Contd.

Name of the Families/species	Station Name / Code						
	Off the Chidiyatapu	Off the Johan Lawrence	Off the Rangat	Off the Sound Island	Off the East Island	Off the Narcondam Island	Off the Barren Islands
	(St. 1)	(St. 2)	(St. 3)	(St. 4)	(St. 5)	(St. 6)	(St. 7)
<i>Chaetoceros convolutum</i>		20 (0.61)	10 (0.37)	19 (0.10)			
<i>Chaetoceros costatus</i>						12 (1.28)	
<i>Chaetoceros curvisetus</i>	9 (0.92)	71 (2.12)	20 (0.74)	58 (0.29)			
<i>Chaetoceros danicus</i>		10 (0.30)					
<i>Chaetoceros dichæta</i>	9 (0.92)						
<i>Chaetoceros diversus</i>	46 (4.59)	133 (3.94)	127 (4.83)	466 (2.35)	13 (0.93)		
<i>Chaetoceros indicus</i>		41 (1.21)	39 (1.49)			12 (1.28)	
<i>Chaetoceros lorenzianus</i>	28 (2.75)	204 (6.06)	186 (7.06)	466 (2.35)		12 (1.28)	11 (1.85)
<i>Chaetoceros messanensis</i>				3 (0.20)			
<i>Chaetoceros neopolitanum</i>		29 (1.12)					
<i>Chaetoceros pelagicus</i>		10 (0.30)		39 (0.20)		12 (1.28)	
<i>Chaetoceros peruvianus</i>	19 (1.83)	41 (1.21)	20 (0.74)	19 (0.10)	13 (0.93)	12 (1.28)	
<i>Chaetoceros pseudocurvisetus</i>	31 (0.91)		39 (0.20)				
<i>Chaetoceros</i> sp.	28 (2.75)	61 (1.82)	20 (0.74)	175 (0.88)	13 (0.93)	23 (2.56)	11 (1.85)

Table 2. Contd.

Name of the Families/species	Station Name / Code						
	Off the Chidiyatapu	Off the Johan Lawrence	Off the Rangat	Off the Sound Island	Off the East Island	Off the Narcondam Island	Off the Barren Islands
	(St. 1)	(St. 2)	(St. 3)	(St. 4)	(St. 5)	(St. 6)	(St. 7)
<i>Chaetoceros teres</i>				58 (0.29)			
<i>Corethron hystrix</i>	9 (0.92)	20 (0.61)	69 (2.60)	291 (1.47)			11 (1.85)
Coscinodisceae							
<i>Coscinodiscus centralis</i>		20 (0.61)					11 (1.85)
<i>Coscinodiscus gigas</i>	28 (2.75)	82 (2.42)	10 (0.37)	175 (0.88)	13 (0.93)		11 (1.85)
<i>Coscinodiscus lineatus</i>				136 (0.69)	13 (0.93)		
<i>Coscinodiscus marginatus</i>	28 (2.75)	92 (2.73)	20 (0.74)	291 (1.47)	13 (0.93)		11 (1.85)
<i>Coscinodiscus</i> sp.			10 (0.37)				
<i>Melosira mummuloides</i>	9 (0.92)			58 (0.29)			
<i>Melosira</i> sp.						23 (2.56)	
<i>Skeletonema costatum</i>	28 (2.75)	82 (2.42)	176 (6.69)	2214 (11.17)			11 (1.85)
<i>Thalassiosira</i> sp.				58 (0.29)			
Cynophyceae							
<i>Trichodesmium</i> sp	269 (26.61)	378 (11.21)	186 (7.06)	175 (0.88)		208 (23.08)	125 (20.37)

Table 2. Contd.

Name of the Families/species	Station Name / Code						
	Off the Chidiyatapu	Off the Johan Lawrence	Off the Rangat	Off the Sound Island	Off the East Island	Off the Narcondam Island	Off the Barren Islands
	(St. 1)	(St. 2)	(St. 3)	(St. 4)	(St. 5)	(St. 6)	(St. 7)
Fragilaroideae							
<i>Asterionellopsis glacialis</i>		20 (0.61)	20 (0.74)				
<i>Asterionellopsis</i> sp.				39 (0.20)		23 (2.56)	
<i>Climacodium frauenfeldianum</i>	112 (3.33)	29 (1.12)	39 (2.20)	13 (0.93)	23 (2.56)	23 (3.70)	
<i>Fragilaria crotonensis</i>	9 (0.92)	20 (0.61)		58 (0.29)			11 (1.85)
<i>Fragilaria cylindrus</i>		20 (0.61)					
<i>Fragilaria oceanica</i>		31 (0.91)	49 (1.86)	39 (0.20)	39 (2.80)		
<i>Grammatopha undulata</i>						12 (1.28)	
<i>Lycmophora lyngbei</i>	9 (0.92)						
<i>Thalassionema nitzschioides</i>	28 (2.75)	133 (3.94)	157 (5.95)	1786 (9.01)	66 (4.67)	12 (1.28)	
<i>Thalassionema</i> sp.					13 (0.93)		
<i>Thalassiothrix frauenfeldii</i>			49 (1.86)				
<i>Thalassiothrix longissima</i>			29 (1.12)	252 (1.27)		12 (1.28)	11 (1.85)
Hemiaulineae							
<i>Cerataulina dentata</i>				369 (1.86)	13 (0.93)	12 (1.28)	

Table 2. Contd.

Name of the Families/species	Station Name / Code						
	Off the Chidiyatapu	Off the Johan Lawrence	Off the Rangat	Off the Sound Island	Off the East Island	Off the Narcondam Island	Off the Barren Islands
	(St. 1)	(St. 2)	(St. 3)	(St. 4)	(St. 5)	(St. 6)	(St. 7)
<i>Cerataulina</i> sp.	9 (0.92)	92 (2.73)	118 (4.46)		13 (0.930)		
<i>Hemiaulus hauckii</i>		41 (1.21)	10 (0.37)			12 (1.28)	
<i>Hemiaulus indicus</i>		31 (0.91)	10 (0.37)	58 (0.29)		12 (1.28)	
<i>Hemiaulus sinensis</i>	37 (3.67)	31 (0.91)	20 (0.74)	136 (0.69)			
Naviculoideae							
<i>Amphipora decussata</i>					13 (0.93)		
<i>Amphipora giganticum</i>					13 (0.93)		
<i>Amphora leneolata</i>				19 (0.10)	53 (3.74)		
<i>Amphora</i> sp.					39 (2.80)		
<i>Diploneis robustus</i>	9 (0.92)				13 (0.93)		
<i>Diploneis</i> sp.					105 (7.48)	12 (1.28)	
<i>Diploneis weissflogii</i>					13 (0.93)		
<i>Navicula directa</i>	9 (0.92)	61 (1.82)	39 (1.49)	291 (1.47)	158 (11.21)	139 (15.38)	45 (7.41)
<i>Navicula granii</i>		10 (0.30)					

Table 2. Contd.

Name of the Families/species	Station Name / Code						
	Off the Chidiyatapu	Off the Johan Lawrence	Off the Rangat	Off the Sound Island	Off the East Island	Off the Narcondam Island	Off the Barren Islands
	(St. 1)	(St. 2)	(St. 3)	(St. 4)	(St. 5)	(St. 6)	(St. 7)
<i>Navicula longa</i>	37 (3.67)	10 (0.30)	59 (2.23)				
<i>Navicula pelagica</i>				602 (3.04)			
<i>Navicula</i> sp.				388 (1.96)	158 (11.21)		45 (7.41)
<i>Pleurosigma angulatum</i>	9 (0.92)	20 (0.61)	20 (0.74)	78 (0.39)	39 (2.80)		
<i>Pleurosigma galapagense</i>					13 (0.93)	12 (1.28)	
<i>Pleurosigma normanii</i>				19 (0.10)	79 (5.61)	12 (1.28)	
<i>Tropidoneis semistriata</i>					13 (0.93)		
<i>Tropidoneis</i> sp.						12 (1.28)	
Oxytoxaceae							
<i>Oxytoxum scolopax</i>				58 (0.29)			11 (1.85)
Peridiniaceae							
<i>Goniaulax scrippsae</i>		10 (0.30)					
<i>Goniaulax</i> sp.				58 (0.29)			
<i>Peridinium achromaticum</i>	9 (0.92)	10 (0.30)		97 (0.49)		12 (1.28)	34 (5.56)

Table 2. Contd.

Name of the Families/species	Station Name/ Code						
	Off the Chidiyatapu	Off the Johan Lawrence	Off the Rangat	Off the Sound Island	Off the East Island	Off the Narcondam Island	Off the Barren Islands
	(St. 1)	(St. 2)	(St. 3)	(St. 4)	(St. 5)	(St. 6)	(St. 7)
<i>Peridinium cerasus</i>	9 (0.92)			58 (0.29)		12 (1.28)	
<i>Peridinium globulum</i>		71 (2.12)		155 (0.78)	13 (0.93)	35 (3.85)	
<i>Peridinium oblongatum</i>		10 (0.30)					
<i>Peridinium oceanicum</i>		20 (0.61)		19 (0.10)			
<i>Peridinium ovatum</i>		20 (0.61)					11 (1.85)
<i>Peridinium pallidum</i>		20 (0.61)					
Prorocentriaceae							
<i>Ornithocercus steinii</i>					13 (0.93)		
<i>Prorocentrum micans</i>		10 (0.30)		39 (0.20)			
Soleniae							
<i>Dactyliosolen fragilissimis</i>	19 (1.83)	112 (3.33)	49 (1.86)	408 (2.06)	13 (0.93)	23 (2.56)	
<i>Guinardia cylindrus</i>		20 (0.61)					23 (3.70)
<i>Guinardia delicatula</i>	19 (1.83)	10 (0.30)	20 (0.74)				
<i>Guinardia flaccida</i>	9 (0.92)	20 (0.61)	29 (1.12)	78 (0.39)			

Table 2. *Contd.*

Name of the Families/species	Station Name / Code						
	Off the Chidiyatapu	Off the Johan Lawrence	Off the Rangat	Off the Sound Island	Off the East Island	Off the Narcondam Island	Off the Barren Islands
	(St. 1)	(St. 2)	(St. 3)	(St. 4)	(St. 5)	(St. 6)	(St. 7)
<i>Leptocylindrus danicus</i>		10 (0.30)		97 (0.49)			
<i>Leptocylindrus minimus</i>	37 (3.67)	102 (3.03)	108 (4.09)	136 (0.69)			23 (3.70)
<i>Rhizosolenia alata</i>	46 (4.59)	245 (7.27)	59 (2.23)	175 (0.88)		12 (1.28)	23 (3.70)
<i>Rhizosolenia castracanii</i>				78 (0.39)			
<i>Rhizosolenia imbricata</i>		51 (1.52)		39 (0.20)		12 (1.28)	
<i>Rhizosolenia setigera</i>	28 (2.75)	51 (1.52)	59 (2.23)	252 (1.27)	66 (4.67)	23 (2.56)	11 (1.85)
Total	1009	3367	2637	19825	1408	902	614
Total number of species	39	61	44	61	33	32	28

Table 3. Shannon -Wiener diversity index (H) and Evenness (J) of study area in Andaman Sea

Station Name/Code/ Index	Off the Chidiyatapu	Off the Johan Lawrence	Off the Rangat	Off the Sound Island	Off the East Island	Off the Narcondam Island	Off the Barren Islands
	(St. 1)	(St. 2)	(St. 3)	(St. 4)	(St. 5)	(St. 6)	(St. 7)
Shannon-Wiener Diversity Index	3.12	3.64	3.26	2.76	2.96	2.90	3.00
Evenness	0.85	0.88	0.86	0.67	0.85	0.84	0.90

CONCLUSION

The study provided valuable information about the density and diversity of phytoplankton species in the Northwestern part of Andaman Sea. Phytoplankton production considered to be the prime indicators of possible global warming and climate change on the entire ecosystem. They are the indicators of productivity as well of the marine environment which will help us to assess the fishery and other resources potential exists in the sea. Hence seasonal sampling would be

required in future to understand the succession pattern and diversity strength of the phytoplankton community in the Andaman Sea.

ACKNOWLEDGEMENTS

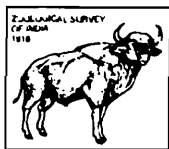
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HYDROGRAPHICAL AND DIVERSITY OF PHYTOPLANKTON COMPOSITION AND COMMUNITY STRUCTURE IN CHENNAI COASTAL WATERS

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INTRODUCTION

Distribution and behavior of nutrients (which are essential for plankton growth) in the coastal environments, particularly in near shore waters and estuaries exhibit considerable seasonal variations depending on the local conditions of rainfall, quantum of fresh water inflow, tidal incursion and on some biological activity like phytoplankton uptake and regeneration and the seasonal distribution of nutrients and various abiotic and biotic processes affecting the nutrients cycle of different coastal environments (Choudhury and Panigrahy, 1991). Further, the environmental conditions such as topography, water movement and stratifications, salinity, oxygen, temperature and nutrients characterising particular water mass also determine the composition of its biota (Karande, 1991). Thus, the nature and distribution of the flora and fauna in the aquatic system are mainly controlled by the fluctuations in the physical and chemical characteristics of the water body.

In the marine environment, phytoplankton as primary producers form the vital source of energy. They initiate the marine food-chain and the secondary (zooplankton) and tertiary (shell

fish, finfish and others) producers depend on phytoplankton directly or indirectly for food. Phytoplankton species undergo spatio-temporal changes in their distribution due to the differential effects of changing physical, chemical and biological factors in individual species. Of the many marine biotic components, phytoplankton can be used as bio-indicators since they reflect even the subtle changes taking place in their immediate environment by changing their species composition, biomass, community structure, chlorophyll pigment content and productivity.

Hence the present investigation was carried out in the Chennai coastal waters of the Bay of Bengal, with a view to understand the various physico-chemical characteristics and their influence on the phytoplankton population density, the species composition, community structure (diversity, richness, evenness and dominance index), chlorophyll 'a' content and productivity of phytoplankton of two stations in the Chennai coast (Stations 1 and 2).

MATERIALS AND METHODS

Water samples were collected at monthly intervals in two stations (Kasimedu and

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Thiruvatriyur) (stations 1 and 2) of Chennai coast (Fig. 1) for a total period of six months from January to June 2007 for the estimation of various physico-chemical and biological (phytoplankton community structure, chlorophyll 'a' content and productivity of phytoplankton) parameters.

Atmospheric and surface water temperature was measured using a standard centigrade thermometer. Light penetration in the water column was measured with the help of a Secchi disc and the light extinction co-efficient (LEC) was calculated using Pool and Atkins (1929) formula. Salinity was estimated with the help of a Salinometer model E-2 and pH was measured using a Elico pH meter (Model Li-120). Dissolved oxygen was estimated by the modified Winkler's method of Strickland and Parsons (1972). For the analysis of nutrients, (dissolved inorganic phosphate, nitrate, nitrite and reactive silicate) adopting the standard procedures described by Strickland and Parsons (1972).

Phytoplankton samples were collected at monthly intervals from the surface water of

the study areas by towing a plankton net (Mouth diameter 0.35 m) made of bolting silk (No. 30, mesh size 48 μ m) for half an hour. These samples were preserved in 4 per cent formalin and used for qualitative analysis. For the quantitative analysis of phytoplankton, the settling method described analysis was carried out using Utermohi's inverted plankton microscope. Phytoplankton was identified using the standard literature (Hustedt, 1930–1966; Venkataraman, 1939; Desikachary, 1959 and 1987; Hendey, 1964; Steidinger and Williams, 1970); Taylor, 1976; Anand *et al.*, 1986). Species diversity index (H') was calculated using the Shannon and Weaver's (1949) formula. Species richness (SR) was calculated as described by Gleason (1922).

Evenness index (J') (equitability) was calculated using the formula of Pielou (1966). Dominance index (δ) was calculated using the formula of Mc Naughton (1967) as described by Ignatiades and Mimicos (1977). Chlorophyll 'a' in phytoplankton was estimated using the standard method described by Stickland and Parsons (1972). Primary productivity was

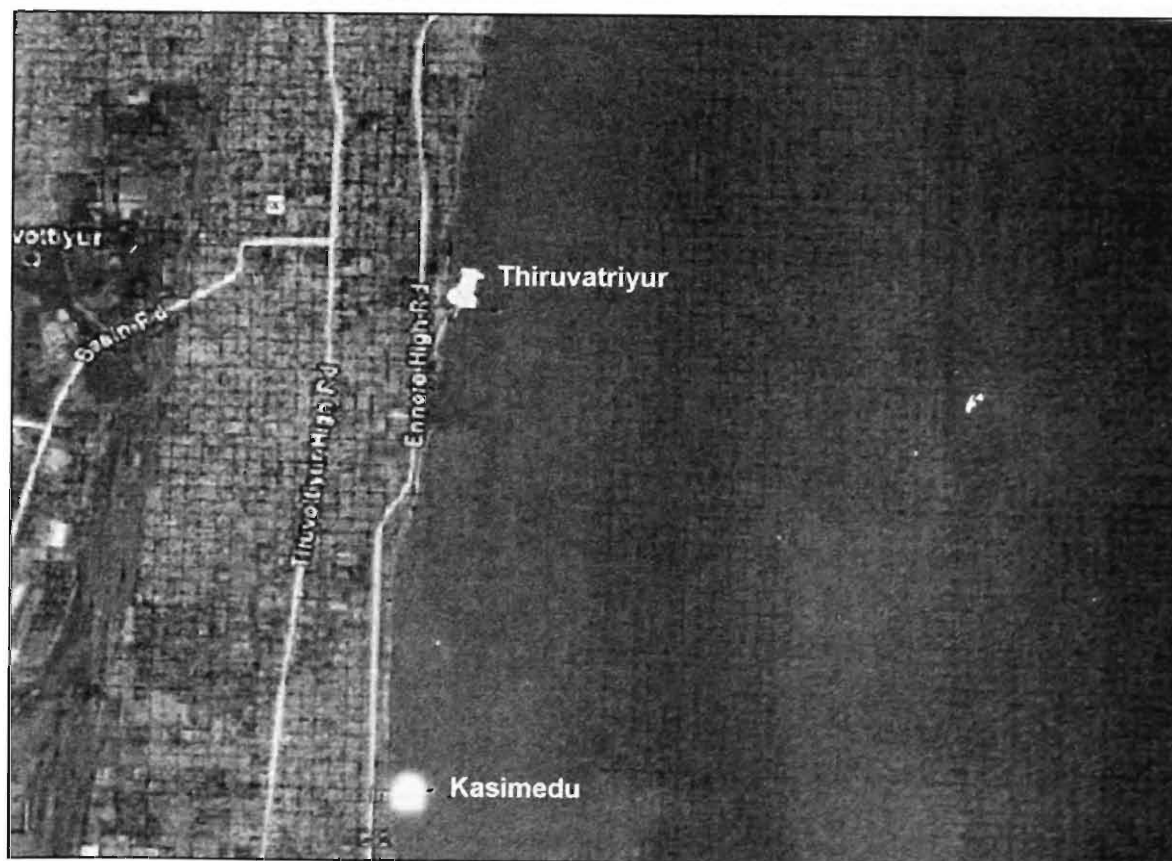


Fig. 1. Map showing the study area

estimated by adopting the light and dark bottle technique (Stickland and Parsons, 1972).

RESULTS AND DISCUSSION

During the present study monthly variation of physico-chemical parameters, like temperature (air and surface water), LEC, salinity, pH, dissolved oxygen, inorganic nitrate, nitrite, inorganic phosphate, reactive silicate, particulate organic carbon, biological oxygen demand, chemical oxygen demand and biological parameters (phytoplankton) were recorded for a period of six months from January to June 2007 and the values are given below (Fig. 2-18).

Air temperature ranged from 28 to 34°C. The minimum temperature (28°C) was recorded in January at station 2 and the maximum (34°C) in the month of May, at both the stations (Fig. 2). In the present study, the peak values of air temperature were recorded during the summer (May). The surface water temperature varied from 25° to 31°C. Minimum surface water temperature (25°C) was recorded during the

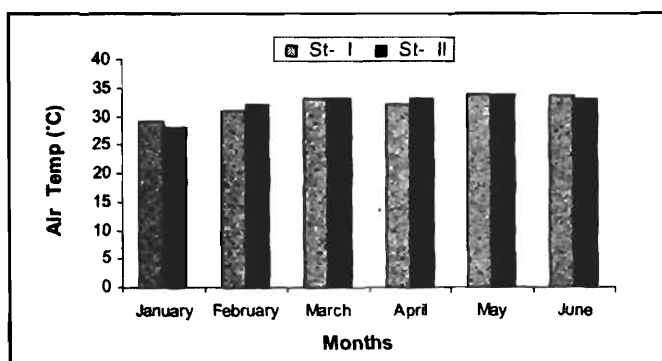


Fig. 2. Monthly variations in air temperature at stations 1 and 2

month of February, at station 1 and the maximum (31°C) in the month of May, at both the stations (Fig. 3). Generally, surface water temperature is influenced by the intensity of solar radiation, evaporation, fresh water influx and cooling mix up with ebb and flow from adjoining neritic waters. The water temperature was high during summer could be attributed to high solar radiation (Govindasamy *et al.*, 2000; Santhanam and Perumal, 2003; Thillai Rajasekar *et al.*, 2005; Saravanakumar *et al.*, 2008a,b). The observed spatial variation in

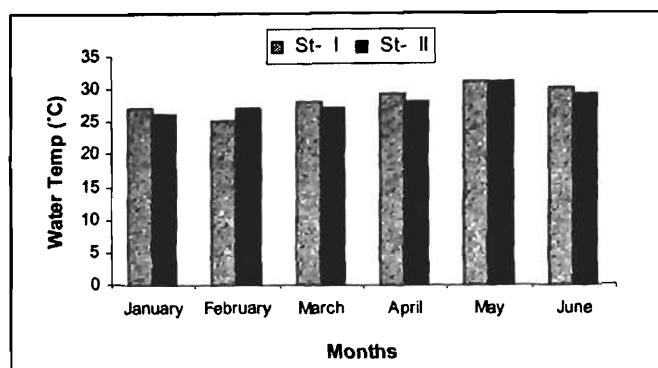


Fig. 3. Monthly variations in surface water temperature at stations 1 and 2

temperature could be due to the viable intensity of prevailing streams and the resulting mixing of water (Reddi *et al.*, 1993). The salinity values ranged from 32 to 36 ppt. Minimum salinity (32 ppt) was recorded during the month of January, at station 2 and the maximum salinity (36 ppt) in the month of May and June at station 1 (Fig. 4). Presently, wide salinity variations were observed between two stations in different seasons. The salinity was found to be high in summer and low in post monsoon in both the

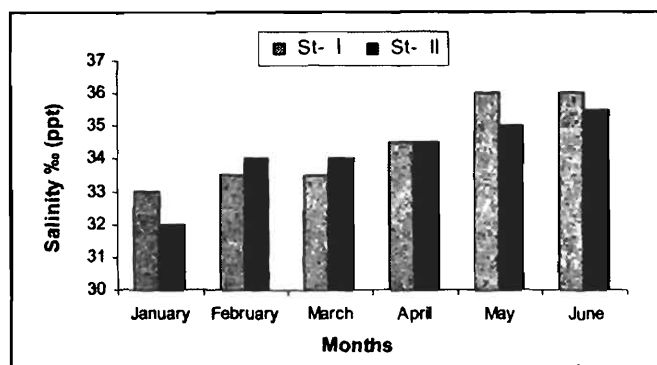


Fig. 4. Monthly variations in salinity at stations 1 and 2

stations. The recorded higher values could be attributed to the low amount of rainfall, higher rate of evaporation and also due to neritic waters dominance, as reported by earlier workers in other areas (Gowda *et al.*, 2001; Rajasegar 2003 and Ashok Prabu *et al.*, 2008). The hydrogen ion concentration (pH) values varied from 7.7 to 8.6. Minimum value (7.7) was recorded during the month of January, at station 2 and maximum value (8.6) in the month of May and June, at station 1 and May, at station 2 (summer season) (Fig. 5). Hydrogen ion concentration (pH) in surface waters remained alkaline through out the study period at both the stations with maximum during summer season. The uptake CO_2 by the

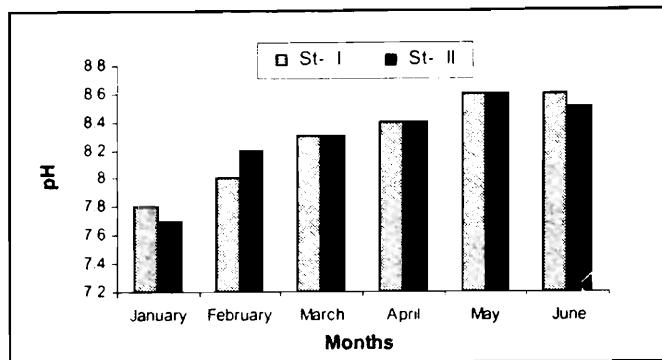


Fig. 5. Monthly variations in pH recorded at stations 1 and 2

photosynthesizing organisms especially phytoplankton from the sea water could have increased pH levels during summer season and high biological activity (Das *et al.*, 1997; Saravanakumar *et al.*, 2008 a,b). Dissolved oxygen concentration varied from 4.9 to 6.4 ml/l. Minimum oxygen concentration (4.9 ml/l) was recorded during the month of May, at station 1 and the maximum (6.4 l/l) in the month of January, at station 2 (Fig. 6). The observed high post monsoonal values might

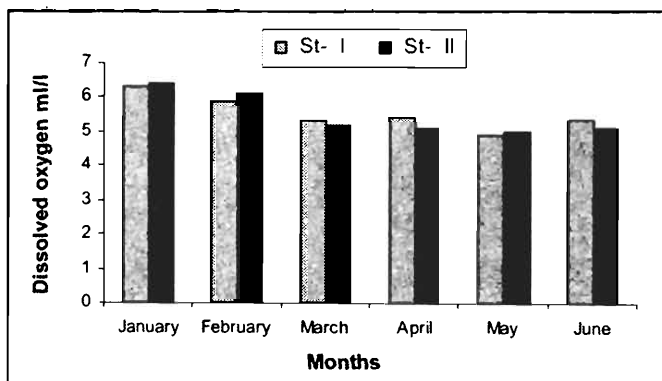


Fig. 6. Monthly variations in Dissolved oxygen recorded at stations 1 and 2

be due to the cumulative effect of higher wind velocity coupled with rainfall and the resultant fresh water mixing (Mitra *et al.*, 1990 and Rajkumar *et al.*, 2009). The light extinction coefficient varied from 5.1 to 6.9. Minimum value (5.1) was recorded during the month of February (post monsoon), at station 1 and the maximum (6.9) in the month of June (Summer season), at station 2 (Fig. 7).

Nutrients

Nutrients are considered as one of the most important parameters in the marine

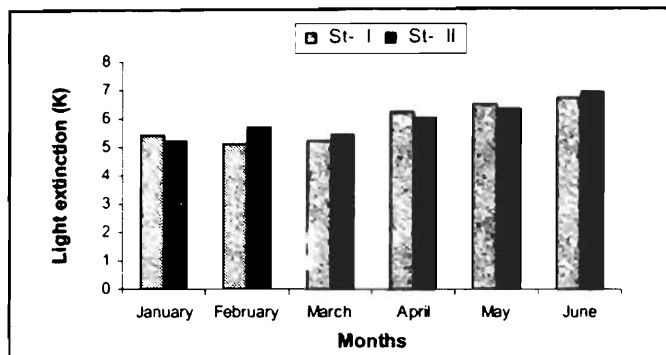


Fig. 7 Monthly variations in light extinction coefficient recorded at stations 1 and 2

environment influencing growth, reproduction and metabolic activities of living beings. Distribution of nutrients is mainly based on the season, tidal conditions and fresh flow from the land source. The nitrate concentration varied from 1.82 to 29.22 μM . Minimum nitrate concentration (1.82 μM) was recorded during the month of June (summer), at station 1 and the maximum (29.22 μM) recorded in the month of February (Post monsoon), at station 2 (Fig. 8). The possible way of nitrates entry is through oxidation of ammonia from nitrogen to nitrite formation (Rajasegar, 2003). Low values of nitrates during summer may be due to its utilization by phytoplankton as evidenced by high photosynthetic activity and also due to the neritic water dominance, which contained only negligible amount of nitrate (Rajashree Gouda and Panigrahy, 1993; Das *et al.*, 1997 and Ashok Prabu *et al.*, 2008). The nitrite concentration varied from 1.48 to 12.14 μM .

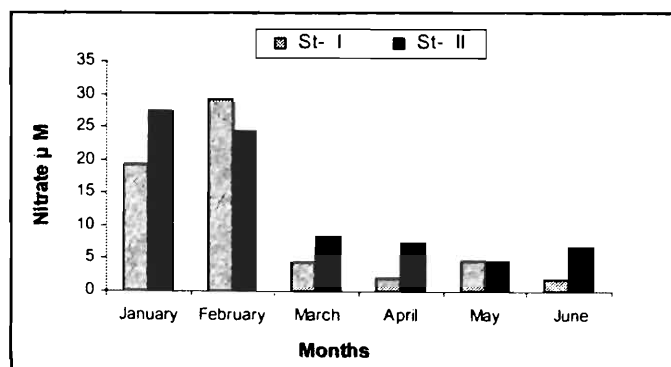


Fig. 8. Monthly variations in nitrate recorded at stations 1 and 2

Minimum nitrite concentration (1.48 μM) was recorded during the month of June (summer), at station 1 and the maximum (12.14 μM) recorded during the month of February (post

monsoon), at station 1 (Fig. 9). Low value of nitrite during summer may be due to less fresh water inflow and high salinity (Murugan and Ayyakkannu, 1991 and Ashok Prabu *et al.*, 2008). Further, denitrification and air-sea interaction exchange of chemicals are also

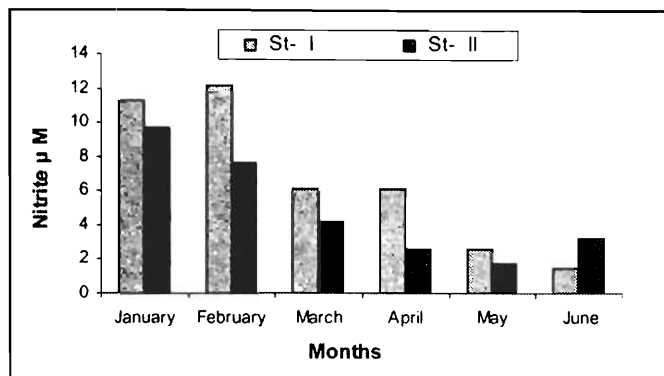


Fig. 9. Monthly variations in nitrite recorded at stations 1 and 2

responsible for this increased value (Choudhury and Panigrahy, 1991). The inorganic phosphate concentration varied from 2.04 to 11.2 µM. Minimum phosphate concentration (2.04 µM) was recorded during the month of May (summer), at station 2 and the maximum (11.2 µM) in the month of January (post monsoon) at station 1 (Fig. 10). The variation may also be due to the processes like adsorption and desorption of phosphate and buffering action of sediment under varying environmental conditions (Rajasegar, 2003 and Ashok Prabu *et al.*, 2008). Moreover, the

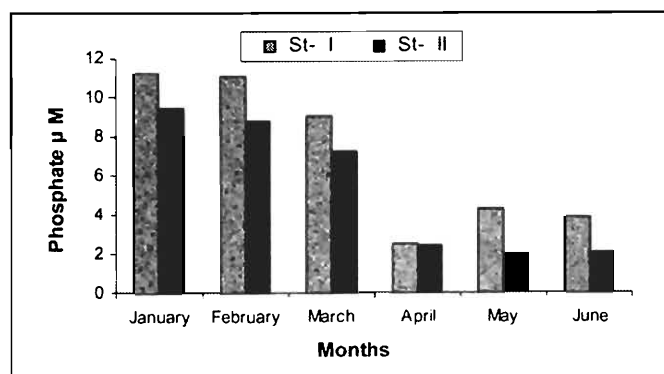


Fig. 10. Monthly variations in inorganic phosphate recorded at stations 1 and 2

weathering of rocks soluble alkali metal phosphate, the bulk which are carried in to the estuaries are also responsible for the higher values of phosphate (Gowda *et al.*, 2001). The reactive silicate concentration varied from 2.78

to 56.09 µM. Minimum reactive silicate concentration (2.78 µM) was recorded during the month of April (summer), at station 1 and the maximum (56.09 µM) during the month of February (Post monsoon) at station 1 (Fig. 11). The silicate content was higher than the other nutrients (Nitrate, Nitrite and Phosphate), due to the turbulent nature of water, the silicate from the bottom sediment might have been

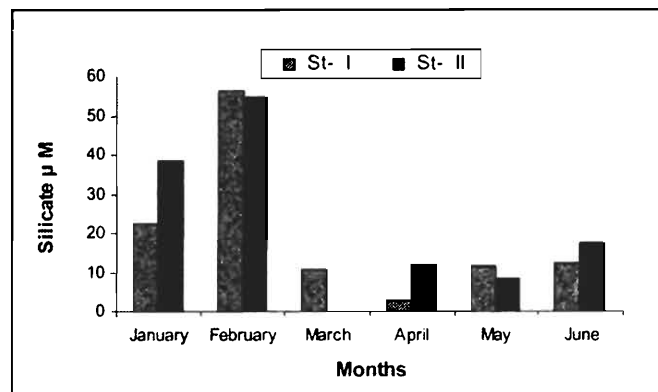


Fig. 11. Monthly variations in reactive silicate recorded at stations 1 and 2

exchanged with overlying water (Rajasegar, 2003). The low values during the summer could also attributed to uptake of silicates by phytoplankton for their biological activity (Saravanakumar *et al.*, 2008a, b).

Phytoplankton

A total of 114 species of phytoplankton were identified in the present study period from both the stations. Of which, 89 species belong to diatoms (Bacillariophyceae), 16 species to dinoflagellates (Dinophyceae), 5 species to blue-greens (Cyanophyceae) and 4 species greens (Chlorophyceae) (Table 1). At station 1, 63 species of diatoms, 9 species of dinoflagellates, 3 species of blue-greens and 2 species of greens constituting a total of 77 species were recorded. At station 2, 75 species of diatoms, 12 species of dinoflagellates, 3 species of blue-greens and 4 species of greens constituting a total of 94 species were recorded. Phytoplankton species numbering 37 (26 species of diatoms, 7 species of dinoflagellates, 2 species of blue-greens and 2 species of greens) were restricted to station 1 whereas 20 species (14 species of diatoms, 4 species of dinoflagellates and 2 species of blue-greens) were restricted to station 2. Species

Table 1. Check list of phytoplankton species recorded from January to June 2007 at stations 1 and 2

Sl. No.	Name of the species	St. I	St. II
	<i>BACILLARIOPHYCEAE (DIATOMS)</i>		
1	<i>Achnanthes brevipes</i>	+	+
2	<i>Amphiprora</i> sp.	+	+
3	<i>Amphora coffeaeformis</i>		+
4	<i>A. ovalis</i>		+
5	<i>A. proteus</i>		+
6	<i>Asterionella glacialis</i>	+	+
7	<i>Bacillaria paradoxa</i>	+	+
8	<i>Bacteriastrum</i> sp.	+	
9	<i>B. hyalinum</i>	+	
10	<i>B. delicatulum</i>	+	+
11	<i>B. varians</i>		+
12	<i>B. comosum</i>	+	+
13	<i>Bellerochea malleus</i>	+	
14	<i>Biddulphia</i> sp.	+	
15	<i>Biddulphia obtuse</i>		+
16	<i>B. heteroceros</i>	+	+
17	<i>B. mobiliensis</i>	+	+
18	<i>Chaetoceros messanensis</i>	+	+
19	<i>C. curvisetus</i>		+
20	<i>C. indicus</i>		+
21	<i>C. affinis</i>	+	+
22	<i>C. debilis</i>	+	
23	<i>C. diversus</i>	+	+
24	<i>C. brevis</i>		+
25	<i>C. orientalis</i>	+	+
26	<i>Coscinodiscus granii</i>	+	
27	<i>C. thori</i>	+	
28	<i>C. ecentricus</i>	+	+
29	<i>C. gigas</i>		+
30	<i>C. centralis</i>	+	+
31	<i>C. radiatus</i>	+	+
32	<i>C. lineatus</i>	+	+
33	<i>Coscinodiscus</i> sp.		+
34	<i>Cyclotella stelligera</i>		+
35	<i>Cyclotella</i> sp.	+	+
36	<i>Ditylum brightwelli</i>	+	+
37	<i>D. sol</i>	+	
38	<i>Ditylum</i> sp.		+
39	<i>Diploneis smithii</i>	+	+

Table 1. Contd.

Sl. No.	Name of the species	St. I	St. II
40	<i>D. interrupta</i>		+
41	<i>Fragilaria intermedia</i>	+	
42	<i>F. oceanica</i>	+	+
43	<i>Guinardia</i> sp.		+
44	<i>Gyrosigma balticum</i>	+	+
45	<i>Gyrosigma</i> sp.	+	+
46	<i>Hemidiscus</i> sp.	+	
47	<i>Leptocylindrus danicus</i>		+
48	<i>Leptocylindrus</i> sp.	+	+
49	<i>Lithodesmium undulatum</i>		+
50	<i>Melosira sulcata</i>		+
51	<i>Melosira</i> sp.	+	
52	<i>Navicula henneydii</i>	+	+
53	<i>N. capitata</i>	+	+
54	<i>N. clavata</i>		+
55	<i>N. gracilis</i>	+	+
56	<i>N. granulata</i>	+	+
57	<i>N. hasta</i>	+	+
58	<i>N. indica</i>		+
59	<i>N. longa</i>	+	+
60	<i>Nitzschia longissima</i>	+	+
61	<i>N. pungens</i>		+
62	<i>N. seriata</i>	+	+
63	<i>N. closterium</i>	+	+
64	<i>N. filiformis</i>	+	+
65	<i>N. obtusa</i>		+
66	<i>N. paradoxa</i>	+	+
67	<i>Pinnularia</i> sp.	+	
68	<i>Planktoniella sol</i>	+	+
69	<i>Pleurosigma elongatum</i>	+	+
70	<i>P. normani</i>	+	+
71	<i>P. directum</i>	+	+
72	<i>P. angulatum</i>	+	+
73	<i>P. aestuarii</i>	+	+
74	<i>P. balticum</i>	+	+
75	<i>Rhizosolenia setigera</i>		+
76	<i>R. styliiformis</i>	+	+
77	<i>R. cylindrus</i>		+
78	<i>R. imbricata</i>	+	
79	<i>R. alata</i>		+

Table 1. Contd.

Sl. No.	Name of the species	St. I	St. II
80	<i>R. robusta</i>	+	+
81	<i>Skeletonema costatum</i>	+	+
82	<i>Skeletonema</i> sp.	+	+
83	<i>Stephanopyxis</i> sp.	+	+
84	<i>Synedra</i> sp.	+	
85	<i>Thalassionemnitzschoides</i>	+	+
86	<i>Thalassiothrix frauenfeldii</i>		+
87	<i>Thalassiothrix longissima</i>	+	+
88	<i>Triceratium favus</i>	+	+
89	<i>Triceratium reticulum</i>		+
	DINOPHYCEAE (DINOFLAGELLATES)		
90	<i>Ceratium macroceros</i>	+	
91	<i>C. furca</i>	+	+
92	<i>C. lineatum</i>		+
93	<i>C. tripos</i>		+
94	<i>C. longipes</i>	+	+
95	<i>C. fusus</i>		+
96	<i>C. trichoceros</i>	+	+
97	<i>Dinophysis caudata</i>	+	
98	<i>Dinophysis</i> sp.		+
99	<i>Gymnodinium</i> sp.	+	+
100	<i>Noctiluca</i> sp.	+	
101	<i>Prorocentrum micans</i>		+
102	<i>Protoperdinium ceanicum</i>		+
103	<i>P. elegans</i>	-	+
104	<i>P. depressum</i>	+	
105	<i>P. divergens</i>	+	+
	CYANOPHYCEAE (BLUE GREENS)		
106	<i>Anabaena</i> sp.	+	+
107	<i>Lyngbya</i> sp.	+	
108	<i>Merismopedia</i> sp.		+
109	<i>Oscillatoria</i> sp.	+	
110	<i>Trichodesmium</i> sp.		+
	CHLOROPHYCEAE (GREENS)		
111	<i>Desmidium simplex</i>	+	+
112	<i>Pediastrum duplex</i>		+
113	<i>Pediastrum</i> sp.		+
114	<i>Protococcus</i> sp.	+	+

Table 2. List of various hydrographical and phytoplankton composition during January to June 2007 at stations land 2.

Parameters	Stations	Jan	Feb.	Mar	Apr.	May	June
Air temperature (°C)	I	29	31	33	32	34	33.5
	II	28	32	33	33	34	33
Water temperature (°C)	I	27	25	28	29	31	30
	II	26	27	27	28	31	29
Light extinction (K)	I	6.7	6.5	6.2	5.2	5.1	5.4
	II	6.9	6.3	6	5.4	5.7	5.2
Salinity ‰ (ppt)	I	33	33.5	33.5	34.5	36	36
	II	32	34	34	34.5	35	35.5
pH	I	7.8	8	8.3	8.4	8.6	8.6
	II	7.7	8.2	8.3	8.4	8.6	8.5
Dissolved oxygen (ml/l)	I	6.3	5.9	5.3	5.4	4.9	5.3
	II	6.4	6.1	5.2	5.1	5	5.1
Primary productivity (gm cm ³ /hr)	I	1.02	0.84	1.14	1.26	1.36	1.28
	II	0.98	0.86	0.88	1.67	1.42	1.26
Chlorophyll (Mgm ⁻³)	I	0.76	0.56	0.84	1.52	2.44	2.04
	II	0.77	0.74	1.42	2.11	2.32	2.01
Silicate (µM)	I	22.43	56.09	10.71	2.78	11.34	12.34
	II	38.32	54.41	29.27	11.72	8.17	17.38
Phosphate (µM)	I	11.2	11.04	9.03	2.47	4.22	3.88
	II	9.42	8.77	7.19	2.37	2.04	2.07
Nitrate (µM)	I	19.34	29.22	4.32	2.11	4.72	1.82
	II	27.41	24.41	8.27	7.44	4.53	6.78
Nitrite (µM)	I	11.26	12.14	6.11	6.15	2.56	1.48
	II	9.68	7.61	4.17	2.56	1.8	3.27
Phytoplankton Population density (cells/l)	I	14,800	18,600	17,900	24,000	31,500	29,000
	II	9,000	14,200	17,300	22,800	23,000	22,700
Sp. diversity	I	3.25	3.62	3.6	4.12	4.31	4.14
	II	3.02	3.24	3.56	4.05	4.06	4.1
Sp. Richness	I	1.12	1.17	1.16	1.72	1.95	1.75
	II	0.91	1.1	1.15	1.68	1.69	1.67
Sp. Evenness	I	0.98	0.96	0.98	0.98	0.98	0.98
	II	1	0.97	0.97	0.97	0.97	0.98
Sp. Dominance index	I	20.74	20.21	19.17	20.14	16.08	17.24
	II	25.61	21	19.28	18.29	21.71	18.07

numbering 57 (49 species of diatoms, 5 species of dinoflagellates, 1 species of blue-greens and 2 species of greens) were found at both the stations.

In the present study, diatoms formed the dominant group followed by dinoflagellates, blue-greens and greens at both the stations.

Percentage contribution of each group of phytoplankton was thus in the decreasing order as follows : Diatoms > Dinoflagellates > Blue-greens > Greens. In station 2 recorded more percentage of diatoms and dinoflagellates than station 1. Phytoplankton species composition was more at station 2 (sea) than at station 1. At

both stations, the dominant forms were the diatoms and dinoflagellates. Similar observations of diatom domination amidst various groups of phytoplankton were made by Thangaraj (1984) and Vasantha (1989) from the Portonova waters, Murugan (1989) from the Cuddalore Uppanar backwaters, Ananthan (1991) from the Parangipettai and Cuddalore marine environs, Patterson Edward and Ayyakkannu (1991) from the Kollidam estuary, Kannan and Vasantha (1992) and Mani (1992 and 1994) from the Pitchavaram mangroves, Govindasamy (1992) from the Coromandel coast, Sampathkumar (1992) from the Tranquebar - Nagapattinam coast and Murugan and Ayyakkannu (1993) from the Cuddalore-Uppanar backwaters.

Phytoplankton population density varied from 9,000 to 31,500 cells. Minimum density (9,000 cells l⁻¹) was recorded during the month of January (post monsoon), at station 2 and the maximum (31,500 cells) during the month of May (summer), at station 1 (Fig. 12). High phytoplankton population density and species diversity were observed during the summer season at both the stations. The phytoplankton population density was maximal (31,500 cells at station 1 and (23,000 cells at station 2) during the month of May (summer season). This could be attributed to the increased salinity, pH, temperature, dissolved oxygen and more intensity of light, prevailed during the month of May (summer). The higher density during the summer season especially coincided with the lower concentration of nutrients and this might be due to the utilization of the phytoplankton (Ananthan, 1995). In general, the

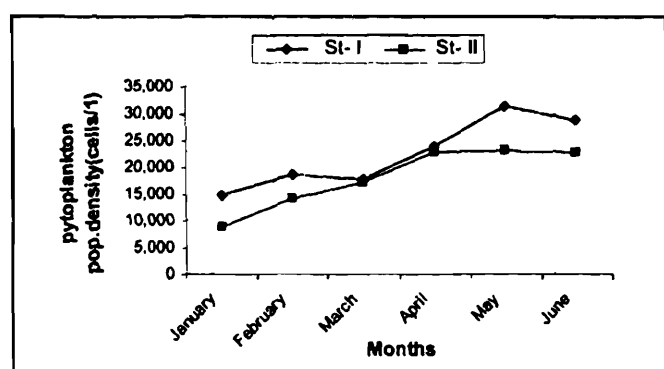


Fig. 12. Monthly variations in phytoplankton population density recorded at stations 1 and 2

population density recorded during the present investigation was lesser than the density reported earlier from various other marine environs (Anbazhagan, 1988; Vasantha, 1989; Patterson Edward and Ayyakkannu, 1991; Saraswathi, 1993; Mani, 1994; Ananthan, 1995; Geetha Madhav and Kondalarao, 2004 and Ananthan *et al.*, 2008).

The species diversity index (H') varied from 3.02 to 4.31. The minimum species diversity (3.02 bits/ind) was observed during the post monsoon season. The maximum species diversity (4.31 bits/ind) was observed during the summer season (Fig. 13). The species diversity values reported now are similar to the values obtained by Patterson Edward and

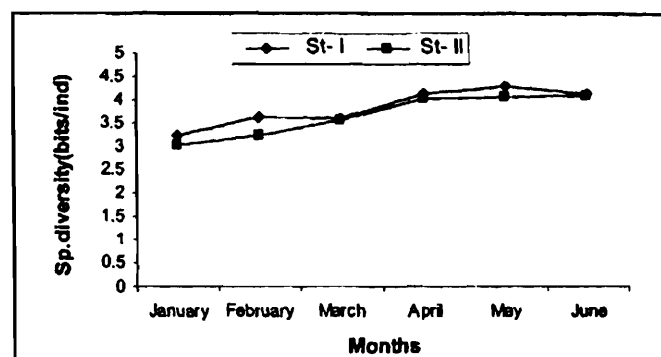


Fig. 13. Monthly variations in species diversity recorded at stations 1 and 2

Ayyakkannu (1991) in the Kollidam estuary. The species richness varied between 0.91 and 1.95. Minimum species richness (0.91) was noticed during January (post monsoon), at station 2 and the maximum (1.95) in May (summer) at station 2 (Fig. 14). Species richness was maximum (1.95) during the summer season. These values are comparatively lesser than the values reported earlier by Saraswathi

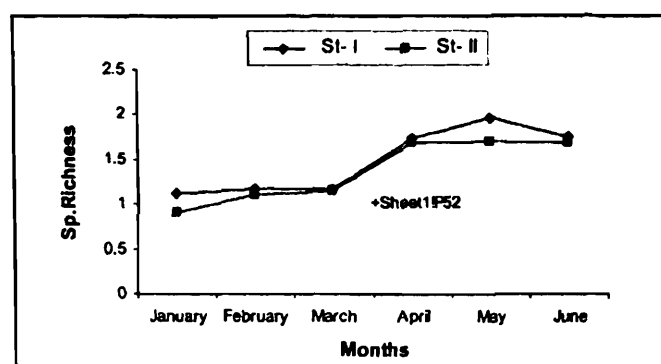


Fig. 14. Monthly variations in species richness recorded at stations 1 and 2

(1993) from the Arasalar and Kaveri estuaries. The species evenness index (j') was found to be between 0.96 and 1.0. Minimum species evenness index (0.96) was recorded during the month of February (post monsoon) and the maximum (1.0) during the month of January (post monsoon), at station 2 (Fig. 15). Species dominance index (d) was found to be between 16.08 and 25.61. Minimum dominance index (16.08) was recorded during the month of May (Summer) at station 1 and the maximum (25.61) during the month of January (post monsoon), at station 2 (Fig. 16).

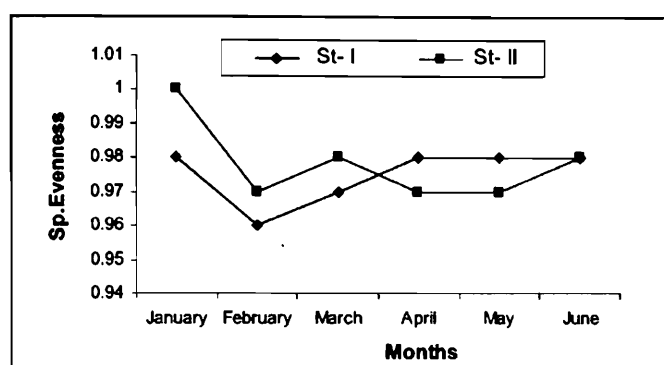


Fig. 15. Monthly variations in species evenness recorded at stations 1 and 2

during the month of January (post monsoon), at station 2 (Fig. 16). Species dominance index was maximal during the post monsoon season coincided with lower population density, lower species diversity and lower species richness.

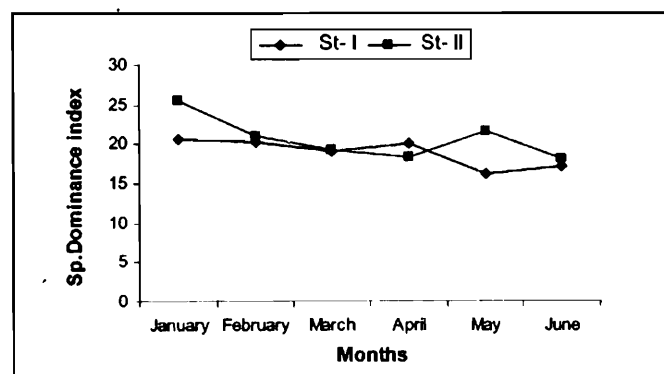


Fig. 16. Monthly variations in Species dominance index $\bar{d}$ recorded at stations 1 and 2

The chlorophyll 'a' concentration varied from 0.56 to 2.44 mg m^{-3} . Minimum concentration (0.56 mg m^{-3}) was recorded during the month of February (post monsoon), at station 1 and the maximum (2.44 mg m^{-3}) in May (summer), at station 1 (Fig. 17). Chlorophyll 'a' is the principal photosynthetic pigment responsible for primary production in

the aquatic realms. In the present study, chlorophyll 'a' concentration was low during the month of February (post monsoon) and higher (summer) in May (summer), coinciding

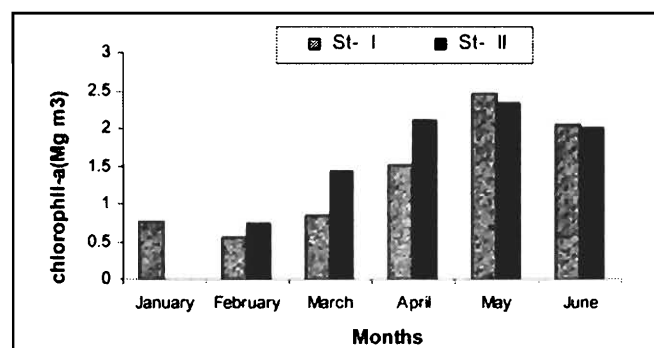


Fig. 17. Monthly variations in chlorophyll 'a' recorded at stations 1 and 2.

with lower (post monsoon) and higher (summer) population density gross primary productivity respectively. Low value of chlorophyll 'a' was observed during post monsoon season due to heavy rain, low light intensity and high turbidity water. In general, distribution of chlorophyll 'a' closely followed the phytoplankton cell counts and the maximum value was obtained during peak the phytoplankton population density as reported by Gouda and Panigrahy (1989) and Akpan and Offem (1993). Similar observations have been made by Satyanarayana *et al.*, (1990) from Vishkapatnam harbour, Selvaraj *et al.*, (1990) and Ananthan *et al.*, (2008) from the Pondicherry coast. The primary productivity varied from 0.84 to 1.67 g C m^{-3} . Minimum productivity (0.84 g C m^{-3}) was recorded during the month of February (post monsoon), at station 1 and the maximum (1.67 g C m^{-3}) in the month of April (summer), at station 2 (Fig. 18). The maximum values of gross primary

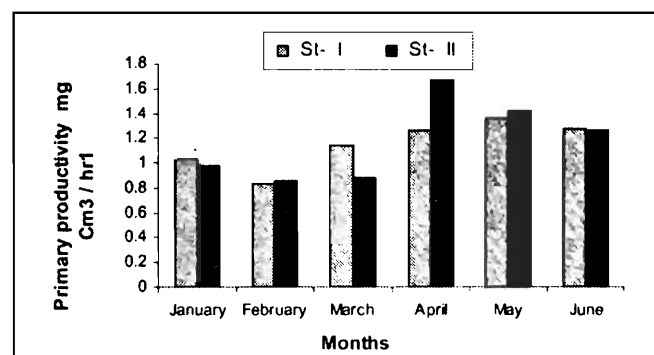


Fig. 18. Monthly variations in primary productivity recorded at stations 1 and 2

production were reported in May (summer) and the minimum value was recorded in January (post monsoon), because of low salinity and low population density. Similar values were recorded from the Tranquebar-Nagapattinam coast (Sampathkumar, 1992), Pondicherry coast (Ananthan, 1995) and Vellar estuary (Rajasegar *et al.*, 2000).

SUMMARY AND CONCLUSION

During the present investigation, hydrographical parameters, phytoplankton composition and community structure (species composition, population density, species diversity, species richness, species evenness, species dominance index, chlorophyll 'a' and primary production) carried out in two consecutive seasons (post monsoon and summer) in the Chennai coastal waters (two stations) along the southeast coast of India revealed the following trends.

The physico-chemical parameters were subjected wide monthly variations. During the present study, maximum level of physico-chemical parameters, like atmospheric temperature, surface water temperature, salinity and pH were recorded during the summer season than post monsoon season, at both the stations. High concentration of LEC, dissolved oxygen, inorganic nitrate, nitrite, inorganic phosphate and reactive silicate were recorded during the post monsoon season at

both the seasons. A total of 114 species of phytoplankton were identified the present study period from both the stations in which, 89 species belong to diatoms (Bacillariophyceae), 16 species to blue-greens (cyanophyceae) and 4 species greens (chlorophyceae) (Table 1).

The maximum phytoplankton population density. Chlorophyll a and primary productivity were registered during the summer seasons. Maximum species diversity, species richness, species evenness were recorded during the summer season at both stations. Minimum species diversity, species richness, species evenness were recorded during the post monsoon season at both the stations. The maximum species dominance index was noticed during January (post monsoon). Of the two stations, more nitrite, inorganic phosphate, reactive silicate population density, species density, species richness and chlorophyll 'a' concentration were recorded at station 1 than at station 2.

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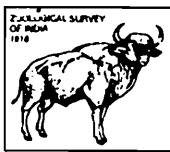
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OCCURRENCE OF GREEN NOCTILUCA SCINTILLANS BLOOMS IN COASTAL WATERS OF GULF OF MANNAR MARINE BIOSPHERE RESERVE, INDIA

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INTRODUCTION

Sea surface near the coast becomes bright red in a very short period due to massive blooms of phytoplankton. Blooms of Cyanobacteria and Dinoflagellata often cause such major problems in fresh water and marine habitats respectively. Sieburth (1979) reported blooms of *Olisthodiscus* of Chrysophyta and *Phaeocystis* of Prymnesiophyceae in coastal waters (Sieburth, 1979). *Noctiluca* a substantial bloom-forming marine dinoflagellate in the ocean was reported uncommon in coastal waters of India. The red water phenomenon has been reported from several areas and often associated with mass mortality of fish and other marine organisms. In Indian waters the occurrence of this phenomenon due to *Trichodesmium* has been observed chiefly in the Arabian sea off Mangalore (Prabhu *et al.*, 1965), in West Coast (Prakash and Sarma, 1964), Gulf of Mannar (Chacko, 1942; Chidambaram and Mukundan Unny, 1944), and East Coast (Ramamurthy and Seshadri, 1966; Daniel *et al.*, 1976). Most of these blooms have been attributed to the *Trichodesmium erythraeum*, a blue green algae or to the *Chattonella marina* or *Gonyaulax polygramma*, raphidodphytes. Similarly, occurrence of the blooms of *Noctiluca scintillans*

was reported in the Arabian sea off Mangalore (Katti *et al.*, 1988), West Coast (Naqvi *et al.*, 1998; Sahayak *et al.*, 2005) East Coast (Iyer, 1936; Sargunam *et al.*, 1989; Mohanty *et al.*, 2007) and in Andaman and Nicobar islands (Eashwar *et al.*, 2001; Dharani *et al.*, 2004). These blooms in association with other green flagellates.

Although several instances of phytoplankton blooms in the coastal waters of the Indian Ocean have been reported, there has been no report of 'red tide' formation by *Noctiluca scintillans* in Gulf of Mannar Marine Biosphere Reserve. During the second week of October 2008 areas in and around Mandapam and the Kilakkarai group of islands of the Gulf of Mannar have borne the brunt of devastation caused by the abnormal blooming of *Noctiluca scintillans* (Fig. 1). The present survey was conducted during and after blooming to assess the water quality changes, the effect of blooming on the marine bio-diversity.

STUDY AREA

Gulf of Mannar Marine Biosphere Reserve

Gulf of Mannar Biosphere Reserve extends from Rameswaram island to Tuticorin in direction and lies between 8°45'N-9°25'N and

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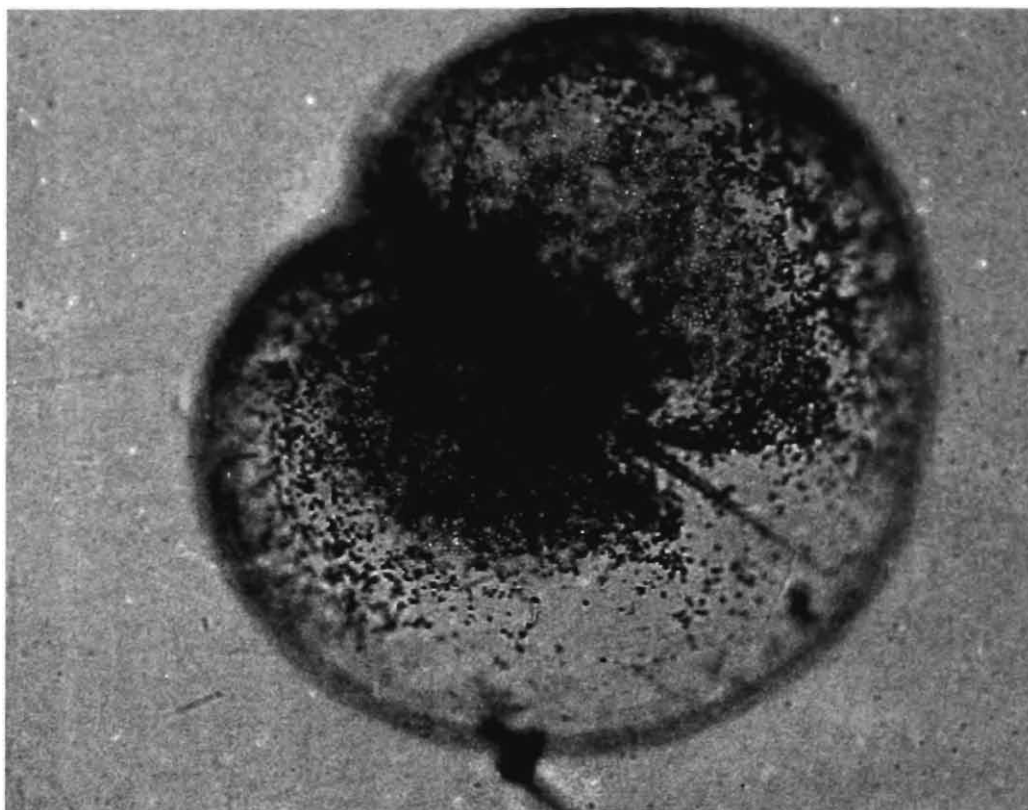


Fig. 1. Microscopic view of *Noctiluca scintillans*

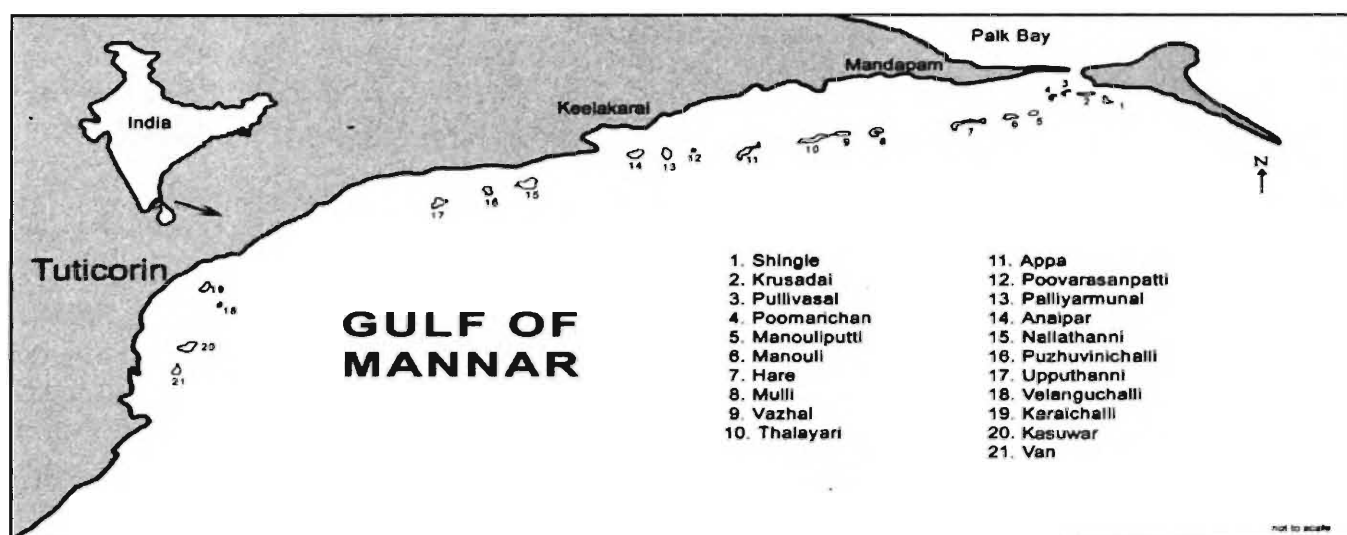


Fig. 2. Gulf of Mannar Marine Biosphere Reserve

78°5' E - 79°30' E, extends to a distance of 140 km. There are 21 islands running almost parallel to the coastline of Mannar. These islands lie are situated between 8°47'N - 9°15'N and 78°12'E-79°14' E and at an average distance of about 8km from the coastline of Gulf of Mannar. It is bounded by Palk Bay, Rameshwaram Island in the north side; by Ramanathapuram district in the northwest and west Tuticorin district in the south and by Bay of Bengal in the east (Fig. 2). It is endowed

with three distinct ecosystems namely corals, sea grass and mangroves.

Gulf of Mannar experiences a tropical climate under the spell of both southwest and northeast monsoons. However, southwest monsoon contributes little while north east contributes moderate to heavy rainfall during October to mid-December with occasional gales. The mean annual rainfall varies from 762 mm to 1270 mm. The period from January to

May is marked by hot climate. Wind direction is north-northeasterly from June to December and changes to westerly during the period. The wind speed is lowest in November and high in August.

The Ocean currents in Gulf of Mannar area are swift. The sea is rough between April and August and calm during September and stormy during June to August. Tidal amplitude area is about half the meter. At Pamban the tides are irregular, owing to the wind force.

The drainage system in the coastal part of Gulf of Mannar consists of Vaigai, Kappali, Kottanguli river, Gundar, Vembar and Kallar and its tributaries. The trend of the river from NW to SE. Vaigai and Vaippar are the biggest rivers in the study area. All rivers in the study area are non-perennial and get water only during rainy.

MATERIALS AND METHODS

Ten sampling points were fixed along the coast from Mandapam to Earvadi. Surface sea water samples were collected from the surface using clean bottles and analysed for various physicochemical parameters such as temperature, salinity and pH, using standard methods. Temperature was measured using a mercury thermometer having a resolution of

0.1°C. Phytoplankton density was measured using Utermohl's sedimentation technique and counted using Sedgwick-Rafter counting chamber, with the aid of an inverted microscope. Phytoplankton was identified by following standard taxonomic monographs.

RESULTS AND DISCUSSION

Physio-chemical properties of water

The results of the physio-chemical parameters of the water and density of *Noctiluca scintillans* are presented in the table 1. The temperature varied from 27°C to 29°C. A maximum temperature (29°C) was observed in areas viz Indra Nagar, Periapattanam and Vazhai theevu where blooming occurred while minimum temperature (27°C) was recorded at areas where no blooms. Salinity and pH also showed such similar trend. Salinity varied from 32 to 34 and pH from 8.2 to 8.4 ppt. The density of *Noctiluca* is usually a few hundred cells/litre but it has gone up to 12.7 lakh cells/litre. It was reduced 800×10^5 in and around Periapattanam during the survey period. The dissolved oxygen level which used to be 5-6 ml/litre has gone down to as low as 0.64 ml / litre during the blooming period.

The outbreak of 'red tide' phenomenon caused by blooming of *N. scintillans* has

Table 1. Variations of density of *N. scintillans* and physio-chemical parameters observed in the sea water of various places in Gulf of Mannar during bloom in 2008

Sl. No.	Name of the station	Density of <i>N. scintillans</i>	Temperature °C	Salinity	pH
1.	Kumaranthoppu, Vedhalai,	0×10^5	27	32	8.2
2.	Seeniappa Dharka, Naval Base	15.75×10^5	27	32.3	8.2
3.	Nochiyoorani	3.33×10^5	27	32.3	8.2
4.	Pudhumadam	55.5×10^5	27	32	8.2
5.	Indra Nagar	800×10^5	29	34	8.2
6.	Periapattinam	346.5×10^5	29	34	8.4
7.	Kalimankundu	370×10^5	28	34	8.4
8.	Vazhatheevu	51×10^5	29	34	8.4
9.	Keelakari	46.66×10^5	27	34	8.4
10.	Erwadi	6×10^5	29	32	8.2

considerably reduced the oxygen level which probably would have depleted considerable marine fauna. The situation was very bad in Vazhatheevu, where mortality was very high and it might be the centre of *Noctiluca* bloom. Sea water around 50 km radius of Periapattinam look green and muddy in patches. The species is colourless but the presence of photosynthetic green endosymbiont is responsible for the green colour sea water. The colour of the sea might change to pinkish red or orange depending upon the endosymbiont of the species, the green-coloured water was observed along the 50 km coast from Mandapam to Keelakarai

Impact on the biodiversity

The origin of the bloom was from Periyapattinam and it had spread to several areas from Keelakari to Thonithurai. The depletion of dissolved oxygen in marine water causing breathing problems for many fish species resulted in their death during the blooming days. Fish species such as Rabbit fish, Parrot fish, Goat fish, serranis, silverbellies, surgeon fishes and other benthic fishes, mostly associated with coral reefs were affected by the blooming of dinoflagellate. Thousands of varieties of marine animals including highly endangered Sea turtle *Chelonia mydas*, edible/ornamental fishes, eels (Moray), crabs, sea horses, sea anemones, lobsters, sea cucumbers (*Holothuria atra*) and urchins and bivalves (*Donax faba*, *D. cuneatus*, *Fustinus colus* and *Babylonia spirata*) were washed ashore along Mandapam – Keelakarai stretch. The lagoon areas of the islands are awash with dead fishes of all sizes and varieties. Coral species such as *Acropora cythera*, *Acropora nobilis* and *Monitpora digitata* also have been bleached in Vazhai island and Mulli island.

Dinoflagellates causing mortality of fish and other marine animals have been recorded for the Calicut coast in 1922 by Hornell and Ramasamy Naidu. Many bottom forms get loosened and float up to the surface. Large numbers of bottom inhabiting sipunculids (Peanut worm) were washed ashore in Periapattinam and this could be accounted for

only by some such explanation as the one given above. Similar observation was already made in Madras coast during 1935 by Aiyar (1936).

CONCLUSION

Although Dinoflagellate bloom was reported several times in various coastal regions of India, it was reported first time in Gulf of Mannar during the second week of October 2008. It is suspected, as the sea was rough during those days, that there have been violent currents, churning the bottom of the sea, affecting the fish in the area. The mortality of fishes and other organisms was due to the putrefaction and pollution caused by the dead algae and the clogging of the gills with the consequent asphyxiation and related hydrobiological disturbances should have been supplemental factors. Bright sunshine could also have been responsible for the swarming of the algae in large patches by the acceleration of the photosynthetic activity. When it was cloudy the absence of sunlight, the thick layer of floating algae and increase in temperature the water had caused the death of the algae and polluted the waters causing the liberation of the offensive smell. With light showers during subsequent days the dead algae had settled down to the bottom and the balance in the water was restored.

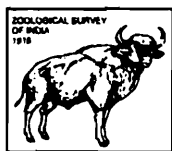
Sudden dilution of salinity in coastal waters by addition of freshwater as drain-off from land during heavy rains. The addition of large quantities of nutrients either by upwelled oxygen-depleted water or by land drainage. The possibility in sudden increase of certain external metabolites or growth factors due to the presence and interaction of microorganisms and phyto-zoo plankton constituents promoting an increase in cell division.

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ANTIBACTERIAL, TOXIC AND HAEMOLYTIC ACTIVITY OF THE SPONGE, *CALLYSPONGIA (CLADOCHALINA)* *DIFFUSA* (RIDLEY, 1884)

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INTRODUCTION

Sponges have colonized all aquatic habitats, and belong to the Phylum Porifera, which occupies a taxonomic position in between single celled 'Protozoa' and the most advanced triploblastic animals. They suspend in water and also actively filter the food particles and are therefore known as filter feeders. Hence, they are called "*Porifera*" or Pore Bearers (Latin : Porus-Pore; Fera - Bearing). In many benthic (sea bottom) region, sponges are often the dominant groups (Hooper, 2000). In addition to their ecological importance in coral reef ecosystem and on the soft sea bed, sponges are the exciting resources of new therapeutic compounds with potential values to the pharmaceutical industries. Though they are sedentary (sessile) animals with lack of movement to escape and protect themselves from potential predators, they have developed special structural ornaments, so called "spicules" and they also secrete toxic substances as their main weapon of defense. Those toxic substances received much attention from the public, biochemist and pharmacologists as they are the potentially useful drugs. The pioneer work on sponge nucleoside by Mayer and Hamann (2005) play a major role in promoting the search of

bioactive substances from marine sponges. Some of the toxic substances extracted from marine sponges were proved to have beneficial pharmaceutical effect on respiratory, cardiovascular, gastrointestinal, anti-inflammatory, antitumour, and antibiotic activities in humans.

Among the 15,000 species found to exist, taxonomists have scientifically described 8000 species of sponges in and around the world. Most of them are found in marine environment except the family Spongillidae, which are seen in freshwater ponds and lakes (Dendy, 1887-89; Annandale 1914-1915; Burton, 1930). In the Gulf of Mannar and Palk Bay region (Southeast coast of India) 275 species have been reported by Thomas (1968), belonging to the class Demospongiae. Over 60 per cent of potentially useful compounds discovered so far from living organisms have been obtained from marine animals, out of which 70 per cent are from sponges. The drug potential of the 'wonder compounds' from sponges triggered off a worldwide interest in those groups. Sponges have a remarkable power of growing into complete sponges and so the potential for aquaculture of sponges is also great, thus to meet the demand for natural product extraction.

The discovery of Arabinose nucleotides from the sponge *Cryptotethya crypta* de Laubenfels (Valid name: *Tethya crypta*) with biomedical properties has contributed to world wide interest in biochemistry of this group in general. This discovery led to the use of this compound as a potent antiviral and antitumor drug and both are currently in clinical uses viz., ara A (9-B-D-arabinofuranosylalanine) and ara-C (1-B-D-arabinosillaytosine) (Lazarus and Anita Mary, 2000). Mycalamide-A from the sponge *Mycale* sp. Halichondrin-B from the sponge *Halichondria okadai*, Averone and Averol from the sponge, *Dysidea* sp. Dercitin from the sponge, *Dercitus* sp., Aerophysinin-1 from the sponge *Aplysina aerophoba* and *Ianthella ardis* are all promising compounds and their trials are not at various stages. These are all antitumor and cytotoxic compounds which have been isolated from sponges.

Bacteria, fungi and viruses can easily invade any sponge and a few with biomedical potentials (anti HIV, anti HSV₁, HSV₂, VSV₃ and etc.) are now under clinical trials. All these indicate that bioactive compounds are developed to compact ecological stress created by various intruders.

In India, various chemicals are being screened for chemicals with a view to develop 'wonder drugs'. Considering the pivotal role of sponges in the study of marine product chemistry, the innumerable new compounds with biomedical potentials were isolated from sponges in recent years. The sponges are said to be the richest sources of bioactive compounds, but researches were being carried out so far regarding their pharmacological properties. Scanty Richet (1906) has observed that, alcoholic extract of the marine sponge, *Suberites domunculus*, when injected, was toxic to some laboratory animals and they prepared a toxin from the extract, which he called "suberitine". When suberitine was injected intravenously, dogs or rabbits developed vomiting, diarrhea, prostration, intestinal hemorrhages and respiratory distress. The present study was carried out to assess the toxicity assay (LD₅₀) and antibacterial activities

from a sponge species (*Callyspongia (cladochalina) diffusa*).

MATERIALS AND METHODS

The species of marine sponges *Callyspongia (cladochalina) diffusa* (Class: Demospongiae) were collected from the shallow waters of the Palk Bay region (Lat. 9°17' N Long. 79°17'): Gandhi Nagar, southeast coast of India. Specimens were collected by using skin diving from Gandhi Nagar of Palk Bay region southeast coast of India. In the present study, the toxicity, haemolytic activity and antibacterial activities of the crude extract of *Callyspongia (cladochalina) diffusa* were studied against ten species of human pathogenic bacteria such as *Staphylococcus aureus*, *Salmonella typhi*, *Salmonella paratyphi*, *Klebsiella oxytoca*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Proteus mirabilis*, *Lactobacillus vulgaris*, *Vibrio cholera* and *Klebsiella pneumoniae*.

Preparation of crude extracts

The initial aqueous methanol extract was concentrated in the laboratory under reduced pressure and the lyophilized powder was extracted with 1 : 1 mixture of methanol and dichloromethane. At the same time, the methanol soaked, cut pieces (100 g) were further diced and extracted with the same mixture of solvents with desired concentrations. These concentrations were prepared by mixing the known amount of crude extract in a carrier solvent, acetone (w/v) and then subjecting them to larvicidal and insecticidal screening.

Preparation of erythrocyte suspension

Haemolytic activity of crude toxin was tested against goat and chicken blood. The blood samples were collected from the respective animals by using 2.7 percent EDTA anticoagulant at 5 percent of the volume of blood. The blood samples were centrifuged at 5,000 rpm for 7 minutes with normal saline (pH 7.2). The supernatant was discarded and the RBC pack was resuspended in normal saline. This process was repeated thrice and finally, the concentrate was obtained from the final RBC pack which was used to prepare 1

percent RBC suspension (Venkateshwara Rao *et al.*, 2003).



Fig. 1. *Callyspongia (cladochalina) diffusa*

Haemolytic assay

A series of two fold dilution of the toxin (100 ml) was made using normal saline (pH 7.2), starting from the first well to last well with proper mixing. An equal volume of 1 per cent RBC suspension (1 ml of RBC pack mixed in 99 ml of 0.9 per cent saline) was prepared and was added to each well. The plate was gently shaken and was allowed to stand for two hours at room temperature and the results were documented. Appropriate controls (positive and negative) were also included in the titer plate. The reciprocal of the highest dilution of the toxin showing haemolytic activity was taken as one hemolytic unit (HU). The formation of a compact button at the bottom of the well indicated a negative haemolytic activity.

Toxicity assay and determination of LD 50

The lethal and paralytic activities were studied in the Ocypode crab, *Ocypode macrocera* (Fig. 2). Crabs weighing 5 ± 2 g were collected from the seashore of Parangipettai coast. A crude toxin of sponge species, (*C. diffusa*) was injected into the collected crabs, at the junction of body and chelate leg. A group of five animals were given various doses. 0.25, 0.50, 0.75, 1.0ml of crude toxin stock solution was prepared and the effect of these concentrations on the colour change, foaming, paralytic effect and restlessness of the crabs were also observed.



Fig. 2. Showing the crab, *Ocypode macrocera*

Anti bacterial susceptibility assays

The extract was tested for inhibition of bacterial growth against ten human pathogenic bacteria. Microbial assay were carried out by the well diffusion technique in Petri dishes (Kelman *et al.*, 2001). Inocula of overnight cultures of each bacterial strain were streaked on the surface of Muller Hinton agar plates. Then 20 μ l of the extract was pipetted inside the well and the solvent was allowed to evaporate. The well was then placed on the surface of an inoculated agar. The test plates were incubated for 24 hrs at 37°C and the solvent controls were performed in each case. Areas of inhibited bacterial growth were observed as clear halos (zones) around the wells.

RESULTS AND DISCUSSION

Haemolytic Activity

The results of the haemolytic activity tests showed a very good hemolytic effect in the first wells of goat blood and two wells in chicken blood with the haemolytic effect of 32 HU/g and 16 HU/g respectively (Fig. 3). The methanol extract of *callyspongia diffusa* induced pronounced haemolysis on chicken and goat erythrocytes. The present result confirms those of earlier studies; Stempien (1970), who reported the haemolytic activity halitoxin of genus. Fusetani *et al.*, (1981) reported that the sterol derivatives from halichondriidie sponges *viz.*, possessed haemolytic activity Mebs *et al.*,

(1985) reported the haemagglutination and haemolytic activity of aqueous extract from 48 tropical sponge species. Thus the result of the present study indicate that, haemolytic activity being the indicator of cytotoxicity, makes the extract of *Callyspongia diffusa* worthwhile to for further study for the antitumor/antineoplastic activities. This might ultimately lead to the detection of anticancer compounds.

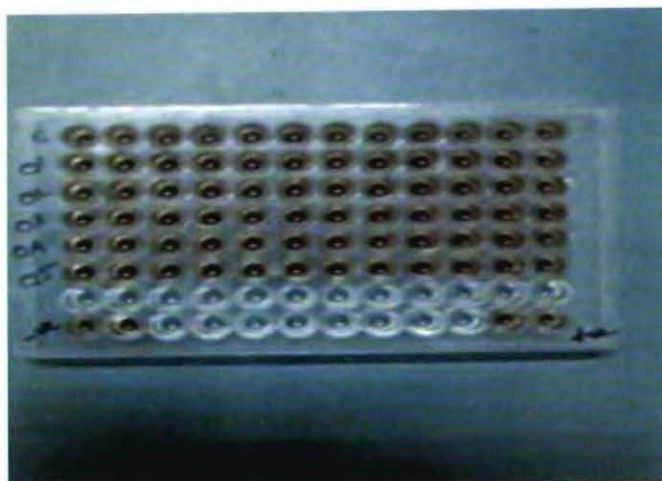


Fig. 3. Haemolytic assay with goat blood and chicken blood

Toxicity Assay

The minimum lethal dose of venom extracted from *C. diffusa* was found to be 0.05ml per 5 ± 2 g crab (*O. macrocera*). The result of the further observations made on the colour change of the crab foaming paralytic effect and restlessness of the crabs were given in table 1. The response of Ocypode crab injected with crude extract venom (Fig. 4 and 5) in the present study was similar to that of the result of coelenterate toxin done by Lane and Dodge (1988) and of alptasia toxin by Blanquet (1968).

King *et al.*, (1989) have noticed the same effect on drosophila files for hydrozoa toxin. The extract may contain an enzyme, acid protease and this was associated with the crab lethality. Collagen has been already reported from invertebrates such as the crab, *Uca pugilator* by Eisen *et al.*, (1973). Nuclear alteration and dissolution of intercellular collagen was as a result of collagenase, protease and lectin



Fig. 4. Injection of crude toxin



Fig. 5. Foaming of crab

Table 1. Toxicity assay and determination of LD 50

Sl. No.	Concentration (5 mg/ml)	No. of animals	Observation				
			Death within 30 min	Colour change	Foaming	Paralytic effect	Restlessness
1	0.25	10	Nil	+	-	+	+
2	0.50	10	Nil	+	-	+	-
3	0.75	10	10	+	+	+	-
4	1.00	10	10	+	+	-	-

Plate 1



1. *Staphylococcus aureus*



2. *Salmonella typhi*



3. *Salmonella paratyphi*



4. *Klebsiella oxytoca*



5. *Pseudomonas aeruginosa*

Plate 2



6. *Escherichia coli*



7. *Proteus mirabilis*



8. *Lactobacillus vulgaris*



9. *Vibrio cholerae*



10. *Klebsiella pneumoniae*

activities of the extract. Lethal proteins caused action channel formation in cell membranes and this channel formation may be the mechanism of toxic action of venom. Due to the above investigation, the presence of collagenase of well as channel forming proteins in the venom might be the cause for this death. The present results suggest that, the toxicity may depend on the concentration of the extract.

Antibacterial activity of *C. diffusa*

The methanol extract of *C. diffusa* was found to be active against the ten species of bacterial pathogens under study (Plate 1 and 2). The inhibition zone ranged from 7mm to 10mm. Maximum inhibition zone was (10mm) against *Pseudomonas aeruginosa* and *Salmonella paratyph*, while the minimum inhibition zone was (7mm), against *Salmonella typhi* and *Klebsiella Pneumoniae*. The zone of inhibition was about 9 mm against *Pseudomonas aeruginosa* and no inhibition zones of growth against other three bacterial strains were found. The crude extract was thus tested for antibacterial activity and the result showed that, the extract inhibited the growth of *Vibrio cholerae*. But, in the saline extract, a clear inhibition zone was observed against the pathogen. Bergquist and Bedford (1978) suggested that the antibacterial agents produced by sponges may have a role in enhancing the efficiency which retain bacterial food and also reported the indicated that activity was higher in temperate species than tropical species (87 per cent as opposed to 58 per cent) and sponge extract more frequently

inhibited the growth of marine bacteria. The present study revealed that the crude extract inhibited the bacterial colonies.

CONCLUSION

In the present investigation, antimicrobial lethal and haemolytic activity of sponge (*Callyspongia diffusa*) extract tested. The extract obtained from, *Callyspongia diffusa*, showed (concentration 2 per cent, 4 per cent, 6 per cent, 8 per cent) haemolytic and antibacterial activity. The extract was tested against bacterial pathogens like *Lactobacillus vulgaris*, *Proteus mirabilis*, *Klebsiella pneumoniae*, *Salmonella typhi*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*, showed species specific antibacterial activity. The extract derived from sponge (*Callyspongia diffusa*) also contains a toxic component which was tested against the crab, *Ocypode macrocera* it causes tetany of the leg muscles, which results in paralysis and death. This activity was found to be dosage dependent. The same extract also showed against Chicken and Goat erythrocytes. This has to be further investigations.

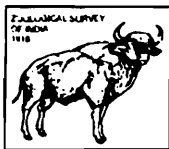
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OCCURRENCE AND BIOMEDICAL APPLICATIONS OF TUNICATE, *PHALLUSIA NIGRA* SAVIGNY 1816, FROM TUTICORIN COAST, INDIA

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INTRODUCTION

The study of marine organisms as a source of biologically active compound is considered a very lucrative field, having already led to the discovery of various new pharmacological tools and medicines (Bhakuni, 1994; Munro *et al.*, 1999 and Faulkner, 2000). The great biodiversity found in marine environments is one of the most important phenomena (De Vries and Beart, 1995; and Munro *et al.*, 1999). Studies performed at the United States National Cancer Institute have shown that marine organisms show a higher incidence of cytotoxic compounds than any other zoological group (Munro *et al.*, 1999).

Tunicates, comprising the Ascidians; commonly called Sea squirts (Subphylum: Urochordata, Class Ascidiacea) are dominant organisms in many marine communities, having a wide geographic distribution (Seed and O'Connor, 1981; Schmidt and Warner, 1986; Todd and Turner, 1988; Teo and Ryland, 1994). Tunicates are filter feeders that live as sessile benthic animals or passive floaters in the

planktonic layers (Melvin *et al.*, 2000). Among the marine organisms, the ascidians belonging to the families of Didemnidae and Polycitoridae have most prolific sources of biologically active compounds (Watters and Van den Brenk, 1993). Many authors explained the ecological success on the basis of the ability of these animals to synthesise secondary metabolites, which possess an important defensive role against predation. Some ascidians such as *Phallusia nigra* have chemical defence system, high vanadium content and an acidic tunic protection from predators (Stoecker, 1980). In addition, other species of tunicates are also a source of important anti-viral, anti-tumour and anti-leukemic compounds (Kobayashi *et al.*, 1988; Rinehart *et al.*, 1983).

MATERIALS AND METHODS

Specimen Collection, Identification and Extraction

Bulk samples (680 gms. in wet wt.) of *Phallusia nigra* Savigny, 1816 were collected as common and persistent biofoulants from the

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cement blocks, pilings and pearl oyster cages of Tuticorin coast (Lat. 8°47'20" and Long. 78° 09' 70"), Tamil Nadu, India by SCUBA diving at the depth ranging from 4 to 6 m between May and June, 2008. Species were identified by Dr. V.K. Meenakshi (sample reference Voucher No # AS 2140). The freshly collected specimens were soaked in methanol at the site of collection until workup. The initial methanol extract was decanted and the ascidian material was extracted with 1:1 DCM/MeOH (3 x 0.5 L) at room temperature. The combined extract including initial methanol extract was filtered, the solvent was removed under reduced pressure to give predominantly an aqueous suspension and it was extracted with ethyl acetate (3 x 0.5 L), concentrated under reduced pressure to give a dark brown gummy mass (13.5 gms). This crude extract was further studied for biological activities.

Protein estimation

Protein content was estimated by following Bradford *et al.* (1976). The freeze dried tissues of *P. nigra* were grounded into a fine powder using mortar and pestle. The Standard protein sample was prepared at 2 mg/mL of BSA. The assay relies on the binding of the dye Coomassie Blue G 250 to the protein molecule measured colorimetrically at 595 nm. Dilutions of protein standards with concentrations of 20,

40, 60, 80 and 100 µg/100 µL were assayed. The amount of protein is showed in Table 1.

Table 1. Cytotoxicity of *P. nigra* extracts against *Artemia salina* larvae

S. No.	Extracts	LC ₅₀ (µg mL ⁻¹)
1.	Control (DMSO + Saline)	-
2.	Crude	130
3.	Methanol	145
4.	Dichloromethane	67
5.	2-Ethoxy Ethanol	35
6.	Acetone	69
7.	n-Butanol	52
8.	Ethylacetate	21
9.	Diethyl ether	43

Bioassays

Extracts of *Phallusia nigra* were tested for hemolytic assay, cytotoxicity using brine shrimp lethality assay, analgesic, CNS depressant activity, paw edema formation and antibacterial activities.

Hemolytic assay

Crude and 1:1 DCM/MeOH extracts were assayed on chicken, goat and human erythrocytes (A, B, AB and O blood groups)

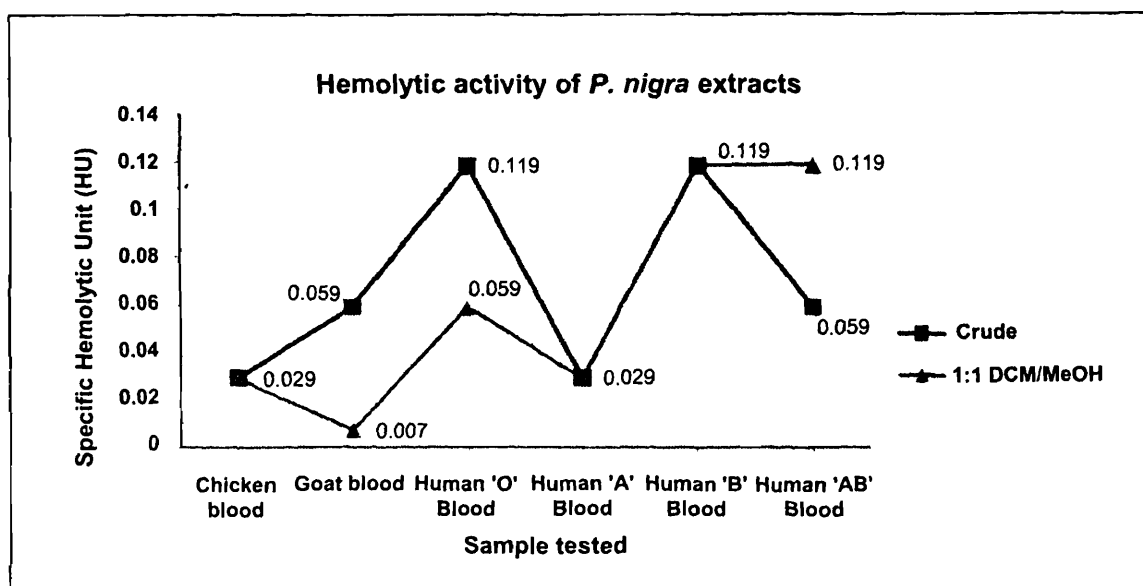


Fig 1. The extent of *in vitro* hemolytic activity of *Phallusia nigra* toxin on chicken, goat and human erythrocytes

followed by Pani Prasad and Venkateshvaran, (1997). Chicken and goat blood were obtained from the nearby slaughterhouse in Parangipettai, while the human blood was obtained from the local hospital using 2.7 per cent ethylenediaminetetraacetic acid (EDTA) solution as an anticoagulant at 5 per cent of the blood volume and immediately brought to the laboratory. The blood was centrifuged thrice at 5,000 rpm for five minutes 1 per cent erythrocytic suspension was prepared for hemolysis assay.

Cytotoxicity using brine shrimp lethality assay

Cytotoxic effects on *Artemia salina* (brine shrimp) lethality assay was followed by Meyer *et al.* (1982). The Crude, Methanol, Dichloromethane, 2-Ethoxy ethanol, Acetone, n-Butanol, Ethylacetate and Diethyl ether extracts were tested by dissolving the extracts in 100 μ L of DMSO and incorporated into 5 ml of sea water. Each concentration (10, 20, 40, 60, 80 100 μ g/mL) was tested thrice and a control DMSO was done each time. The LC_{50} values of brine shrimp were obtained from counts using the probit analysis method described by Litchfield and Wilcoxon (1949).

Analgesic activity

Tail-flick method

Analgesic activity was measured according to the method described by D'amour and Smith (1941) using Tail Flick Analgesia Meter (Harvard, USA 50-9495, 230 V and 50 Hz) with a variable 150 W, 25 v lamp as the heat source. During the testing period the rats were restrained in a plastic tube, to which they had

been previously adapted twice (10 min) a day for three days. The tail flick latency was recorded as the time onset of stimulation to the withdrawal of the tail from a light beam. The beam of the light was focused on some spot, at about 6 cm from the tip of the tail of each animal. The crude and 1:1 DCM/MeOH extracts were dissolved in DMSO at the dose of 5 mg/kg of body weight and then injected *i.p.* to rats. Rats without administration of any toxin or known painkiller was used as control while those injected *i.p.* with paracetamol (Crocine[®] at 0.25mL/170 $\pm$ 2 gm) will serve as reference standards.

Hotplate method

Hot plate method was described by Eddy and Leimbach (1953). In this method, animals were individually placed on a hotplate and maintained for 55 °C. Reaction of animals such as paw licking or jump response was taken as an end point. Extracts were injected at dose level of 5 mg/kg of body weight was injected *i.p.* to mice (20 $\pm$ 2 gm).

CNS depressant activity

The CNS depressant activity was followed by Dews, (1953) and Kulkarni & Dandiya (1975) using Actophotometer (Medicraft, Model No: 600 M-6 D S.No. PA-0135). Male albino mice (20 $\pm$ 2 gm) were housed with a 12:12 hour dark - light cycle. The concentrations of extract were 2 mg/kg of body weight. A mouse without administration of any toxin or known painkiller was used as control while those injected *i.p.* with paracetamol (Crocine[®] at 0.25 ml) served as reference standard. The basal

Table 2. Analgesic activities in terms of tail flick response of *P. nigra* extract at 5 mg.kg⁻¹ of 170 $\pm$ 20 g male rats

Sl. No.	Intensity of light (lux)	Treatment	Response time before extract injection (Sec)	Response time (Sec) after extract injection				
				15 min	30 min	45 min	60 min	120 min
1.	5	Control	2.6	3	4	6	5	4
2.	5	Crocine [®]	3.4	3	4	3	2	2
3.	5	Crude	5.0	5	6	4	3	3
4.	5	1:1 MeOH/DCM	5.2	4	5	5	6	3

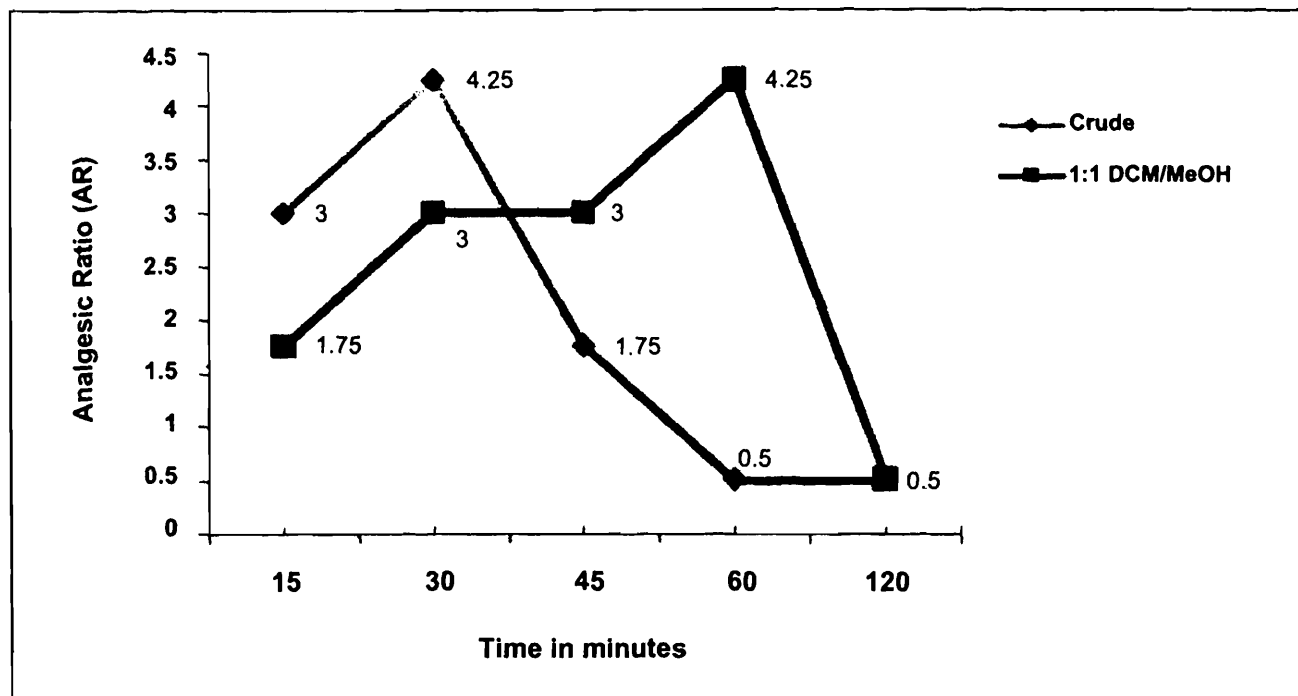


Fig 2. Analgesic ratio in terms of tail flick response of the *P.nigra* extract at specific time intervals

reaction time and administration of crude extracts after 15, 30, 45, 60 and 120 min were noted and percentage decrease of motor activity represented.

Paw Edema formation

Paw edema formation was measured by according to Smith (2002). A group of two mice in each case was injected subplantarily with

0.1 μ L of the crude toxin in the right footpad and with 0.1 mL of buffered saline in the left footpad. Two hours after injection, percentage of size increase was measured and the growth of the envenomated paw relative to the saline-injected paw was taken as the edema ratio (ER). The minimum edematous dose was defined as the dose causing 105 per cent ER.

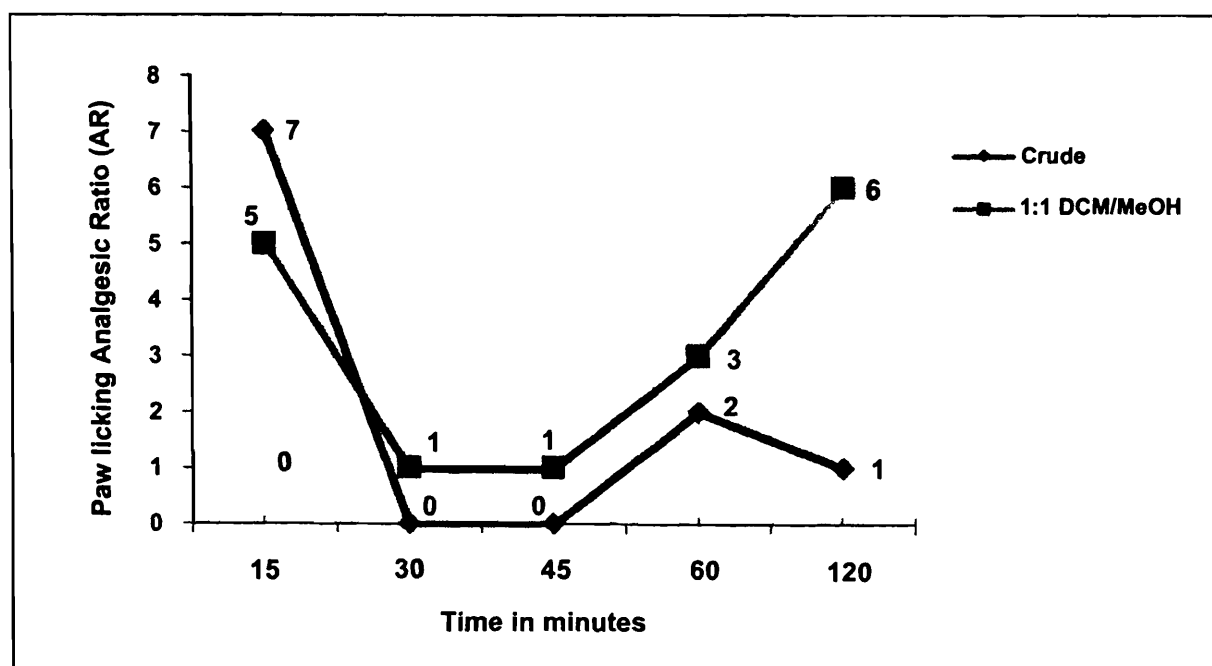
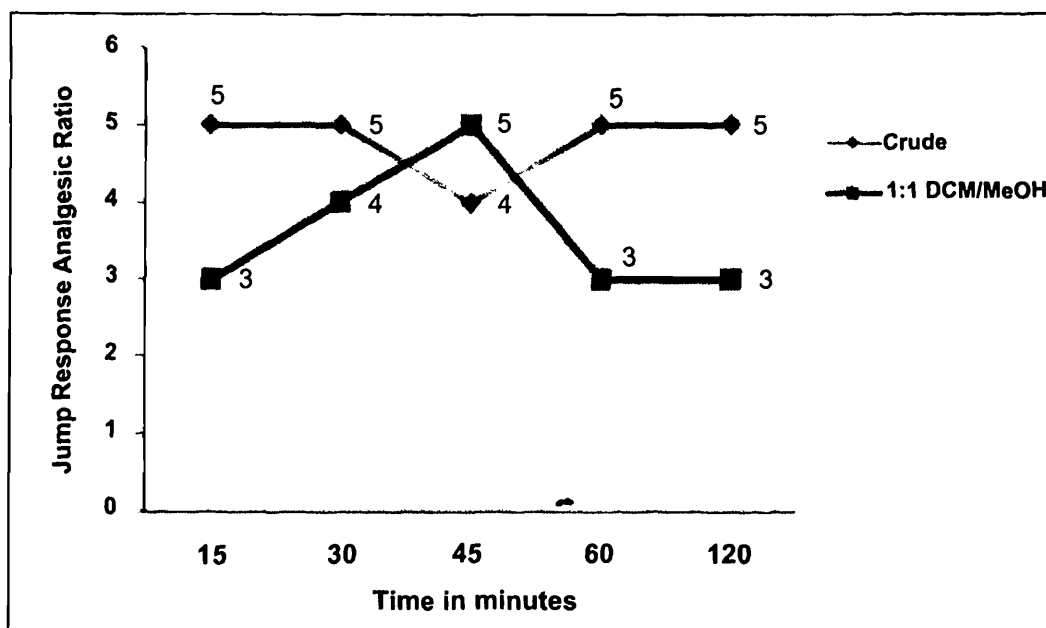


Fig 3. Analgesic ratio (Hot plate method) in terms of paw licking of the *P.nigra* extract at specific time intervals

Table 3. Analgesic activities in terms of Hotplate response of *P.nigra* extract at 2 mg.kg⁻¹ of 20 ± 2 g male albino mouse

Sl. No.	Treatment	Basal reaction time (Sec)		Reaction time (Sec) after extract administration									
				Paw licking					Jump Response				
		Paw licking	Jump Response	15 min	30 min	45 min	60 min	120 min	15 min	30 min	45 min	60 min	120 min
1.	Control	2		3	2	2		3	2	1	3	3	2
2.	Standard	3	4	3	4	2	2	3	4	3	2	2	3
3.	Crude	2	8	9	2	2	4	3	7	7	6	7	7
4.	1:1MeOH/DCM	3	6	7	3	5	8	2	5	6	7	5	5

**Fig 4.** Analgesic ratio (Hot plate method) in terms of jump response of the *P.nigra* extract at specific time intervals

Antimicrobial activity

Antibacterial test

Crude, Methanol, Dichloromethane, 2-Ethoxy ethanol, Acetone, Chloroform, n-Butanol, Ethylacetate and Diethyl ether extracts were tested against human and shrimp pathogenic bacteria by standard disc-diffusion assay followed by McCaffrey and Erdean (1985). All extracts were tested twice at a concentration of 2 mg of crude extract was dissolved in 50 µL of each extract per disc.

Preliminary characterization of compound

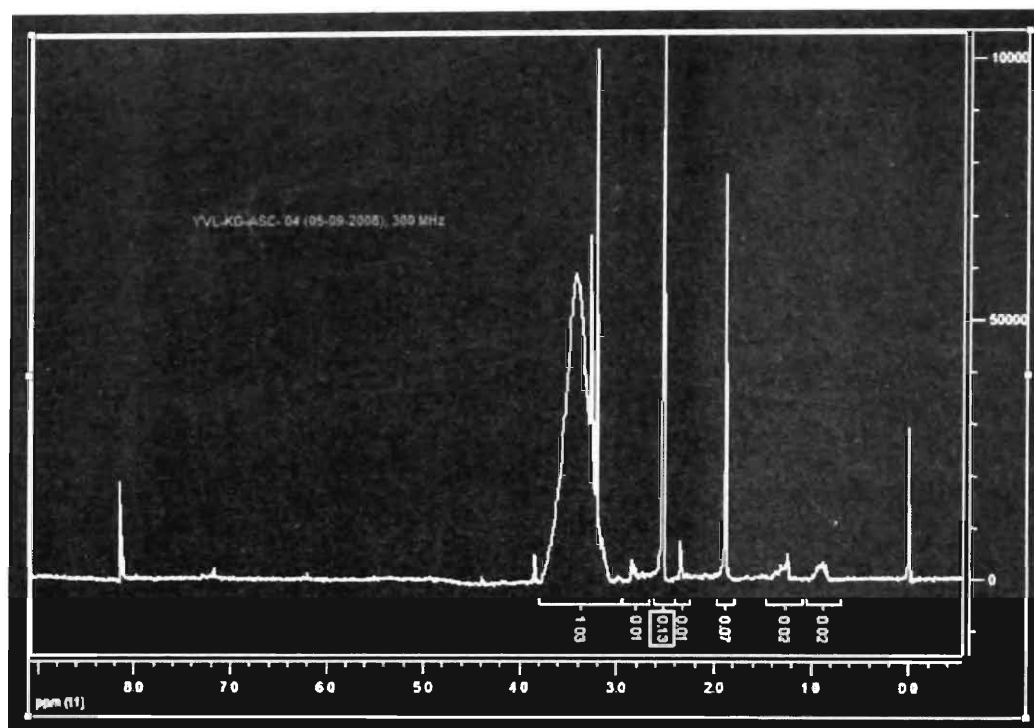
¹H NMR spectra were performed at Bruker Avance 300 MHz NMR Spectrophotometer operating at 400.24 and 100.614 observations. The crude sample was dissolved in DMSO/CDCl₃ as solvents, TMS as internal reference.

Spectra were acquired using a 5 mm ¹H dual tuned probe. Temperature was maintained at 25° C.

RESULTS AND DISCUSSION

Protein estimation

The amount of protein in *Phallusia nigra* showed 543 µg/gm of tissue. The result clearly indicates the high amount of protein and other biochemical components present in their body. The people in the East and certain parts of the Mediterranean have realised and appreciate the food value of *Phallusia nigra* because of its low calorific value and high content of proteins. Today people prefer to use pharmaceutical products of natural origin because of their lesser side effects. The present investigation supports, *P. nigra* was found to contain high food value



5.0. Preliminary Characterisation of the compound using ^1H NMR Study

Fig. 5. showing the ^1H NMR study of crude compound using Bruker Avance 300 MHz

and thus surpass many marine food sources in terms of value added marine food (Rajesh and Ali, 2008).

Hemolysis study

Fig. 1 shows the hemolytic activity of crude and 1:1 DCM/MeOH extracts on chicken, goat and human erythrocytes. The hemolytic features were present in the crude toxin as well as DCM/MeOH extracts, but activity was slightly differed considerably the types of blood we have used. Chicken blood, like groups A, B, O and AB of human erythrocytes were the vulnerable to lysis provoked by these *P. nigra* extracts. The crude extracts on 'O' & 'B' of human erythrocytes and 1:1 DCM/MeOH extracts on 'B' and 'AB' of human erythrocytes were showed maximum of 0.119 Specific Hemolytic Unit and minimum 0.007 Specific Hemolytic Unit was recorded only on 1:1 DCM/MeOH extracts of goat blood. The specific hemolytic unit calculations were broadly represented in Plate 1.

Cytotoxicity using brine shrimp lethality assay

P. nigra extracts have been tested at 10, 20, 40, 60, 80 and 100 $\mu\text{g mL}^{-1}$ and showed the results of highest cytotoxicity assay conducted,

indicating the presence of cytotoxic compounds in this ascidian. The LC_{50} values are given in Table 1. *P. nigra* extracts are toxic against *Artemia salina* larvae; Methanolic and crude extract are more toxic and they showed LC_{50} values of 145 and 130 respectively, than digitalin ($\text{LC}_{50} = 151 \mu\text{g mL}^{-1}$) and Caffeine ($\text{LC}_{50} = 306 \mu\text{g mL}^{-1}$) and it is correlated with previous works done by Meyer, *et al.* (1982) and Jimenez, *et al.* (2003). The species studied in the present work, *P. nigra*, have not been previously investigated for the presence of cytotoxic compounds from this coast.

The LC_{50} values and their standard deviation were obtained from the 24 hrs. counts of brine shrimp nauplii using the probit analysis method.

Analgesic activity

Analgesic activity of *P. nigra* extracts on tail flick and hot plate method was analysed by using rats and mice respectively. After administration of crude and 1:1 DCM/MeOH extracts *i.p.* at a dose level of 5 mg kg^{-1} of body weight (a dose equal to the *i.p.* LD_{50}) did not cause any mortality in rats and mice; but, it showed maximum analgesic ratio (Table 2). The reaction time was noted at 15, 30, 45, 60 and

120 min after the crude extract administration. Analgesic activity was expressed as a ratio between the difference in reaction time of envenomated rat and control since analgesic potential is proportional to the difference in tail flick latency between the toxin and control. In tail flick method, the maximum analgesic ratio was recorded 4.25 in 15 and 30 min after *P.nigra* extract administration of Crude and 1:1 MeOH/DCM extract. Whereas maximum

jumping response and paw licking of 7 and

CNS depressant activity latency

Both crude and 1:1 MeOH/DCM extracts showed maximum of 74.20 per cent and 66.83 per cent respectively. It's strongly showed the percentage decrease of motor activity has been calculated from the basal score and after 30 min of injection of extract. The results were shown in Table 4.

Table 4. Central Nervous System activity of *P.nigra* extract at 2mg.kg⁻¹ of 20± 2 g male albino mouse

Sl. No.	Treatment	Body weight (gms)	Locomotor activity (scores) in 10 min		
			Before treatment	After treatment	%decrease of motor activity
1.	Control	20.85	534	485	9.1
2.	Standard	22.02	382	345	9.6
3.	Crude	21.02	438	113	74.20
4.	1:1MeOH/DCM	20.44	600	199	66.83

Paw Edema formation

The anti inflammatory response of crude and 1:1 MeOH and DCM extracts showed only moderate effects. These findings indicate the role of *P.nigra* as a trigger for the development of edema (inflammatory response) *in vivo* in male albino mice.

Table 5. Paw edema formation effect of *P.nigra* extract on at 2mg.kg⁻¹ of 20± 2 g male albino mouse

Sl. No.	Treatment (0.1 mgkg ⁻¹)	Body weight (gms)	
		Before injection	After injection
1.	Crude	22.94	23.50
2.	1:1 MeOH/DCM	20.18	19.42

Antibacterial activity

In the study, the tunicate *P.nigra* seems to be a promising source of antibacterial compound were screened to evaluate antibacterial activity in Crude, Methanol, Dichloromethane, 2-Ethoxy Ethanol, Acetone, Chloroform, n-Butanol, Ethylacetate, Diethyl ether extracts, because tunicates have been

already established as a group with higher percentage of bioactivity (Carte, 1996; Prem Anand and Patterson Edward, 2002). It showed high and moderate antibacterial activity against 10 pathogens assayed but highest activity was seen against *Staphylococcus aureus* (n-Butanol-17 mm) are shown in Table 6.

CONCLUSION

Screening and presence of biomedical compounds in *P. nigra* found along the Tuticorin coast of India are a rich source of compounds with cytotoxic properties. Activities found in *P. nigra* showed promising results and the most suitable one for in-depth, chemical and biological characterisation. Large scale isolation will be necessary to obtain sufficient quantities of pure compounds for structure elucidation and further pharmacological evaluation.

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Table 6. Antibacterial activity of *Phallusia nigra* against human and shrimp pathogens

Pathogens	Zone of Inhibition* (mm)								
	C	M	DCM	E	A	CH	B	EA	DE
<i>Staphylococcus aureus</i>	7	13	6	9.5	5	6	17	7.5	6.5
<i>Salmonella typhi</i>	13	15	12	5.5	6	12.5	7	7.5	12
<i>Salmonella paratyphi</i>	12	11	9	8	2	4	7	4	8
<i>Klebsiella oxytoca</i>	7	6	5.5	6	3	3	4	12	4
<i>Klebsiella pneumonia</i>	8.5	6.5	5	9	6	5	3	4	7
<i>Vibrio cholerae</i>	7	12	6.5	7	5	8	7	7.5	11
<i>Pseudomonas aeruginosa</i>	8.5	8	6	5	7	7.5	8.5	2	2
<i>E. coli</i>	7.5	5.5	4.5	6	5	4	3.5	4	7
<i>Proteus mirabilis</i>	9	10	8.8	7	6.5	4.5	2	7	6.5
<i>Lactobacillus vulgaris</i>	9	9	8	6	6	4	6	5	8

C = Crude; M= Methanol; DCM = Dichloromethane; E = 2-Ethoxy Ethanol; A= Acetone; CH= Chloroform; B = n-Butanol; EA= Ethylacetate; DE= Diethyl ether.

*Zone in mm indicates the distance from the border of the disc to the edge of the clear zone.

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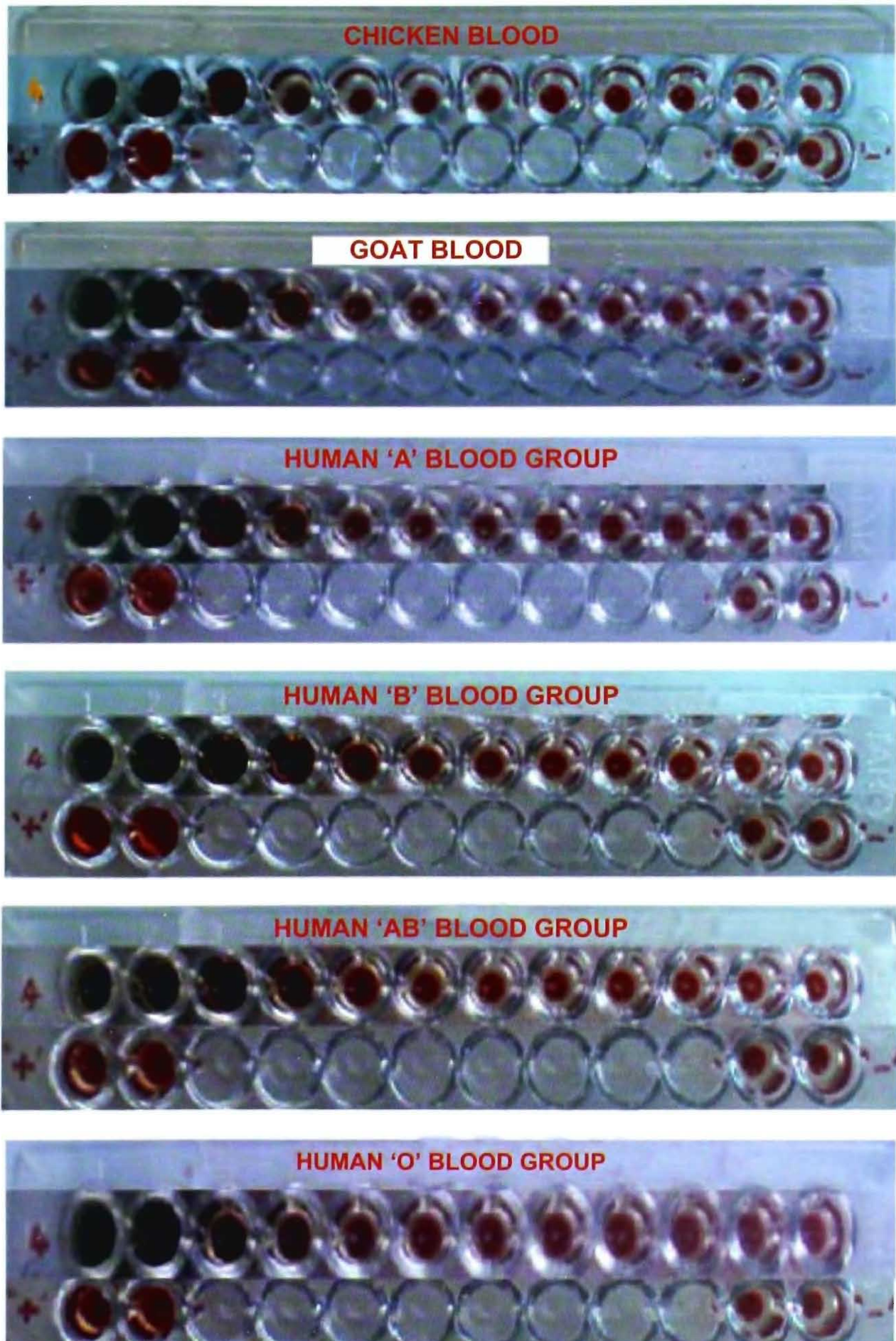
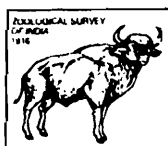


Plate 1. Showing the hemolytic activity of *P. nigra* extracts on various blood groups



EFFECT OF TRIBUTYLTIN ON THE DIFFERENT SPECIES OF MUSSEL ALONG THE SOUTH EAST COAST OF INDIA

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INTRODUCTION

Marine pollution occurs due to the entry of potentially harmful chemicals, particles, industrial, agricultural and residential waste or due to the spread of invasive organisms. Biofouling is the attachment and growth of organisms on a surface like hull of a ship. Biofouling causes considerable economic losses by increasing frictional drag on the ship, by increasing fuel consumption, induce metal corrosion, impair heat transfer etc. To reduce such economic losses paints containing antifouling compounds like Tributyltin is used. Tributyltin is a commonly used antifouling compound which is highly toxic to non-target organisms.

TBT can cause high level mortality, shell deformation, retardation of cell growth, imposex etc. TBT has been banned in many countries but not in India. Mussels were used as biological indicators and monitored for survival, bioaccumulation and growth. Mussel growth was the primary biological response used to quantify TBT effects. Chemical analyses were used to estimate TBT contamination in tissues. The effects of TBT on survival and bioaccumulation in different species of Mussels were done. The present study was conducted

to find the range of variability in tissue concentrations of Tributyltin in green and brown mussel.

Marine pollution occur due to the entry of potentially harmful chemicals, particles, industrial, agricultural and residential waste or due to the spread of invasive organisms. Most source of marine pollution is land based. The pollution often comes from non point sources such as agricultural runoff and windblown debris. Many potentially toxic chemicals adhere to tiny particles which are then taken up by plankton and benthos animals, most of which are filter feeders. In this way, the toxins are concentrated upward within ocean food chains. Many particles combine chemically in a manner highly depletive of oxygen causing estuaries to become anoxic.

Biofouling is the attachment and growth of organisms on a surface like hull of a ship. Biofouling causes considerable economic losses by increasing frictional drag on the ship, by increasing fuel consumption, induce metal corrosion, impair heat transfer etc. to reduce such economic losses paints containing antifouling compounds like Tributyltin is used. Tributyltin is a commonly used antifouling compound which is highly toxic to non-target

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organisms Tributylins are organic compounds containing 3 alkyl groups attached to the tin atom exhibiting biocidal activity against a wide range of organisms hence are used as antifouling agents in paints applied for marine vessels. Its use has increased high concentration of TBT in water column, sediments, and tissues of marine organisms, thereby causing contamination of aquatic and marine environments.

All ships including Indian ships use the antifouling paint containing TBT as there is no regulation as on date in India and several other countries to ban the use of TBT in antifouling agents. International maritime organization was expected to endorse a recommendation from its Maritime Environment Protection Committee that the application of TBT based coatings should be prohibited from January 2008. However the treaty was not ratified by the required number of countries and has not been put in to practice yet (Camillo *et al.*, 2004).

TBT can cause high level mortality, shell deformation, retardation of cell growth, imposex etc. TBT has been banned in many countries but not in India. Tributyltin membrane adaptation capability could determine the survival of the cell. Mussels were used as biological indicators and monitored for survival, bioaccumulation and growth. Mussel growth was the primary biological response used to quantify TBT effects. Chemical analyses were used to estimate TBT contamination in water and tissues. Mussels have been most extensively used to monitor contamination by measuring tissue accumulation with chemical analyses (Philips *et al.*, 1986). They have also been used to monitor biological effects of contamination by measuring biological responses related to growth, physiology and reproduction (Bayne *et al.*, 1985). A laboratory and field study has shown that TBT is highly toxic to molluscs and that filter-feeding bivalves readily accumulate TBT (Salzar *et al.*, 1986).

Juvenile mussels have advantages over adults as bioindicators

1. They grow faster and provide a greater range of response (Ebdon *et al.*, 1989)

2. The growth process is not affected by gametogenesis (Wade *et al.*, 1988)
3. Bioaccumulation in short term test with fast growing juveniles more accurately reflects recent environmental changes (Fischer *et al.*, 1983, 1988) and
4. They may be more sensitive to TBT.

The present study was done to find the accumulation of Tributyltin on *Perna viridis* and *Perna indica* in two different places.

MATERIALS AND METHODS

Sampling of Mussels

The specimens of mussel *Perna viridis* and *Perna indica* were collected from Chennai port and Mahabalipuram of Tamilnadu. They were collected during July to December 2008 along the south east coast of India. Specimens of each species were randomly collected during low tide in considerable numbers.

The identification of *Perna viridis* and *Perna indica* was based on the characteristics of the shell, shape and color of the mantle edge and shell. Juvenile mussels *Perna* species were transplanted from the collection site to test site and monitored during 12 week exposure periods. Serial mussel measurements were made in the field collected weekly. Growth measurements included whole animal wet weights and lengths.

Transplantation Procedure

Green mussel and brown mussels for transplant were collected by hand from a relatively uncontaminated site (Mahabalipuram) along the Tamil Nadu coast. The mussels were kept in uncontaminated seawater for about 1 month before transplantation. Around 30 Green mussels and 30 Brown mussels were transplanted for one month. Pretreatment of tissue samples was performed in the same way as for natural samples

20-150 mussels were collected per analytical sample according to the objective. The samples were kept in cold storage (< 10 degree C) until

pretreatment in the Laboratory. Pretreatment was carried out within the day of sampling. Water retained inside the shell was completely removed with stainless strainer, the byssus was discarded and the mean whole weight of the sampled Mussel species was measured. Mussels from each sampling site was divided in to groups according to shell length 1.5-1.8 cm, 1.8-3 cm, 3-4 cm, 4-5 cm, 5-6 cm, and 7-8 cm. After taking out the soft tissues, the adhering water was fully removed by draining for 20 mts in a stainless strainer for the study of Tributyltin distribution in the soft tissues, 50-70 individuals in shell length were dissected in to gill, viscera, mantle and muscle. Finally sample was separately homogenized (10,000 rpm, 10 mts) and then frozen (-40 degree c).

Analytical Procedure

The determination of TBT is homogenized soft tissue (3g) in Green mussel and Brown mussel was carried out using sonication with tropolone - benzene, propyl derivation and gas chromatography with flame photometric detection. Each organotin peak in the environment samples was verified by the addition of organotin standard. Based on the internal standard (Triphenyltin chloride (TPeT)). Tributyltin values in the extract were expressed as the chlorides. The limit of detection (S/N=2) was .5 -.7 ng (Chloride) g-1 wet weight for the Tributyltin in both the Mussel samples. The reported concentration was expressed as a mean value of three determinations from one extract and was converted by reagent blank and recovery of Tributyltin.

RESULTS AND DISCUSSION

The results of 6 replicate analyses of both mussel species of the uncontaminated sample was 15-27 ng (chloride) g-1 wet weight which was the average level of samples from Mahabalipuram and is compared with propylated standard. Table 1 indicates the recovery rate of TBT in both mussels through the analytical procedure. The recovery was in the range 80-81 per cent. The Relative standard deviation ranged from 13.8 to 15 per cent.

Whereas in case of mussel of 3-5 cm (1-2 yrs) old has the same concentration and accumulation pattern of Tributyltin compound in soft tissue. The biological characteristics show small mussels of both species would lead to high accumulation of contaminants.

The variability of Tributyltin in case of Green mussel and Brown mussel is that juvenile mussels accumulates more whereas the mussels of 3-5 cm in length (1-2 yrs) old shows more or less the same pattern refer Table 3 and the other 3-5 cm, 5-6 cm, 6-7 cm ranges also varies. This clarifies that there is no relationship between shell length and accumulation level in whole soft tissue.

Table 1. The Recovery of TBT in Green and Brown Mussel by the analytic procedure

	TBT in Green mussel	TBT in Brown mussel
Recovery (%)	80	80.4
RSD (%)	14.7	13.8

Number of analyses= 6; Tpet: Absolute recovery, 78%

Table 2. Sample collection of Natural Green and Brown Mussel

Shell length/cm	1.5-1.8	1.8-3	3-4	4-5	5-6	6-7
Average weight individuals/g wet Green mussel	.38-.62	.9-2.0	2.6-6.3	6.0-9.1	9.3-15	14-21
Average weight individuals /g wet Brown mussel	.27- .53	.75-2.3	2.5-7	7.3-9	10.1-17	13-22
Number of collected mussels	150	100	50	30	25	25

Tributyltin accumulation levels in mussels of different size

There is no relationship between accumulation level in whole soft tissues and shell length. Accumulation pattern in *Perna viridis* of 1.5-1.8 in shell length had 1.6 more the level of TBT compound than those of mussels of 3 cm or above. Whereas in case of mussel of 3-5 cm (1-2 yrs) old has the same concentration level and accumulation pattern of Tributyltin compounds in soft tissue and as of the Brown mussel of 1.5-1.8 had 1.3 more

the level of TBT compound than those of mussels of 3 cm. In our study juvenile mussels accumulated more TBT Table 4. The biological characteristics show small mussels of both species would lead to high accumulation of contaminants.

There could be variability in TBT contamination due to ecological aspects of Mussels. The advantage of using these mussels is that they permit the detection of TBT in trace levels.

Table 3. Variability of TBT concentration in different sized Natural mussels in Mahabalipuram; Ratio of concentration to the value of 3-5 cm sample

	1.5-1.8 cm	1.8-3 cm	3-5 cm	5-6 cm	6-7cm
TBT/Green mussel	1.3	1.2	1(19.1)a	.80	.88
TBT/Brown mussel	1.0	1.1	1(4.2)a	.80	2.1

The mean of actual concentration value (ng g⁻¹)

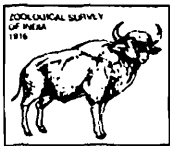
Table 4. Variability of TBT in Green and Brown mussel transplanted in Chennai port

TBT	1.5-1.8 cm	1.8-3 cm	3-5 cm	5-6 cm	6-7 cm
Green mussel	1.6	1.42	.9	.84	.88
Brown mussel	1.3	1.60	1.2	1	1.7

Concentration value (ng g⁻¹)

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DIVERSITY OF CORAL AND ITS ASSOCIATED FAUNA IN GREAT NICOBAR ISLAND, ANDAMAN AND NICOBAR ISLANDS

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INTRODUCTION

The Great Nicobar Island is the southernmost landmass in Andaman and Nicobar Archipelago. The total area of this island is 1044 km². It is a tropical and sub-tropical moist broadleaf forest biome and located in the Indo-Malayan bio-geographic zone. The Great Nicobar Biosphere Reserve (GNBR) of this island is one of the 15 Biosphere Reserves in India, created under the Man and Biosphere Programme of Ministry of Environment and Forests, Government of India. The Great Nicobar Island is located about 60°N of the equator and only about 145 km away from Sumatra Island of Indonesia. The Great Nicobar Island with a total area of 1044 km² encompasses two National Parks, the Galathea National Park (185 km² area) which represents Galathea river basin composed of low-lying hills not exceeding 250m and the Campbell Bay National Park (520 km² area) with the high mountain ranges reaching to a height of 670m. The extremely high endemism and extraordinary diversity at the species and community levels make the Great Nicobar Island is one of the hottest hotspots in the world.

Coral reefs are highly productive marine ecosystem in the world with annual gross production rates in the range of 2000-5000g cm⁻² through efficient retention and recycling of nutrients (Mann, 1982). Coral reefs of the world cover an estimated area of 600,000 km² (Smith, 1978; Klepays, 1997). Over half of this (54 per cent) lies in the Mediterranean Indian Ocean. Of the remaining, Pacific reefs account for 25 per cent, Atlantic reefs for 6 per cent, Caribbean reefs for 9 per cent, Red Sea reefs for 4 per cent and Persian Gulf reefs for 2 per cent. Majority of the coral reef areas are concentrated on western sides of these oceans (Scheer, 1985). The growth rate of coral and a coral reef depends on the factor such as light intensity, water temperature, salinity, turbidity, food availability, competition for space and predation. Upward growth of coral colonies is generally between 1 and 10 cm per year under favourable conditions (Lally and Parsons, 1997). A number of threats have caused serious declines in the distribution and condition of the coral reefs during recent decades. In particular, the El-Nino event of 1997-98 produced extremely high water temperature that caused bleaching and mortality of corals

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on a global scale. The Indian Ocean was said to be particularly badly affected by this event and most of the corals of East Africa and in central and northern Indian Ocean corals bleached and died due to this effect (Linden *et al.*, 2002).

There is relatively little information on the coral reef ecosystems around the Andaman and Nicobar Islands, when compared to many other island groups in the Indian Ocean. The studies on taxonomy of Indian coral reef started in India as early as 1847 by Rink in Nicobar Islands. Alcock (1893) conducted the earliest survey on these islands and described the general topography. Later Alcock (1902) described 25 species of deep sea *Madreporaria* dredged by Royal Indian Marine Survey Ship *Investigator* from depth of more than hundred fathoms, around Andaman Islands. Sewell (1922) provided the first account of the ecology and formation of reefs in the region after visiting the Nicobar Islands. He subsequently visited the Andamans (Sewell, 1925), reporting that the coastline was edged by fringing reefs and that there was a barrier reef, 350 km in length off the west coast between 10°-12°N. Reef structures have since been described by Reddiah (1977); Pillai (1983); Mahadevan and Easterson (1983); Jeyabaskaran (1999). Pillai (1983) described *Acropora* dominated seaward reefs, and *Porites* dominated leeward reefs. Sheltered areas close to mangroves were colonised by *Porites* and *Favia* on sand, except in flood channels. Jeyabaskaran (1999) conducted the most recent quantitative survey of benthic cover, around the Andaman and Nicobar Islands, incorporating sites at: Cinque Island, Little Andaman, John Lawrence, Henry Lawrence, Great Nicobar and North Reef. In the past few decades many coral reef surveys have been conducted by the scientific team of Zoological Survey of India (Reddiah, 1977; Venkataraman and Rajan 1998; Turner *et al.*, 2001, 2009; Venkataraman 2003; Raghunathan *et al.*, 2010a,b,c; Madhan Chakkaravarthy *et al.*, 2010; Ramakrishna *et al.*, 2010a,b).

The identification of coral species began since Matthai (1924), who listed coral species

from the Andaman based on collections in the Indian Museum in Calcutta. Pillai (1983) listed 135 coral species from this region. Turner *et al.* (2001) lists 197 species within 58 genera. Wilkinson (2000) sources that 203 hard coral species occur in these islands. The faunal studies other than corals have also been carried out at different reef locations of the Andaman and Nicobar Island. More than 1200 fish species have recorded around Andaman and Nicobar (Rajasuriya *et al.*, 2002). In-depth information on coral reef ecology and community structure is limited to few studies on some specific reef sites only. The percentage cover of live corals has been estimated for the islands of the Mahatma Gandhi Marine National Park (Dorairaj and Soundarajan, 1997; Arthur, 1996; Kulkarni *et al.*, 2001) and North Reef, Cinque Island, Twin Islands reef, West Rutland Island, Tarmugli Island, Flat Island, South Button, Outram Island, Henry Lawrence Island, Minerva ledges and Neil Island (Turner *et al.*, 2001, 2009). These studies also listed species wise distribution for these reef areas. In addition, Kulkarni *et al.* (2001) addressed several ecological parameters in their study, which include sedimentation, terrestrial zone influence and other anthropogenic factors.

There has been a growing concern in recent years, over the status of reefs for the sustenance and survival of living corals associated with them. As a result, there is an increasing awareness now-a-days, of the need for coral reef conservation and management through research monitoring programmes at the national and international levels.

MATERIALS AND METHODS

The status of corals and its associated faunal communities in terms of density and diversity was assessed in 3 stations viz. Shastri Nagar (Lat. 06°36.300' N, Long. 94° 54.137' E), Gandhi Nagar (Lat. 06° 50.496' N, Long. 93°53.680' E) and Campbell Bay (Lat. 07° 01.249' N, Long. 93°54.321' E) in Great Nicobar Island during the year 2008-2009 employing Line Intercept Method following English *et al.* (1994). Zooplankton samples were collected by surface

haul using Heron-Tranter Plankton net having 0.7m dia mouth, 3m long with a mesh size of 200 μ for 10 minutes at 2 knot speed whereas for phytoplankton, fifty litres of seawater samples were concentrated to 250ml by filtering through 20 μ mesh sized plankton net. The intertidal and subtidal macrobenthos in the study area are estimated during low tide by quadrat method. Besides, the surface seawater quality parameters such as, salinity (Refractometer, Model ERMA), temperature, pH (Water Quality Analyser, Model SYSTRONICS) transparency (Secchi disc) and turbidity (Turbidity Meter Model EUTECH Instruments ECTN100IR) were also measured at all the study sites.

The species diversity was calculated according to the Shanon-Weiner formula.

$$H' = \sum P_i \log e P_i$$

Where P_i = proportion of the i th species in the collection and H' = Diversity of a theoretically infinite population.

RESULTS AND DISCUSSION

Physico-chemical Parameters

The physico-chemical parameters of the seawater are the prime factors indicating the quality of the coastal waters which directly influence the primary and secondary productivities, and tertiary producers in the marine environment. The data on these parameters obtained from seawater samples collected from all the places of present study and the results are depicted in table 1. The mean surface seawater temperature ranged from 27.5 to 29.82°C at Campbell Bay and Shastri Nagar respectively. The difference of

salinity range (33.27 to 33.87ppt) might be attributed to the rainfall followed by river runoff in these regions. The minor fluctuations in the salinity might be also attributed to the variable quantities of freshwater inflow through the Straits of Malacca, South China Sea and tropical rain forests of Sumatra Islands. The concentration of hydrogen ions (pH) did not show significant variation between stations as well as regions and varied from 7.2 in Gandhi Nagar to 7.4 in both Shastri Nagar and Campbell Bay.

The transparency in terms of penetration of light in the seawater column was also measured at all the places and it ranged from 7.5m in Shastri Nagar to 8.5m Campbell Bay. The quintessence of the results acquired for seawater transparency indicated that all the stations of study have high light penetration. The turbidity of seawater was also measured by Nudson Turbidity Unit (NTU) and it was found minimum (715) at Gandhi Nagar and maximum (720) at both Campbell Bay and Shastri Nagar. The intertidal exposure during low tide at the surveyed area ranged from 30 to 50 m at Gandhi Nagar and Campbell Bay respectively. The lower tidal exposure in intertidal region of Andaman is mainly due to the impact of December 2004 earthquake cum Tsunami that struck in these islands causing the uplift of landmass of North Andaman and submergence of Nicobar Islands by 1m respectively.

Phytoplankton

Phytoplankton is the primary producers of the marine trophic level and plays a vital role while assessing the health of the marine

Table 1. Physio-chemical Parameters in seawater of Great Nicobar Island

Sl. No.	Area	Temp. (°C)	Salinity (ppt)	pH	Transparency (m)	Turbidity (NTU)	Intertidal exposure (m)
1.	Shastri Nagar	29.2	33.87	7.4	7.5	720	35
2.	Gandhi Nagar	28.0	33.27	7.2	7.7	715	30
3.	Campbell Bay	27.5	33.51	7.4	8.5	720	50

environment. The results of phytoplankton samples collected from surface seawater of all the stations along the study area in Great Nicobar Island are presented in tables 2-3. A total of 48 species of phytoplankton belonging to 33 genera were recorded from the study area. Among them the maximum of 48 species obtained from Gandhi Nagar while the minimum of 32 species recorded from Campbell Bay. The total cell count of phytoplankton was encountered as high, $93.10 \times 10^2 \text{ L}^{-1}$ at Gandhi Nagar and as low $66.15 \times 10^2 \text{ L}^{-1}$ at Campbell Bay. The low phytoplankton

productivity in Campbell Bay might be due to the localized stress caused by anthropogenic activities. Each species of phytoplankton has a particular response to different growth rates. These differences and the species specific responses to different growth physico-chemical parameters favour different species at different times and allow many species to co-exist in the same body of water (Lally and Parsons, 1997). The species diversity of phytoplankton was also calculated during the study period and the diversity maxima (2.71) at Gandhi Nagar and minima (2.30) at Campbell Bay.

Table 2. Phytoplankton productivity and diversity in Great Nicobar Island

Sl. No.	Area	Tide	Cell count (No. $\times 10^2 \text{ L}^{-1}$)	Species Diversity (H')
1.	Shastri Nagar	BHL	85.17	2.40
2.	Gandhi Nagar	LT	93.10	2.71
3.	Campbell Bay	LT	66.15	2.30

Table 3. Distribution of phytoplankton in Great Nicobar Island

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
1	<i>Actinotychus undulatus</i>	P	P	P
2	<i>Amphora lineolata</i>	P	P	
3	<i>Amphora ostreoria</i>	P	P	P
4	<i>Asteronella japonica</i>	P	P	
5	<i>Biddulphia heteroceros</i>		P	P
6	<i>Campylodiscus iyengarii</i>	P	P	
7	<i>Ceratium axiale</i>	P	P	P
8	<i>Ceratium azoricum</i>		P	P
9	<i>Ceratium furca</i>	P	P	
10	<i>Ceratium trichoceras</i>	P	P	P
11	<i>Chaetoceros coarctatus</i>	P	P	P
12	<i>Chaetoceros lorenzianus</i>	P	P	P
13	<i>Climacosphenia moniligera</i>	P	P	P
14	<i>Closterium</i> sp.	P		
15	<i>Coelosphaericum kuetzingianum</i>	P	P	P
16	<i>Coscinodiscus eccentricus</i>		P	
17	<i>Coscinodiscus jonesianus</i>	P	P	P
18	<i>Coscinodiscus oculus iridis</i>	P	P	
19	<i>Coscinodiscus</i> sp.	P	P	P
20	<i>Cyclotella stelligera</i>	P	P	

Table 3. Contd.

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
21	<i>Fragillaria crotonensis</i>	P	P	P
22	<i>Fragillaria oceanica</i>	P	P	P
23	<i>Gossleriella tropica</i>	P	P	
24	<i>Grammatophora mirificum</i>	P	P	P
25	<i>Gyrosigma balticum</i>	P	P	
26	<i>Hemiculus hauckii</i>	P	P	P
27	<i>Lauderia annulata</i>	P	P	P
28	<i>Lyngbya confervoides</i>	P	P	P
29	<i>Melosira</i> sp.	P	P	
30	<i>Nitzschia seriata</i>		P	P
31	<i>Nitzschia sigma</i>	P	P	
32	<i>Ornithocerus steinii</i>	P	P	P
33	<i>Oscillatoria limosa</i>	P	P	P
34	<i>Pediastrum simplex</i>		P	P
35	<i>Phyrophacus harologicum</i>	P	P	
36	<i>Pleurosigma angulatum</i>	P	P	P
37	<i>Pleurosigma elongatum</i>	P	P	P
38	<i>Prorocentrum maximum</i>	P	P	P
39	<i>Prorocentrum micans</i>	P	P	P
40	<i>Protoperidinium depressum</i>	P	P	P
41	<i>Protoperidinium oceanicum</i>	P	P	
42	<i>Rhaphoneis discoides</i>		P	P
43	<i>Rhizosolenia cylindricus</i>	P	P	
44	<i>Striatella delicatula</i>		P	P
45	<i>Surirella flaminensis</i>		P	P
46	<i>Surirella maximum</i>	P	P	P
47	<i>Thalassiothrix longissima</i>		P	
48	<i>Thalassiothrix nitzschioides</i>	P	P	P
	Total no. of species	39	48	32

P - present

Zooplankton

The zooplankton is the secondary producers or primary consumers and their productivity is highly responsible for the fishery potential. Zooplankton being secondary producer plays a crucial role in the transfer of energy to higher trophic level in the sea; the continental slope water of Andaman is oligotrophic in nature with low primary productivities. The production of

large quantities of detritus, therefore, appears to supplement the inadequacy of these waters. The data for the qualitative and quantitative estimation of zooplankton and its distribution and diversity are shown in tables 4-5. Altogether, 76 species of zooplankton belonging to 19 groups were recorded from the study area. However, total number of species observed at Shastri Nagar, Gandhi Nagar and Campbell Bay were

62, 76 and 61 respectively. The results of zooplankton study clearly indicated that the copepods were the predominant group as they represented by 37 species followed by foraminiferans which comprised of 19 species. Quite a number of species were commonly found in all the stations, and they are larval forms of annelids, chaetognaths, most of the copepods, ostracods, crustacean larvae viz. megalopa, nauplii and zoea, ostracods, fish eggs and veliger larvae of gastropods.

The biomass of zooplankton in terms of fresh weight, dry weight and volume were estimated. The mean minimum values for these variables were 3170mg/100m³, 752 mg/100m³ and 5.5 ml/100m³ at Campbell Bay and maximum of 3220 mg/100m³, 818 mg/100m³ and 6.0 ml/100m³ volume in Shastri Nagar respectively. The numerical density of zooplankton varied from 20150 to 22980 no./100m³ for Shastri Nagar and Gandhi Nagar respectively. The species diversity of zooplankton was also calculated at all the stations and it showed high index of 2.92 at Campbell Bay and low of 2.12 at Shastri Nagar.

The density, biomass and distribution of zooplankton obtained from the present study

is significantly correlated with the phytoplankton productivity and indicated the balanced state of primary production and primary consumption during the period of observation. However, the low values of zooplankton productivity observed in Campbell Bay might be attributed to the poor phytoplankton productivity in that particular regions due to low light penetration coupled with high values of turbidity and diel vertical migration of zooplankton.

The epitome of the results obtained for the zooplankton biomass, distribution and density form the present study once again confirms that the Andaman Sea is the highly productive sea of Indian Ocean. The presently sampled station have moderate productivity as they fall in neritic waters of Andaman Sea and it is corroborated with the variations observed by Rezai *et al.* (1981) in Straits of Malacca where the biomass of zooplankton was generally higher in waters close to the near coastal areas than in the offshore areas. The availability of nutrients in higher concentration which leads to primary productivities in the coastal waters could be the causative factor for this trend of variation.

Table 4. Quantitative estimation of zooplankton in Great Nicobar Island

Sl. No.	Area	Numerical Density (No./100m ³)	Fresh weight (mg/100m ³)	Dry weight (mg/100m ³)	Volume (ml/100m ³)	Species diversity (H')
1.	Shastri Nagar	20150	2320	818	6.0	2.12
2.	Gandhi Nagar	22980	3210	791	5.8	2.35
3.	Campbell Bay	21370	3170	753	5.5	2.89

Table 5. Distribution of zooplankton in Great Nicobar Island

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
	(1). Foraminiferans			
1	<i>Amhistegina lessoni</i> d'Orbigny	+	+	
2	<i>Amphisorus hemprichii</i> Ehrenberg	+	+	+
3	<i>Cibicides lobatulus</i> d'Orbigny	+	+	+
4	<i>Calcarina calcar</i> d'Orbigny		+	+

Table 5. Contd.

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
5	<i>Globigerina tricolunoides</i>	+	+	
6	<i>Globigerina sacculifer</i> (Brady)	+	+	+
7	<i>Loxostomum limbatum</i> var <i>costulatum</i> (Cushman)	+	+	+
8	<i>Loxostomum rostrum</i> (Brady)		+	+
9	<i>Loxostomum truncatum</i> Phleger and Parker	+	+	+
10	<i>Planobulina mediterranensis</i> d'Orbigny	+	+	+
11	<i>Quinqueloculina seminulum</i> (Linne)	+	+	+
12	<i>Quinqueloculina subcuneata</i> Cushman		+	+
13	<i>Rosalina floridana</i> (Cushman)	+	+	+
14	<i>Rosalina globularis</i> d'Orbigny	+	+	+
15	<i>Rosalina bradyi</i> (Cushman)	+	+	+
16	<i>Siphonia reticulata</i> (Czjzek)	+	+	+
17	<i>Spirillina lateseptata</i>		+	+
18	<i>Triloculina oblonga</i> (Montagu)	+	+	
	(2). Appendicularians			
19	<i>Oikopleura dioica</i>	+	+	+
	(3). Copepods			
20	<i>Acartia southwelli</i> Sewell	+	+	+
21	<i>Acrocalanus gracilis</i> Giesbrecht	+	+	+
22	<i>Corycaeus catus</i> F. Dahl		+	+
23	<i>Corycaeus danae</i> Giesbrecht	+	+	+
24	<i>Corycaeus speciosus</i> Dana	+	+	+
25	<i>Centropages dorsispinatus</i>	+	+	+
26	<i>Euchaeta concinna</i>	+	+	+
27	<i>Eucalanus attenuatus</i> (Dana)	+	+	+
28	<i>Euterpina acutifrons</i> (Dana)	+	+	+
29	<i>Isias tropica</i> Sewell	+	+	+
30	<i>Longipedia coronata</i> Claus	+	+	+
31	<i>Longipedia weberi</i> A. Scott	+	+	+
32	<i>Lucicutia flavicornis</i> (Claus)	+	+	
33	<i>Macrocypris mima</i>	+	+	+
34	<i>Macrosetella gracilis</i> (Dana)	+	+	+
35	<i>Metacalanus aurivilli</i> Cleve	+	+	+
36	<i>Metis jausseamei</i> (Richard)	+	+	+
37	<i>Microsetella norvegica</i> (Boeck)	+	+	+
38	<i>Nannocalanus minor</i> (Claus)	+	+	+
39	<i>Oithona brevicornis</i> Giesbrecht	+	+	+

Table 5. Contd.

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
40	<i>Oithona similis</i> Claus	+	+	+
41	<i>Oncaea venusta</i> Philippi	+	+	
42	<i>Paracalanus parvus</i> (Claus)	+	+	+
43	<i>Pontella danae</i> Giesbrecht	+	+	+
44	<i>Pontellina plumata</i> (Dana)	+	+	+
45	<i>Pseudodiaptomus serricaudatus</i> (T. Scott)	+	+	+
46	<i>Sapphirina nigromaculata</i> Dana	+	+	
47	<i>Sapphirina ovatolancoelataa</i> Dana	+	+	+
48	<i>Temora discaudata</i> Giesbrecht	+	+	+
	(4) Amphipods			
49	<i>Hyperia medusarum</i>		+	+
	(5) Isopods			
50	<i>Angeliera phreaticola</i> Chappuis and Delamare Deboutville, 1952	+	+	+
	(6) Ostracods			
51	<i>Conchoecia indica</i>	+	+	+
52	<i>Cypridina sinosa</i>	+	+	
53	<i>Macrocypris minna</i>	+	+	+
	(7) Leptomedusae			
54	<i>Proboscoidactyla stellata</i>	+	+	+
	(8) Crustacean larvae			
55	Cypris larva of Lepas, Barnacle	+	+	+
56	Nauplii	+	+	+
57	Mysis stage of penaeid prawn		+	
	(9) Annelid larvae			
58	Setiger larva	+	+	
59	Spirobis larva		+	+
	(10) Cladocerans			
60	<i>Evadema tergestina</i>	+	+	+
61	<i>Podon</i> sp.		+	+
	(11) Chaetognaths			
62	<i>Sagitta enflata</i>	+	+	+
63	<i>Sagitta hexaptera</i>		+	+
64	<i>Sagitta maxima</i>	+	+	
65	<i>Sagitta robusta</i>	+	+	+
	(12) Doliolids (Cyclomyaria)			
66	<i>Doliolletta gengenbauri</i>		+	+

Table 5. Contd.

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
	(13) Echinoderms			
67	<i>Bipinnaria</i> larva of starfish		+	
68	<i>Echinopluteus</i> larva of sea urchin	+	+	+
	(14) Radiolarians			
69	<i>Acanthometron</i> sp		+	
	(15) Siphonophores			
70	<i>Porpita porpita</i>	+	+	+
	(16) Molluscs			
71	<i>Janthina janthina</i>	+	+	+
72	<i>Spiratella</i> sp.		+	
73	Veliger larva	+	+	+
	(17) Salpids (Desmomyaria)			
74	<i>Salpa maxima</i>	+	+	+
	(18) Opisthobranchs			
75	<i>Crseis acicula</i>	+	+	
	(19) Pisces			
76	Fish eggs	+	+	+
	Total number of species	62	76	61
	Species diversity (H')	2.12	2.9	2.92

Corals

The scleractinian corals of Andaman and Nicobar Islands are highly diverse than other parts of the tropical reefs. A total of 110 species of scleractinian corals belonging to 8 families were reported from the Great Nicobar Island during the survey (Table 6). Among them, a maximum of 78 species reported from Campbell Bay while 61 and 50 species reported at Gandhi Nagar and Shastri Nagar respectively. The family Acroporidae is dominant in the area studied as it represented by 43 species includes the genus *Acropora* (28 species) and *Montipora* (8 species). The formations of corals normally found in lower intertidal area to the maximum depth of 35m. Acroporids distributed at all depths i.e. 2-35m, while representatives of Favids, Fungiids and Poritids occurred at a depth ranged from 0.5 to 28m in Great Nicobar Island.

The data obtained from the present study as well as earlier studies revealed that a total of 431 species of scleractinian corals belonging to 68 genera were reported from Andaman and Nicobar Islands. Among them the family Acroporidae is dominant as it composed of 146 species includes the genus *Acropora* (103 species), *Astreopora* (6 species), and *Montipora* (32 species). It is pertinent to note that among the coral diversity reported from World Oceans, 52.05% species and 60.71% genera of corals recorded from Andaman and Nicobar Islands. Out of 18 families known from Scleractinia, 16 families found in these islands with the exception of families Rhizangiidae and Caryphyllidae. However, in the year 2009 researchers from Pondicherry University, India collected a dead specimen of *Caryophyllia inornata* (Duncan, 1878) belonging to the family Caryphyllidae from Great Nicobar Island at depth of 200m while collecting benthos samples

by van-veen grab and the specimen has been deposited in the National Zoological Collection of Zoological Survey of India. Later on during 2010, ZSI reported a specimen of *Caryophyllia spinigera* from Ritchie's Archipelago in Middle Andaman.

The species diversity (H') of scleractinian corals ranges from 5.243 to 5.758 in Shastri Nagar and Campbell Bay respectively.

The Great Nicobar Island shows a great deal of similarity index (J') in species content of scleractinian corals. The similarity index can be seen from the table cited below.

Name of → Places	Campbell Bay	Gandhi Nagar
↓		
Shastri Nagar	0.484	0.522
Campbell Bay		0.573

Live coral cover

The percentage of live coral cover has been calculated for three places of study. It ranged from 59.53 per cent in Shastri Nagar to 63.71 per cent in Gandhi Nagar. It indicates moderately high level of live coral cover at Great Nicobar Island (Table 7)

Density

The mean numerical density of corals was estimated as 27.64 to 29.31 colonies/10m² at Campbell Bay and Gandhi Nagar respectively (Table 7). Several new coral recruits were observed in all three places of study.

Coral Associated Fauna

The macrobenthic organisms such as sponges, molluscs, echinoderms and crabs along the coral reefs in the study area were assessed.

Table 6. Species composition of Corals in Great Nicobar Island

Sl. No.	Family	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
1	Acroporidae	<i>Acropora aspera</i> (Dana, 1846)	+	+	+
2		<i>Acropora microphthlma</i> (Verrill, 1859)	+	+	-
3		<i>Acropora robusta</i> (Dana, 1846)	+	+	
4		<i>Acropora humilis</i> (Dana, 1846)	+	+	+
5		<i>Acropora chesterfieldensis</i> (Veron & Wallace, 1984)	-	+	-
6		<i>Acropora cerealis</i> (Dana, 1846)	-		+
7		<i>Acropora ocellata</i> (Klunzinger, 1879)	-	+	-
8		<i>Acropora nasuta</i> (Dana, 1846)	+	-	-
9		<i>Acropora papillare</i> (Latypov, 1992)	-	+	-
10		<i>Acropora pulchra</i> (Brook, 1891)	-	+	-
11		<i>Acropora formosa</i> (Dana, 1846)	+	+	+
12		<i>Acropora monticulosa</i> (Bruggemann, 1879)	+	+	+
13		<i>Acropora nobilis</i> (Dana, 1846)	+		+
14		<i>Acropora abrotanoides</i> (Lamarck, 1816)	-	+	-
15		<i>Acropora cythera</i> (Dana, 1846)		+	+
16		<i>Acropora valida</i> (Dana, 1846)	-	+	-
17		<i>Acropora hyacinthus</i> (Dana, 1846)	+	-	+

Table 6. Contd.

Sl. No.	Family	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
18		<i>Acropora gemmifera</i> (Brook, 1892)	+	+	+
19		<i>Acropora spicifera</i> (Dana, 1846)		+	
20		<i>Acropora dendrum</i> (Bassett-Smith, 1890)	+		
21		<i>Acropora bifurcata</i> (Nemanzo, 1967)		+	
22		<i>Acropora grandis</i> (Brook, 1892)		+	
23		<i>Acropora inermis</i> (Brook, 1891)			+
24		<i>Acropora florida</i> (Dana, 1846)		+	
25		<i>Acropora millepora</i> (Ehrenberg, 1834)		+	
26		<i>Acropora divaricata</i> (Dana, 1846)			+
27		<i>Acropora samoensis</i> (Brook, 1891)			+
28		<i>Acropora palifera</i> (Lamarck, 1816)	+	+	
29		<i>Montipora hemispherica</i> (Veron, 2000)			+
30		<i>Montipora hispida</i> (Dana, 1846)		+	
31		<i>Montipora digita</i> (Dana, 1846)		+	
32		<i>Montipora peltiformis</i> (Bernard, 1897)	+		+
33		<i>Montipora meandrina</i> (Ehrenberg, 1834)		+	
34		<i>Montipora varrucosa</i> (Lamarck, 1816)		+	
35		<i>Montipora informis</i> (Bernard, 1897)			+
36		<i>Montipora aequituberculata</i> (Bernard, 1897)	+	+	+
37		<i>Astreopora myriophthalma</i> (Lamarck, 1816)	+	+	
38	Pocilloporidae	<i>Pocillopora damicornis</i> (Linnaeus, 1758)	+	+	+
39		<i>Pocillopora varrucosa</i> (Ellis & Solander, 1786)	+		+
40		<i>Seriatopora hystrix</i> (Dana, 1846)	+	+	+
41		<i>Stylophora pistillata</i> (Esper, 1797)	+		
42		<i>Galaxea fascicularis</i> (Linnaeus, 1767)	+	+	
43		<i>Psammocora contigua</i> (Esper, 1797)			+
44	Agariciidae	<i>Pachyseris gemmae</i> (Nemanzo, 1955)	+	+	
45		<i>Pachyseris speciosa</i> (Dana, 1846)			+
46		<i>Pachyseris rugosa</i> (Lamarck, 1801)		+	
47		<i>Pavona danai</i> (Milne Edwards & Haime, 1860)			+
48	Fungiidae	<i>Ctenactis echinata</i> (Pallas, 1766)	+	+	+
49		<i>Ctenactis crassa</i> (Dana, 1846)			+
50		<i>Diaseris distorta</i> (Michelin, 1843)	+		
51		<i>Fungia danai</i> (Milne Edwards & Haime, 1851)		+	+
52		<i>Fungia fungites</i> (Linnaeus, 1758)	+	+	+
53		<i>Fungia paumotensis</i> (Stutchbury, 1833)	+		+
54		<i>Fungia concinna</i> (Verrill, 1864)		+	

Table 6. Contd.

Sl. No.	Family	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
55		<i>Fungia corona</i> (Doderlein, 1901)	+		
56		<i>Fungia scabra</i> (Doderlein, 1901)	+		
57		<i>Fungia spinosa</i> (Klunzinger, 1879)	-	+	
58		<i>Fungia granolusa</i> (Klunzinger, 1879)	+		
59		<i>Fungia klunzingeri</i> (Doderlein, 1901)	+	+	
60		<i>Fungia horrida</i> (Dana, 1846)			+
61		<i>Fungia repanda</i> (Dana, 1846)		+	+
62		<i>Herpolitha limax</i> (Houttuyn, 1772)	+		
63		<i>Lithophyllon lobata</i> (Horst, 1921)	-	+	-
64		<i>Lithophyllon undulatum</i> (Rehberg, 1892)	-	+	
65	Merulinidae	<i>Hydnophora microconos</i> (Lamarck, 1816)	+		+
66		<i>Hydnophora grandis</i> (Gardiner, 1904)		+	+
67		<i>Hydnophora exesa</i> (Pallas, 1766)		+	
68		<i>Hydnophora rigida</i> (Dana, 1816)		-	+
69		<i>Merulina scabricula</i> (Dana, 1846)	+	+	
70		<i>Merulina ampliata</i> (Ellis & Solander, 1786)	+	+	
71	Mussidae	<i>Symphyllia radians</i> (Milne Edwards & Haime, 1849)	-	+	
72		<i>Symphyllia hassi</i> (Pillai and Scheer, 1776)	+		
73		<i>Symphyllia agaricia</i> (Milne Edwards and Haime, 1849)		+	+
74		<i>Symphyllia recta</i> (Dana, 1846)	+	+	+
75		<i>Lobophyllia pachysepta</i> (Chevalier, 1975)		-	+
76		<i>Lobophyllia hemprichi</i> (Ehrenberg, 1834)	+	+	+
77	Faviidae	<i>Favia pallida</i> (Dana, 1846)	+	+	
78		<i>Favia maxima</i> (Veron and Pichon, 1977)	-	+	+
79		<i>Favia lizardensis</i> (Veron and Pichon, 1977)	-		+
80		<i>Favia matthaii</i> (Vaughan, 1918)	+	+	+
81		<i>Leptastrea purpurea</i> (Dana, 1846)	-	+	
82		<i>Favites abdita</i> (Ellis and Solander, 1786)		+	+
83		<i>Favites pentagona</i> (Esper, 1794)		+	+
84		<i>Favites complanata</i> (Ehrenberg, 1834)	+	+	+
85		<i>Favites halicora</i> (Ehrenberg, 1834)	+	+	+
86		<i>Favites flexuosa</i> (Dana, 1846)	+		
87		<i>Barabattoi laddi</i> (Wells, 1954)		+	
88		<i>Leptoria irregularis</i> (Veron, 1990)	+	+	+
89		<i>Platygyra pini</i> (Chevalier, 1975)		+	+

Table 6. Contd.

Sl. No.	Family	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
90		<i>Platygyra verweyi</i> (Wijsmann-Best, 1976)		+	+
91		<i>Platygyra sinensis</i> (Milne Edwards and Haime, 1849)		+	
92		<i>Platygyra lamellina</i> (Ehrenberg, 1834)	+	+	+
93		<i>Oulophyllia crispa</i> (Lamarck, 1816)			+
94		<i>Diploastrea heliopora</i> (Lamarck, 1816)		+	+
95		<i>Echinophora fruticulosa</i> (Ehrenberg, 1834)		+	+
96		<i>Goniastrea australensis</i> (Milne Edwards and Haime, 1857)		+	
97		<i>Goniastrea retiformis</i> (Lamarck, 1816)	+		+
98		<i>Goniastrea minuta</i> (Veron, 2000)	+	+	+
99		<i>Goniastrea edwardsi</i> (Chevalier, 1971)	+	+	+
100		<i>Pectinia paeonia</i> (Dana, 1846)	+		+
101		<i>Echinophyllia aspera</i> (Ellis and Solander, 1788)		+	+
102		<i>Oxypora crassispinosa</i> (Nemanzo, 1979)		+	+
103	Poritidae	<i>Porites solida</i> (Forskal, 1775)	+	+	+
104		<i>Porites lobata</i> (Dana, 1846)	+	+	+
105		<i>Porites cylindrica</i> (Dana, 1846)	+	+	+
106		<i>Porites annae</i> (Crossland, 1952)	+		
107		<i>Porites rus</i> (Forskal, 1775)		+	+
108		<i>Goniopora tenuidens</i> (Quelch, 1886)		+	
109		<i>Goniopora columna</i> (Dana, 1846)		+	
110	Euphyllidae	<i>Euphyllia glabrescens</i> (Chamisso & Eysenhardt, 1821)		+	
Total Number of Individual Colony of Species			50	78	61
Shannon-Weaver Index (H')			5.243	5.758	5.366
Simpsons Density Index (D)			0.97	0.98	0.972
Pielou's Evenness Index (J')			0.944	0.94	0.926

Table 7. Live coral cover the density of coral and coral associated fauna

Plot No.	Locality	% of Live Coral	Mean Density (No. 10m ⁻²)		
			Coral	Echinoderm	Mollusc
1	Campbell Bay	63.7	29.31	56.21	37.12
2	Shastri Nagar	59.53	27.64	44.28	38.15
3	Gandhi Nagar	63.71	28	54.03	39.12

Sponges

The sponges are found from shallow water to the depth of the ocean. Most sponges need a hard surface for attachment, but some can live on soft sediments. Few species are able to bore in rocks and shells. Sponges are common on rocky reefs, shipwrecks and coral reefs in a wide range of temperature and depths. They inhabit a wide variety of marine and freshwater systems and are found throughout tropical, temperate and polar region. Of the approximately 15,000 sponge species, most occur in marine environments, only about 1% of the species inhabits freshwater. The largest population occurs where there are strong tidal currents, which bring extra food. In Indian seas 451 species of sponges belonging to 3 classes, 17 orders, 65 families and 169 genera has been reported. Tikader *et al.* (1986) given a comprehensive account of sea shore fauna of Andaman and Nicobar Islands. This list

comprises of sponges belonging to 1 species of Calcarea, 16 species of Hexatinellidae and 63 species of Demospongiae. The recent work by Pattanayak (2006) describes 75 species, 48 genera, 35 families from the Andaman and Nicobar Islands. These include 4 new species records, 18 new locality records and 15 species endemic to the Andaman and Nicobar Islands. The work by Pattanayak (2009) this year reports 20 species of Hexatinellida and 122 species of Demospongiae from the National Zoological Collection India, in the Zoological Survey of India, Kolkata; which includes specimens from Andaman also. A total of 17 species of sponges under 16 genera and 12 families were reported from Great Nicobar Island (Table 8). The maximum number of species (14) was found in Shastri Nagar, whereas in other places it ranged from 10-12 species. *Plakortis* sp., *Hyrtios erectus*, *Carteriospongia foliascens*, *Stylissa* sp., *Paratetilla bacca* and *Oceanapia sagittaria* were the species commonly found in all the places.

Table 8. Species Composition of Sponges in Great Nicobar Island

Sl. No.	Species/Genera/Families	Shastri Nagar	Gandhi Nagar	Campbell Bay
	Order HOMOSCLEROPHORIDA Dendy, 1905 Family PLAKINIDAE Schulze, 1880 Genus <i>Plakortis</i> Schulze, 1880			
1	<i>Plakortis</i> sp.	+	+	+
	Order DICTYOCERATIDA Minchin, 1900 Family THORECTIDAE Bergquist, 1978 Genus <i>Hyrtios</i> Duchassaing & Michelotti, 1864			
2	<i>Hyrtios erectus</i> (Keller, 1889)	+	+	+
	Genus <i>Carteriospongia</i> Hyatt, 1877			
3	<i>Carteriospongia foliascens</i> (Pallas, 1766)	+	+	+
	Family IRCINIDAE Gray, 1867 Genus <i>Ircinia</i> Nardo, 1833			
4	<i>Ircinia strobilina</i> (Lamarck, 1816)	+	+	+
	Order HALICHONDRIDA Gray, 1867			
	Family DICTYONELLIDAE Van Soest, Diaz & Pomponi Genus <i>Acanthella</i> Schmidt, 1862			
5	<i>Acanthella klethra</i> Pulitzer-Finali, 1982	+		-
	Genus <i>Liosina</i> Thiele, 1899			
6	<i>Liosina paradoxa</i> Thiele, 1899	+	-	-

Table 8. Contd.

Sl. No.	Species/Genera/Families	Shastri Nagar	Gandhi Nagar	Campbell Bay
	Genus <i>Stylissa</i> Hallmann, 1904			
7	<i>Stylissa carteri</i> (Dendy, 1889)	+	+	
8	<i>Stylissa</i> sp.	+	+	+
	Order SPIROPHORIDA Bergquist & Hogg, 1969 Family TETILLIDAE Sollas, 1886 Genus <i>Paratetilla</i> Dendy, 1905			
9	<i>Paratetilla bacca</i> (Selenka, 1867)	+	+	+
	Order ASTROPHORIDA Sollas, 1888 Family ANCORINIDAE Schmidt, 1870 Genus <i>Ecionemia</i> Bowerbank, 1864			
10	<i>Ecionemia acervus</i> Bowerbank 1864	+	-	+
	Genus <i>Rhabdastrella</i> Thiele, 1903			
11	<i>Rhabdastrella globostellata</i> (Carter, 1883)	+		
	Order HADROMERIDA Topsent, 1894 Family TETHYIDAE Gray, 1848 Genus <i>Tethya</i> Lamark, 1814			
12	<i>Tethya repens</i> Schmidt, 1870		+	
	Order HAPLOSCLERIDA Topsent, 1948 Family CHALINIDAE Gray, 1867 Genus <i>Chalinula</i> Schmidt, 1868			
13	<i>Chalinula nematifera</i> (de Laubenfels, 1954)	+	+	+
	Family PETROSIDAE Van Soest, 1980 Genus <i>Xestospongia</i> De Laubenfels, 1932			
14	<i>Xestospongia testudinaria</i> (Lamarck, 1815)	+	+	+
	Family PHLOEDICTYIDAE Carter, 1882 Genus <i>Oceanapia</i> Norman, 1869			
15	<i>Oceanapia sagittaria</i> (Sollas, 1902)	+	+	+
	Order POECILOSCLERIDA Family CRELLIDAE Dendy, 1922 Genus <i>Crella</i> Gray, 1867			
16	<i>Crella</i> (Grayella) <i>cyathophora</i> Carter, 1869		+	
	Family CRAMBEIDAE Levi, 1963 Genus <i>Monanchora</i> Carter, 1883			
17	<i>Monanchora arbuscula</i> (Duchassaing & Michelotti, 1864)		+	
	Total number of Species	14	12	10

Echinoderms

The echinoderms comprised of echinoids, crinoids, asteroids and ophiuroids. It is known that more than 6000 species of echinoderms are living in various area of the world. In Indian seas, 649 species are reported so far. Bell (1887) for the first time listed the echinoderms from the Andaman and since then many workers reported echinoderms from these Islands and added several species to the echinoderm fauna. In 1983 James, while dealing with sea cucumber and sea urchin resources of the Andaman and Nicobar Islands gave a list of echinoderms known from these Islands. In addition, there have been several revisionary works effecting changes in the nomenclature and status of several taxa. Sastry (2005) attempted to compile all the available published literature on echinoderms of Andaman and Nicobar Islands as well as the materials in the National

Zoological Collection of Zoological Survey of India at Kolkata and Port Blair. It is resulted with a total of 425 species of echinoderms from these Islands. Earlier there were only stray reports of occurrence of individual species of these Islands. The species composition of echinoderms in three places in Great Nicobar Island is presented in table 9. Altogether 30 species of echinoderms belonging to 21 genera and 15 families were recorded from three places. The occurrence of species varied between 8 in Campbell Bay and 16 at Gandhi Nagar. It is to note that all the recorded species of echinoderms are shown different degree of distribution and did not find any species common to all the places of study except *Diadema setosum*. The numerical density of echinoderms was calculated and its maximum (56.21 individuals/10 m²) values found in Campbell Bay while minimum (44.28 individuals/10 m²) at Gandhi Nagar (Table 7).

Table 9. Echinoderms diversity in Great Nicobar Island

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
	Class HOLOTHUROIDEA Order ASPIDOCHIROTIDA Family HOLOTHURIIDAE			
1	<i>Holothuria atra</i> (Jaeger, 1833)	+		-
2	<i>Holothuria impatiens</i> (Forskal, 1775)	+	-	
3	<i>Holothuria edulis</i> (Lesson, 1830)	+	+	-
4	<i>Holothuria fuscocinerea</i> (Jaeger, 1833)	+	+	-
5	<i>Holothuria cinerascens</i> (Brandt, 1835)		-	+
6	<i>Bohadschia marmorata</i> (Jaeger, 1833)	+	-	-
7	<i>Actinopyga mauritiana</i> (Quoy & Gaimard, 1833)	+	-	
	Family STICHOPODIDAE			
8	<i>Stichopus variegatus</i> (Semper, 1868)	+	-	+
9	<i>Stichopus chloranatus</i> (Brandt, 1835)		+	+
	Order APODIDA Family SYNAPTIDAE			
10	<i>Synapta maculata</i> (Chamisso, 1821)	+		
	Class ASTEROIDEA Order VALVATIDA Family OREASTERIDAE			
11	<i>Culcita novaguineae</i> (Muller & Troschel, 1842)		+	+

Table 9. Contd.

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
	Family OPHIDIASTERIDAE			
12	<i>Linckia laevigata</i> (Linnaeus, 1758)	+	+	+
13	<i>Fromia indica</i> (Perrier, 1867)	+		
14	<i>Dactylosaster cylindricus cylindricus</i> (Lamarck, 1816)			+
	Family ASTERINIDAE			
15	<i>Asterina sarsini</i> (de Loriol, 1897)		+	+
	Family ACANTHASTERIDAE			
16	<i>Acanthaster planci</i> (Linnaeus, 1758)		+	
	Class ECHINOIDEA Order ECHINOIDA Family ECHINOMETRIDAE			
17	<i>Echinometra mathei</i> (de Blainville, 1825)	+	+	
	Family DIADEMATIDAE			
18	<i>Diadema setosum</i> (Leske, 1778)	+	+	+
19	<i>Diadema savignyi</i> (Michelin, 1845)	+		
20	<i>Echinothrix calamaris</i> (Pallas, 1774)		+	
	Order TEMNOPLEUROIDA Family TEMNOPLEURIDAE			
21	<i>Mespilia globulus</i> (Linnaeus, 1758)		+	
	Class CRINOIDEA Order COMATULIDA Family HIMEROMETRIDAE			
22	<i>Himerometra robustipinna</i> (P.H. Carpenter, 1912)			+
23	<i>Heterometra crenulata</i> (P.H. Carpenter, 1882)	+		
	Family COMASTERIDAE			
24	<i>Comanthus parvicirrus</i> (Muller, 1841)	+		+
25	<i>Oxycomanthus bennetti</i> (Muller, 1841)	+		+
	Class OPHIUROIDEA Order OPHIURIDA Family OPHIOCOMIDAE			
26	<i>Ophiocoma erinaceus</i> (Muller & Troschel, 1842)		+	
27	<i>Ophiocoma brevipes</i> (Peters, 1851)			+
28	<i>Ophiocoma pussila</i> (Brock, 1888)		+	
	Family OPHIACTIDAE			
29	<i>Ophiactis savignyi</i> (Muller & Troschel, 1842)		+	
	Family OPHIURIDAE			
30	<i>Ophiolepis superba</i> (Clark, H.L, 1842)		+	
	No. of species	16	15	8

Molluscs

Molluscs constitute an important component of marine biodiversity of India on the east and west coasts and the islands of Andaman & Nicobar and Lakshadweep. Five major classes, namely Polyplacophora, Gastropoda, Scaphopoda, Bivalvia and Cephalopoda are represented in India. Against a total of 586 families of molluscs in the world, an estimated 279 families occur in the Indian region. A total of 101 species of gastropods belongs to 36

families were identified from three places of present study (Table 10). The number of species observed in different islands ranged from 38 at Campbell Bay to 47 at Gandhi Nagar. Among them *Turbo (Ocana) cidaris*, *Nerita (Ritena) grayana* and *Nerita (Theliostyla) oryzae* were common to all three places. The data on density of molluscs were also estimated at different places and it ranged from 37.12 to 39.12 individuals/10m² at Campbell Bay and Shastri Nagar respectively (Table 7).

Table 10. Distribution of Molluscs in Great Nicobar Island

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
	Phylum MOLLUSCA Cuvier, 1795 Class POLYPLACOPHORA de Blainville, 1816			
	Order NEOLORICATA Bergenhayn, 1955 Family ISCHNOCHITONIDAE Dall, 1899			
1	<i>Ischnochiton bouryi</i> Dupuis		-	+
2	<i>Ischnochiton winckworthi</i> Leloup	-	-	+
	Family CHITONIDAE Rafinesque, 1815			
3	<i>Chiton granoradiatus</i> Leloup	+	-	-
	Class GASTROPODA Cuvier, 1795 Order ARCHAEOGASTROPODA Thiele, 1925 Family HALIOTIDAE Rafinesque, 1815			
4	<i>Haliotis (Haliotis) asinina</i> (Linnaeus, 1758)	-	-	+
5	<i>Haliotis (Sanhaliotis) varia</i> (Gmelin, 1791)	+	+	-
	Family TURBINIDAE Rafinesque, 1815			
6	<i>Angaria distorta</i> (Linnaeus, 1758)	-	+	+
7	<i>Astraliium rhodostoma</i> (Lamarck, 1822)	+	-	-
8	<i>Turbo (Ocana) cidaris</i> (Gmelin, 1790)	+	+	+
9	<i>Turbo (Turbo) petholatus</i> (Linnaeus, 1758)	-	+	-
	Family NERITIDAE Rafinesque, 1815			
10	<i>Nerita (Amphinerita) articulata</i> (Gould, 1847)	+	-	+
11	<i>Nerita (Nerita) undata</i> (Linnaeus, 1758)		+	-
12	<i>Nerita (Ritena) grayana</i> (Recluz, 1843)	+	+	+
13	<i>Nerita (Theliostyla) oryzae</i> (Recluz, 1841)		+	-
14	<i>Nerita (Theliostyla) squamulata</i> (Le. Guillou, 1841)	+	+	+
15	<i>Neritina communis</i> (Linnaeus, 1758)	+		-
16	<i>Neritina paralella</i> (Rodings, 1798)		+	-
	Family TROCHIDAE Rafinesque, 1815			
17	<i>Trochus (Infundibulum) ochroleucus</i> (Gmelin, 1791)	+	-	+

Table 10. Contd.

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
18	<i>Trochus (Infundibulum) radiatus</i> (Gmelin, 1791)	+	-	
19	<i>Trochus maculatus</i> (Linnaeus, 1758)	+		
20	<i>Trochus niloticus</i> (Linnaeus, 1767)	-	+	+
21	<i>Trochus ochroleucus</i> (Gmelin, 1791)	-		+
22	<i>Umbonium vestiarius</i> (Linnaeus, 1758)	+	+	
23	<i>Calliostoma tranquebarica</i> (Roeding, 1798)		+	
	Order MESOGASTROPODA Thiele, 1925 Family BURSIDAE Thiele, 1925			
24	<i>Bursa granularis</i> (Roeding, 1798)			+
25	<i>Tutufa (Tubufella) rubeta</i> (Linnaeus, 1758)	+		
	Family CERITHIIDAE Fleming, 1822			
26	<i>Rhinoclavis (proclava) kochi</i> (Philippi, 1848)	-	+	
27	<i>Rhinoclavis (Rhinoclavis) aspera</i> (Linnaeus, 1758)	+	+	
28	<i>Rhinoclavis (Rhinoclavis) vertegus</i> (Linnaeus, 1767)			+
	Family RANELLIDAE Gray, 1854			
30	<i>Cymatium (Ranularia) tripum</i> (Lamarck, 1822)	-	+	-
31	<i>Cymatium (Linatella) cumaceum</i> Lamarck, 1816			+
	Family CYPRAEIDAE Rafinesque, 1815			
32	<i>Cypraea (Erronea) cauric</i> (Linnaeus, 1758)	+		-
33	<i>Cypraea (Lyncina) vitellus</i> (Linnaeus, 1758)			+
34	<i>Cypraea (Mauritia) arabica</i> (Linnaeus, 1758)	+	+	
35	<i>Cypraea (Erosaria) erosa</i> (Linnaeus, 1758)	-	+	
36	<i>Cypraea (Cypraea) tigris</i> (Linnaeus, 1758)	+	+	
37	<i>Cypraea (Erosaria) caputserpentis</i> (Linnaeus, 1758)	-		+
38	<i>Cypraea carneola</i> (Linnaeus, 1758)		+	
39	<i>Cypraea isabella</i> (Linnaeus, 1758)	+		
40	<i>Cypraea mauritianaregina</i> (Linnaeus, 1758)			+
41	<i>Cypraea (Leparocypraea) mappa</i> (Linnaeus, 1758)	+	+	-
42	<i>Cypraea talpa</i> (Linnaeus, 1758)			+
	Family NATICIDAE Forbes, 1838			
43	<i>Eunaticina (Eunaticina) papilla</i> (Gmelin, 1758)	+	-	
44	<i>Natica tigrina</i> (Roeding, 1798)	+	+	
45	<i>Natica vitellus</i> (Linnaeus, 1758)	-		+
46	<i>Polinices (Mammilla) melanostoma</i> (Gmelin, 1791)	-	+	
	Family STROMBIDAE Rafinesque, 1815			
47	<i>Strombus marginatus</i> (Linnaeus, 1758)	+	+	
48	<i>Strombus (Laevistrombus) canarium</i> Linnaeus, 1758		+	

Table 10. Contd.

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
49	<i>Strombus (Canarium) mutabilis</i> Swainson, 1821	+	-	
50	<i>Lambis (Lambis) chiragra</i> (Linnaeus, 1758)		-	+
51	<i>Lambis (Millepus) Scorpius indomaris</i> (Abbott, 1961)		+	
52	<i>Lambis (Humphery) tsuncata</i> (Linnaeus, 1758)			+
	Family LITTORINIDAE Gray, 1840			
53	<i>Littorina intermedia</i> (Philippi, 1845)		+	
	Order NEOGASTROPODA Cuvier, 1797 Family BUCCINIDAE Rafinesque, 1815			
54	<i>Engina mendicaria</i> (Linnaeus, 1758)	-	+	
	Family CONIDAE Rafinesque, 1815			
55	<i>Conus canonicus</i> (Hwass in Bruguiere, 1792)	+	-	-
56	<i>Conus coronatus</i> (Gmelin, 1791)			+
57	<i>Conus episcopus</i> (Hwass in Bruguiere, 1792)	+	-	
58	<i>Conus marmoreus</i> (Linnaeus, 1758)	-	+	-
59	<i>Conus nussatella</i> (Linnaeus, 1758)	+	-	-
60	<i>Conus terebra</i> (Born, 1780)	+	+	+
	Family FASCIOLARIIDAE Gray, 1853			
61	<i>Latirus gibbulus</i> (Gmelin, 1791)	+		+
62	<i>Latirus polygonus</i> (Gmelin, 1791)			
63	<i>Pleuroploca filamentosa</i> (Roding, 1798)	-	+	-
	Family MITRIDAE Swainson, 1831			
64	<i>Mitra (Mitra) mitra</i> (Linnaeus, 1758)	+	+	-
65	<i>Mitra (Strigatella) scutulata</i> (Gmelin, 1791)	+		-
66	<i>Mitra (Strigatella) colombelliformes</i> (Kiener, 1838)		+	-
67	<i>Mitra (Strigatella) litterata</i> (Lamarck, 1811)			+
68	<i>Pterygia dactylus</i> (Linnaeus, 1758)	+		-
	Family MURICIDAE da Costa, 1776			
69	<i>Coronia konkanensis</i> (Melvill, 1893)	+	-	
70	<i>Drupa (Ricinus) ricinus</i> (Linnaeus, 1753)	+	+	
71	<i>Drupa rubusidaea</i> (Rodings, 1798)	-		+
	Family NASSARIDAE Iredale, 1916			
72	<i>Nassarius lurida</i> (Gould, 1849)	+	+	+
73	<i>Nassarius stolatus</i> (Gmelin, 1791)			
74	<i>Nassarius subconstrictus</i> (Sowerby, 1899)	+	+	+
	Family OLIVIDAE Latreille, 1825			
75	<i>Oliva miniacea</i> (Roeding, 1798)	+		

Table 10. Contd.

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
	Family TEREBRIDAE H. and A. Adams, 1854			
76	<i>Terebra columellaris</i> (Gray, 1834)		+	+
77	<i>Terebra dimidiata</i> (Linnaeus, 1758)		+	
	Order CEPHALASPIDEA P. Fischer, 1883 Family BULLIDAE Rafinesque, 1815			
78	<i>Bulla ampulla</i> Linnaeus, 1758	+	+	
	Family AGLAJIDAE Plisbry, 1895			
79	<i>Chelidonura punctata</i> (Eliot, 1903)		+	
	Family CHROMODORIDIDAE Bergh, 1891			
80	<i>Chromodoris fidelis</i> (Kelaart, 1858)	+		
81	<i>Hypselodoris infucata</i> (Ruppell & Leuckart, 1830)			+
82	<i>Hypselodoris kanga</i> (Rudman, 1977)		+	
83	<i>Chromodoris colemani</i> (Rudman, 1982)	+		
	Family Facelinidae Bergh, 1889			
84	<i>Moridilla brockii</i> (Bergh, 1888)			+
	Family Phyllidiidae Rafinesque, 1815			
85	<i>Phyllidia varicosa</i> (Lamarck, 1801)			+
	Dorididae Rafinesque, 1815			
86	<i>Halgerda tessellata</i> (Bergh, 1880)		+	
	Class BIVALVIA Linnaeus, 1758 Order NUCULOIDA Dall, 1889 Family ARCIDAE Lamarck, 1809			
87	<i>Barbatia (Barbatia) tenella</i> (Reeve)		+	+
88	<i>Barbatia (Barbatia) cancellata</i> Preston	+		
	Order MYTILOIDA Ferussac, 1822 Family MYTILIDAE Rafinesque, 1815			
89	<i>Perna viridis</i> (Linnaeus)			+
	Family PINNIDAE Leach, 1819			
90	<i>Pinna bicolor</i> Gmelin		+	
91	<i>Atrina (Atrina) vexillum</i> (Born)		+	
	Order VENEROIDA Adame & Adams, 1856			
	Family Chamidae Lamarck, 1809			
92	<i>Chama brassica</i> Reeve	+		
93	<i>Corculum cardissa</i> (Linnaeus)			+
	Family TRIDACNIDAE Lamarck, 1819			
94	<i>Tridacna maxima</i> Roeding	+		
95	<i>Tridacna squamosa</i> Lamarck			+

Table 10. Contd.

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
	Family MACTRIDAE Lamarck, 1809			
96	<i>Macra hepatica</i> Deshayes	-	+	-
97	<i>Macra maculata</i> Gmelin	+	+	-
	Family TELLINIDAE De Blainville, 1924			
98	<i>Tellina (Arcopegia) carnicolor</i> Hanley	+	-	-
	Class CEPHALOPODA Cuvier, 1797 Order NAUTILIDA Agassix, 1847 Family NUTILIDAE Linnaeus, 1758			
99	<i>Nautilus pompilius</i> Linnaeus	+	-	+
	Order SEPIIDA Neaf, 1916 Family SEPIIDAE Keferstein, 1866			
100	<i>Sepia aculeate</i> Ferussac & d' Orbigny	-	+	-
101	<i>Sepia pharaonis</i> Ehrenberg	-	-	+
	Total number of species	45	47	38

Crabs

Crustacean diversity of Andaman and Nicobar Islands is well studied during 20 century by many researchers. Coral reefs inhabit several commonly important crustacean fauna. In 1865, Heller revealed 14 species of hermit crabs from Nicobar Islands. Alcock (1905) further revealed 14 species and 5 new varieties/species of hermit crabs. Reddy and Ramakrishna (1972) found the occurrence of 20 species followed by Tikader *et al.* (1986) reported 37 species lead to a total of 40 species of hermit crabs from Andaman and Nicobar Islands. Species composition of brachyuran crabs of Andaman & Nicobar Islands has been consolidated as 220 species through the reports of Kathirvel (1983) and Tikader *et al.* (1986). A total of 162 species of prawn found in coral reef environment of these Islands are published by Silas *et al.* (1983) and Tikader *et al.* (1986). Apart from that 6 species of lobsters occurred in these Islands (Shanmugam and Kathirvel, 1983). In 2002, Ajmal Khan compiled the list on crustacean fauna from these Islands and it depicts 837 species of crustaceans. In the present study, the occurrence of brachyuran crabs in

Great Nicobar Island was identified and the list of species reported is depicted in table 11. Altogether 52 species of crabs under 21 genera and 5 families were recorded. However, the species of crabs ranged from 45 to 51 at Shastri Nagar and Gandhi Nagar respectively with the species diversity of 4.73 to 4.92 for these places.

Biogeographically, Great Nicobar Island is the most important region and one of the noted areas for speciation in the tropics. The study area in Great Nicobar Island reported 110 species of corals which is about 25.52% of coral species reported from Andaman and Nicobar Islands. Apart from that the coral associated faunal communities such as molluscs, echinoderms, sponges and soft corals are relatively higher in diversity. The detailed study on the continental shelf of the entire part of the Great Nicobar Island may be revealed out several more faunal elements including new records and new species.

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Table 11. Diversity of crabs in Great Nicobar Island

Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
	Family PORTUNIDAE			
1	<i>Charybdis obtusifrons</i> (Leene)	+	+	
2	<i>Charybdis feriata</i> (Linnaeus)			+
3	<i>Charybdis lucifera</i> (Fabricious)		+	+
4	<i>Chrybdis (Goniohellenus) truncata</i> (Fabricius)			
5	<i>Portunus longispinosus</i> (Dana, 1852)	+	+	+
6	<i>Portunus sanguinolentus</i> (Herbst)	+		-
7	<i>Portunus pelagicus</i> (Linnaeus)	+		+
8	<i>Portunus granulatus</i> (Milne Edwards)	-		
9	<i>Scylla serrata</i> (Forsk.)	+		+
10	<i>Thalamita integra</i> (Dana)	-		+
11	<i>Thalamita admete</i> (Herbst)	+	-	
12	<i>Thalamita chaptali</i> (Audouin & Savigny)		+	
13	<i>Thalamita crenata</i> (Latreille)	-	+	+
14	<i>Thalamita prymna</i> (herbst)	+	+	
15	<i>Thalamita quadrilobata</i> (Miers 1884)	-		+
	Family OCYPODIDAE			
16	<i>Macrophthalmus convexus</i> (Stimpson)	-		-
17	<i>Macrophthalmus telescopicus</i> (Owen)		+	
18	<i>Macrophthalmus verreauxi</i> (H. Milne Edwards, 1848)			
20	<i>Macrophthalmus japonicus</i> (de Haan, 1835)		+	+
21	<i>Uca annulipes</i> (Latreille)			+
22	<i>Uca marionis excise</i> Mobill		+	
23	<i>Uca vocans</i> (Linnaeus, 1758)			
24	<i>Uca dussumieri</i> (H.Milne Edwards 1852)		-	
25	<i>Uca chlorophthalmus</i> (Adams & White, 1848)		+	
26	<i>Uca hesperiae</i> (Crane, J. 1975)	-	+	+
	Family GRAPSIDAE			
27	<i>Metopograpsus messor</i> (Forsk. , 1775)			+
28	<i>Grapsus albolineatus</i> (Lamarck, 1818)	+	+	
29	<i>Grapsus grapsus</i> (Linnaeus)		+	+
30	<i>Geograpsus grayi</i> (H. Milne Edwards, 1853)		+	+
31	<i>Geograpsus crinipes</i> (Latreille 1829)		+	
32	<i>Grapsus longitarsis</i> (Dana, 1851)	+	+	
33	<i>Metopograpsus frontalis</i> (Mirs)			
34	<i>Pachygrapsus minutus</i> (A.M. Edwards)			+
35	<i>Pachygrapsus planifrons</i> (de man)		+	+
36	<i>Metaplex distinct</i> (M.Edwards)		+	
37	<i>Metaplex dentipes</i> (Heller)		+	

Table 11. Contd.

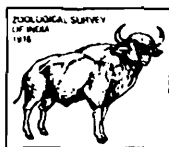
Sl. No.	Species	Shastri Nagar	Gandhi Nagar	Campbell Bay
	Family XANTHIDAE			
38	<i>Atergatis floridus</i> (Rumph)	+		
39	<i>Actaea cavipes</i> (Dana)			+
40	<i>Actaea speciosa</i> (Dana)	+		
41	<i>Epixanthus dentatus</i> (White)	+		
42	<i>Epixanthus frontalis</i> (M. Edwards)	+	+	+
43	<i>Etisus denatus</i> (Herbst)	+		
44	<i>Etisus laevimanus</i> (Randall)		-	
45	<i>Platypodia granulosa</i> (Ruppell)			
46	<i>Zozymus aeneus</i> (Linnaeus)	+	+	+
	Family TRAPEZIIDAE			
47	<i>Trapezia formosa</i> (Smith, 1869)	+	+	+
48	<i>Trapezia cymodoce</i> (Herbst 1797)	+		
49	<i>Trapezia septata</i> (Dana 1852)	+	+	
50	<i>Trapezia digitalis</i> (Latreille, 1828)	+		+
51	<i>Trapezia ferruginea</i> (Latreille)			+
52	<i>Tetralia glaberrima</i> (Herbst)			
	Total no. of Species	45	51	46
	Species Diversity (H')	4.73	4.92	4.75

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MATE GUARDING BEHAVIOUR IN THE DRAGONFLY *PANTALA FLAVESCENS* (ODONATA : LIBELLULIDAE) AT VELLORE, TAMIL NADU

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INTRODUCTION

Reproductive behaviour is important to consider the phenomenon of sperm competition of the diversified reproductive behaviour in dragonflies (Parker, 1970). Because, the fact that even if a male copulates with a female, his sperm does not always fertilize her eggs, is not only clarifying the significance of mate guarding by males, but also it gives us an important view point to understand a series of reproductive behaviour in dragonfly mating system. Also it is important to consider the oviposition site where reproduction occur. In many odonates, males guard their mates after copulation and during oviposition. Some species guard while flying near the female and other species guard while remaining in physical contact with the female (Corbet, 1962; Ueda, 1979; Parr, 1983). Male guarding is absent in some odonates.

MATERIALS AND METHODS

The study was carried out in two different areas Saduppari and Konavatum, which is within 2 km were chosen on the basis of availability of water resources during January

2005 to December 2006. Saduppari-Site-A, a huge lake namely saduppari lake, is the main source of water for the adjoining paddy fields. Besides this lake, small water bodies called pools are also available; but the water in these small pools is not perennial. In Konavatum-Site-B, there are no such water bodies like river, lake, pools, the saduppari lake supplies water to agricultural fields of konavatum. Observation on *P. flavescens* (Fabricius) were made at a pond in Konavatum during the oviposition periods of May, June, September and October during 2005-06 at a small shallow pond. The area of the pond is 2.56 m² in extant (1.6 × 1.6 m). Observations were done in the early morning till sunset in different periods. The mate guarding, oviposition behaviour and oviposition duration of the dragonfly *P. flavescens* was keenly observed with the help of binoculars and the details were noted.

RESULTS

Oviposition in *P. flavescens* recorded in and around the freshwater bodies of lakes, ponds, streams, rivers, pools and vegetation. The study reveals that ovipositing time, seasonal oviposition and duration of oviposition is

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different in different periods. The peak period of oviposition was noticed during the month of May, June, September and October. The duration of oviposition was varied in different

individuals. The duration of oviposition and the number of dips undisturbed and disturbed condition were recorded during 2005 and 2006 (Table 1 and 2).

Table 1. Mean values of oviposition duration during, 2005

Month	Undisturbed			Disturbed		
	Values	Duration min/sec	Number of dips	Values	Duration min/sec	Number of dips
May	MAX	9	8	MAX	10	9
	MIN	6.07	5	MIN	8	5
	AVE	7.76	7	AVE	8.81	7
June	MAX	9	8	MAX	9.2	9
	MIN	7.4	6	MIN	7.4	6
	AVE	7.92	7	AVE	8.13	8
September	MAX	9.1	8	MAX	9.1	9
	MIN	7.4	6	MIN	7.55	7
	AVE	8.07	7	AVE	8.61	8
October	MAX	8.4	8	MAX	9.1	9
	MIN	7.45	6	MIN	8.1	7
	AVE	8.05	7	AVE	8.61	8

N = 275

Table 2. Mean values of oviposition duration during, 2006

Month	Undisturbed			Disturbed		
	Values	Duration min/sec	Number of dips	Values	Duration min/sec	Number of dips
May	MAX	8.55	8	MAX	9.15	8
	MIN	7.45	6	MIN	8.1	7
	AVE	8.14	7	AVE	8.50	8
June	MAX	8.55	7	MAX	9.1	8
	MIN	7.4	6	MIN	8.44	7
	AVE	8.29	7	AVE	8.82	7
September	MAX	7.45	8	MAX	8.14	8
	MIN	5.08	5	MIN	7.01	6
	AVE	6.82	7	AVE	7.68	7
October	MAX	7.47	8	MAX	8.13	7
	MIN	7.03	6	MIN	7.13	5
	AVE	7.22	7	AVE	7.60	6

N = 346

During 2005

In the month of May, the duration of viviposition ranged between 6 to 9 minutes with the number of dips being 5 and 8 but under disturbed conditions, such values were moderately high. It ranged between 8 to 10 minutes with the number of dips as 5 and 9. In the months of June and September, the duration of oviposition and the number of dips exhibits, similar values *i.e.*, ranged between 7 to 9 minutes with the number of dips are 6 and 8. The same duration was also noted under the undisturbed conditions. During October, the duration ranged between 7 to 8 minutes with the number of dips as 6 and 8 but the duration has slightly increased ranging between 8 to 9 minutes with 7-9 dips under disturbed conditions.

During 2006

In the month of May 2006, the duration has ranged between 7 to 8 minutes with the number of dips as 6 and 8 under undisturbed conditions. More or less same findings were observed in the following month (June). Similarly, their disturbed conditions slight change in duration, it has 8 to 9 minutes with number of dips 7 and 8 it was observed in the next month June. In September, the duration was decreased in the same month of the year 2005, it ranged from 5 to 7 minutes and with the number of dips as 5 and 8 under undisturbed conditions. It was observed in under disturbed conditions more or less similar finding within one minute difference with the previous year of 2005 in the same month. During the month of October the duration ranged between 7.47 minutes in the number of dips as 6 to 8 under undisturbed conditions. Slight changes were observed in disturbed conditions and it ranged 7 to 8 minutes with 5 to 7 dips.

The results revealed in both the years (2005 and 2006) that the oviposition duration under disturbed and undisturbed condition was no more or less the same ofcourse, slightly changes were also observed in disturbed conditions.

Guarding behaviour

Males guarded the females after copulation during oviposition. Two types of guarding behaviour were observed in *P. flavescens*. *i.e.*, contact guarding and non-contact guarding. However, the type of guarding behaviour differed in different times.

The contact guarding by the males was observed during the early morning copulation. Morning copulations were elaborate. After the first attempt of copulation, the male brought her female partner to water areas, where she laid eggs without leaving her contact. With the help of claspers, males hold the prothorax of the female so that the female body was on the back of the Females. They continued their flight in this way sustaining the contact guarding, when females were in oviposition. After laying the eggs, they continued to copulate the female responded to the male copulation by bending her abdominal tip so that the genital aperture of the female touched the accessory genitalia of male and continued her mating. Contact guarding was mostly observed in the early hours (6 to 8 am) and in the late hours (4 to 6 pm).

Non contact guarding, some males establish territory near oviposition sites if disturbance occurred by rival males at the oviposition sites, the guarding males fight with them and send out from the site. In this way it protected his mates by non-contact guarding behaviour. The peak period of non-contact guarding was from 12 noon to 3 pm. It started guarding after 10 am. The number of males and females is disproportionate in the oviposition place. The number of males were more than that of females. The relative numbers included 7 males & 4 females, 10 males and 6 females, 11 males & 6 females and so on. The territorial males use non contact guarding and non-territorial males use contact guarding.

The duration of oviposition time was found to be different in contact guarding and non-contact guarding types. The non-contact guarding females by males takes 10 minutes and contact guarding females, just stretches the surface of the water for 40 cm.

DISCUSSION

During the study it reveals that *P. flavescens* during reproductive behaviour used both types of contact guarding and non-contact guarding behaviour according to situations. The results of the field observations emits territorial males use non-contact guarding and non-territorial males use contact guarding.

Usually, territorial males are energetic costs of most protection (Convey, 1989). When disturbances occurred by rival males at the oviposition site, the non-contact guarding males fight with them and send out from the site. Ueda (1979) had reported that the harassment from other males and the probability of female take over. Alcock (1987) had reported that changes in 'quality' (i.e. number of fertilizable eggs of the present mate relative to that of other available females. Another factor is that non-contact guarding male has a merit for maintenance of territory and at the same time it gets female partner at oviposition site. It is suggested that the male have a chance to get a same or new female at the oviposition site.

In *P. flavescens*, non-territorial males use contact guarding because there is much risk to get a female partner over by other territorial males and hence they do contact guarding. Sometimes these males also use non-contact guarding at low male density at the oviposition site. There must be advantages in contact and non-contact guarding. It is known from the guarding behavior that multiple mating hypothesis that non-contact guarding has a merit for a male to copulate with a new coming female during his mate is ovipositing. It has been revealed among many species, female copulates with multiple males, the last male has a high fertilization rate by removing sperm of previous males from female's storage organ, or packing it into the back of the organ by the penis. Accordingly, it is safely assumed that males mate guarding behaviour, contact guarding or non-contact guarding, function to prevent his mate from recopulation with other males and after all to force her to lay eggs fertilized by his own sperm (Parker, 1970).

Mate searching tactics in *P. flavescens*, the territorial males catch females arriving at territory; sneakers catch ovipositing females in secrete from territorial males; opportunistists catch females away from oviposition site. The females have developed some tactics for avoiding male harassment, which interferes with their ovipositing. McMillan (2000) reported that tactics females employed to minimize the interference include rapid escape flight, repeated return visits to the water. The significance of guarding by the male to protect the female against interference from rival males (Sherman, 1983 and Waage, 1984). Some females are more interested to follow the territorial males than the non-territorial males, it may be due to protection and freely enjoying the oviposition takes own time to lay her eggs. Thus, although many hypothesis of advantage of guarding only single factor is not important and several factors may relate to it altogether. Males do not always shift post copulatory behaviour that there flexibility of mate guarding behaviour in *P. flavescens* were observed.

In the field observation, the peak period of oviposition was noticed at the months of May, September, October, and November and slowly declined at the months of June. The two different types of oviposition occurs in *P. flavescens*, tandem oviposition and non-tandem oviposition. Oviposition was observed while they were in tandem with male; while in the first attempt of mating, it started to lay her eggs but males did not release their partners completely; it grasped the head of the females and searched for the water, if found, it took the female to that area for oviposition. Then the female dipped her tip of the abdomen in water while they were in flight and continued her mating in the second attempt. This tandem oviposition was observed particularly in the month of May. In other months September, October and November it was commonly noticed at anytime. The time taken for oviposition depends upon the male strategy because it allows the female for ovipositions just scratch the water at certain distances and take away and again kept down to the water

to spread their eggs. In non-tandem oviposition, females, take her own time to lay her eggs with the care of guarding males. Results revealed that the duration of oviposition was recorded as 6 to 10 minutes with the number of dips 6 to 8. The duration of oviposition and number of dips under disturbed and undisturbed conditions showed that more or less same duration with little changes (Table 1 and 2).

The site selection for oviposition, only by the females in the non-tandem oviposition but the tandem ovipositing females site selected by the male. Though there is no contact guarding males for non-tandem females, when there are increased interference by males, the females may not be able to lay their eggs at a single visit to the water. In order to adopt the high male densities in which intense interference

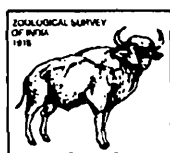
occurs, utilizing both rapid escape and repeated visits to the water in valid tactic females. Species that oviposited mainly in tandem flight spread their eggs over seasonal ponds, which interpreted as spatial risk spreading. Species which performed non-contact guarding and localized their eggs usually in a single pond which interpreted as distinct habitat selection (Schenk *et al.*, 2004).

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STUDIES ON THE DIVERSITY OF ODONATA AND LEPIDOPTERA FAUNA OF MOUNT ABU, RAJASTHAN, INDIA

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INTRODUCTION

Odonata (Damsel and Dragonflies) includes some of the most ancient and beautiful insects ever roamed the earth, as well as some of the largest flying invertebrates ever to have lived. For some 270 million years, odonates with their four long independent membranous wings and long bodies have remained unchanged in their essential form and are dominant invertebrate predators in ecosystem. Their powerful acrobatic flight enables them to catch many small organisms. Now a day they are extensively used in controlling causative agents of malaria and filaria, and of insect pests in different ecosystems on the global basis (Kumar, 2002). Approximately 6,000 species and subspecies belonging to 630 genera in 28 families of Odonata are known from all over the world (Tsuda, 1991), out of which 499 species and subspecies of Odonata under 139 genera belonging to 17 families are reported from India (Prasad and Varshney, 1995). Being predators both at larval and adult stages, they play a significant role in the food chain of forest ecosystem (Vashishth *et al.*, 2002). In addition to this, their value as indicators of quality of the biotope is being increasingly recognized (Subramanian, 2002). Perusal of literature

reveals that no consolidated account is available on the Odonata fauna of Rajasthan, though Agarwal (1957), Bose and Mitra (1976), Prasad and Thakur (1981), Thakur (1985), Tyagi and Miller (1991), Prasad (1996) and Prasad (2004) recorded odonates species from selected localities of Rajasthan.

From India 15,000 species and many more species distributed over 84 families and 18 superfamilies of butterflies and moths recorded (Mondal, 1998), in that 1,501 species are butterfly (Kunte, 2000). Butterflies are the most beautiful and attractive than most other insects and have fascinated human imagination and creativity. They are valuable pollinators when they move from plant to plant, gathering nectar and are the one of the important food chain components of the birds, reptiles, spiders and predatory insects. They are also good indicators of environmental quality as they are sensitive to changes in the environment. Perusal of literature reveals that the workers contributed and documented their work in the Lepidoptera study were de Niceville (1886, 1890), Moore (1890-1903), Marshall & de Niceville (1882), Swinhoe (1893, 1905-1912), Bingham (1905, 1907), Evans (1932), Talbot (1939, 1947), Wynter-Blyth (1957), Cantlie (1962)

and presently Gaonkar (1996), Gunathilagaraj *et al.* (1998, 2000), Gupta and Mondal (2005), Haribal (1998), Heppner (1998), Kumar *et al.* (2007a and 2007b), Kunte (2000), Mathew and Rahamathulla (1993), Mondal (1998), Lewis (1973), Sharma *et al.* (2006), Varshney (1993, 1994 and 1997), Varshney and Gupta (1996) enriched this field. Although India has a rich butterfly fauna, but due to various reasons such as habitat destruction, fire, use of pesticides and weedicides and illegal collection for trade, many species have become very rare and some are on the verge of extinction. Therefore, the present study makes a modest attempt to explore the existing diversity of odonates and Lepidoptera from Mount Abu, Rajasthan, India.

MATERIALS AND METHODS

The field observations and collection of odonates and Lepidoptera were made by using aerial sweep net at different localities *i.e.* Gomukh, Gyan Sarovar, Nakki lake, Guru Shikhar, Anadara point, Trevor point, Sunset point, Waterfall on Abu road and forest area of Mount Abu Wildlife Sanctuary of Mount Abu, Rajasthan during September, 2008. The collected individuals were transferred into insect collection paper packs and were brought to the laboratory, where these were properly stretched, pinned, oven dried for 72 hours at 60°C and preserved in collection boxes. Identification of adult individuals of odonates was carried out using identification keys provided by Fraser (1933, 1934 and 1936) and for Lepidoptera by using identification keys provided by de Niceville (1886, 1890), Moore (1890-1903), Marshall and de Niceville (1882), Swinhoe (1893, 1905-1912), Bingham (1905, 1907), Evans (1932), Talbot (1939, 1947), Wynter-Blyth (1957), Heppner (1998). The Mercury light trap was used for collection of moths at Mountain Field Observatory, Mount Abu. The common species of Odonata and Lepidoptera identified at study site and not to be collected. All the specimens collected from study area deposited in the National Zoological collections maintained by Desert Regional Centre, Zoological Survey of India, Jodhpur, India.

RESULTS AND DISCUSSION

About 25 examples of Odonata and 187 examples of Lepidoptera collected at different localities *i.e.* Gomukh, Gyan Sarovar, Nakki lake, Guru Shikhar, Anadara point, Trevor point, Sunset point, Waterfall on Abu road and forest area of Mount Abu Wildlife Sanctuary. The studies on Odonata and Lepidoptera fauna of Mount Abu, Rajasthan reveals that so far 24 species belongs to 5 families of order Odonata (Table 1) and 32 species belongs to 10 families of order Lepidoptera were recorded (Table 2). The maximum number of Odonata species recorded from Gyan Sarovar (20) followed by Gomukh (15), Nakki lake (14), Waterfall on Abu road (10), Trevor point (5) and Guru Shikhar, Anadara point and Sunset point each having 4 species and for Lepidoptera maximum number of species recorded from Gomukh (27) followed by Gyan Sarovar (21), Nakki lake (20), Guru Shikhar (15), Trevor point (13), Sunset point (6) and Anadara point and Waterfall on Abu road each having 6 species. The study reveals that *Ceriagrion coromandelianum* (Fabricius), *Pseudagrion rubriceps* Selys, *Ischnura aurora* (Brauer), *Orthetrum pruinum neglectum* (Rambur), *Orthetrum sabina* (Drury), *Brachythemis contaminata* (Fabricius), *Crocothemis servilia* (Drury), *Trithemis aurora* (Burmeister) and *Pantala flavescens* (Fabricius) were the dominant species of Odonata and *Danaus chrysippus* (Linnaeus), *Eurema hecabe* (Linnaeus), *Junonia hierta* Fabricius, *Junonia lemonias* Linnaeus, *Utetheisa pulchella* (Linnaeus) and *Ixias marianne* (Cramer) of Lepidoptera. Also the swarm of dragonfly, *Pantala flavescens* (Fabricius), a migratory species is recorded at Gomukh, Gyan Sarovar, Nakki lake, Guru Shikhar, Anadara point and Waterfall on Abu road study sites localities.

On the basis of number of identified species, family Libellulidae was the most dominant family of order Odonata, represented by 15 species, followed by Coenagrionidae (4 species), Aeshnidae and Gomphidae (2 species) and Protoneuridae (1 species). The dominance of family Libellulidae was reported by many earlier workers as Kumar and Mitra (1998)

Table 1. Taxonomic composition of 24 Odonata species recorded from eight localities of Mount Abu, Rajasthan during September, 2008

Sl. No.	Family / Species	Gomukh	Gyan Sarovar	Nakki lake	Guru Shikhar	Anadara point	Trevor point	Sunset point	Waterfall Abu road
(A)	COENAGRIONIDAE								
1	<i>Ceriagrion coromandelianum</i> (Fabricius)	+	+	+	-	-	+	-	+
2	<i>Pseudagrion rubriceps</i> Selys	-	+	+	-	-	+	-	+
3	<i>Ischnura aurora</i> (Brauer)	-	+	+	-	-	-	+	+
4	<i>Rhodischnura nursei</i> (Morton)	+	+	-	-	-	-	-	-
(B)	Protoneuridae								
5	<i>Disparoneura quadrimaculata</i> (Rambur)	-	+	-	-	-	-	-	-
(C)	GOMPHIDAE								
6	<i>Paragomphus lineatus</i> (Selys)	+	-	-	-	-	-	-	-
7	<i>Ictinogomphus rapax</i> (Rambur)	+	+	+	-	+	-	-	-
(D)	AESHNIDAE								
8	<i>Anax parthenope</i> (Selys)	+	-	-	+	-	-	-	+
9	<i>Anax immaculifrons</i> Rambur	+	+	+	-	-	-	-	-
(E)	LIBELLULIDAE								
10	<i>Orthetrum pruinosum neglectum</i> (Rambur)	-	+	+	-	+	+	-	+
11	<i>Orthetrum sabina</i> (Drury)	+	+	+	-	-	+	-	+
12	<i>Orthetrum taeniolatum</i> (Schn.)	-	+	+	-	-	-	-	-
13	<i>Acisoma panorpoides</i> Rambur	+	+	+	-	-	-	-	-
14	<i>Brachythemis contaminata</i> (Fabricius)	+	+	+	+	-	-	-	-
15	<i>Bradinopyga geminata</i> (Rambur)	-	-	+	-	-	-	+	+
16	<i>Crocothemis servilia</i> (Drury)	+	+	+	+	-	+	-	+
17	<i>Diplacodes trivialis</i> (Rambur)	-	+	-	-	-	-	-	-
18	<i>Neurothemis tullia</i> (Drury)	+	+	-	-	-	-	-	-
19	<i>Trithemis aurora</i> (Burmeister)	+	+	+	-	+	+	-	+
20	<i>Trithemis festiva</i> (Rambur)	-	+	-	-	-	-	+	-
21	<i>Trithemis pallidinervis</i> (Kirby)	+	-	-	-	-	-	-	-
22	<i>Palpopleura sexmaculata</i> (Fabricius)	-	+	-	-	-	-	-	-
23	<i>Rhyothemis variegata</i> (Linnaeus)	+	+	-	-	-	-	-	-
24	<i>Pantala flavescens</i> (Fabricius)	+	+	+	+	+	+	+	+
	Total	15	20	14	4	4	7	4	10

Where + = present; - = Absent

Table 2. Taxonomic composition of 32 Lepidoptera species recorded from eight localities of Mount Abu, Rajasthan during September, 2008

Sl. No.	Family / Species	Gomukh	Gyan Sarovar	Nakki lake	Guru Shikhar	Anadara point	Trevor point	Sunset point	Waterfall Abu road
(A)	ARCTIIDAE								
1	<i>Pericallia ricini</i> (Fabricius)	+	-	-	-	-	-	-	-
2	<i>Utetheisa pulchella</i> (Linnaeus)	-	+	-	-	-	-	-	-
(B)	CRAMBIDAE								
3	<i>Cryptographis indica</i> (Saunders)	-	-	+	-	-	-	-	-
4	<i>Spoladea recurvalis</i> (Fabricius)	-	+	+	-	-	-	-	-
(C)	GEOMETRIDAE								
5	<i>Hyposidra successaria</i> Walker	+	-	+	-	-	-	-	-
(D)	LYCAENIDAE								
6	<i>Lampides boeticus</i> Linnaeus	+	+	-	+	-	+	-	-
(E)	LYMANTRIIDAE								
7	<i>Somena scintillans</i> Walker	+	-	+	-	-	-	-	-
(F)	NOCTUIDAE								
8	<i>Helicoverpa armigera</i> (Hübner)	+	-	+	-	-	-	-	-
9	<i>Othreis fullonica</i> (Linnaeus)	+	-	+	-	-	-	-	-
10	<i>Spodoptera litura</i> (Fabricius)	+	-	+	-	-	-	-	-
11	<i>Earias vittella</i> (Fabricius)	+	-	+	-	-	-	-	-
(G)	SATURNIIDAE								
12	<i>Actias selene</i> Hübner	+	-	-	-	-	-	-	-
(H)	NYMPHALIDAE								
13	<i>Ariadne merione</i> Cramer	+	+	-	+	-	+	+	-
14	<i>Danaus chrysippus</i> (Linn.)	+	+	+	+	+	+	+	+
15	<i>Danaus genutia</i> (Cramer)	+	+	+	+	-	-	-	-
16	<i>Hypolimnas misippus</i> (Linn.)	+	+	+	+	-	-	+	-
17	<i>Junonia almana</i> Linn.	+	-	-	-	+	+	-	-
18	<i>Junonia hierta</i> Fabr.	-	+	-	-	-	-	-	-
19	<i>Junonia lemonias</i> Linn.	+	+	+	+	-	+	+	+
20	<i>Junonia orithya</i> Linn.	-	-	-	+	-	+	-	-
21	<i>Neptis hylas</i> Linn.	+	+	+	-	-	-	+	-
22	<i>Melanitis leda</i> (Drury)	+	+	-	+	-	+	-	-
23	<i>Tirumala limniace exotica</i> Gmelin	+	+	-	+	-	+	-	-
(I)	PAPILIONIDAE								
24	<i>Graphium sarpedon luctatius</i> Fruhstorfer	+	+	-	-	-	-	-	-
25	<i>Atrophaneura (Pachliopta) aristolochiae</i> (Fabr.)	+	+	+	+	+	+	-	+
26	<i>Papilio demoleus</i> Linn.	+	+	+	+	-	-	+	-
27	<i>Papilio polytes</i> Linn.	+	+	+	-	-	+	-	-

Table 2. Contd.

Sl. No.	Family / Species	Gomukh	Gyan Sarovar	Nakki lake	Guru Shikhar	Anadara point	Trevor point	Sunset point	Waterfall Abu road
(J)	PIERIDAE	+	+	-	-	-	-	-	-
28	<i>Catopsilia pyranthe</i> Linn.	+	+	-	-	+	-	-	-
29	<i>Eurema hecabe</i> (Linn.)	+	+	+	+	-	+	-	-
30	<i>Delias eucharis</i> Drury	+	+	+	+	-	-	+	-
31	<i>Ixias marianne</i> (Cramer)	+	+	+	+	+	+	+	+
32	<i>Ixias pyrene</i> Moore	+	+	+	+	+	+	+	+
	Total	27	21	20	15	6	13	9	6

+ = Species present; - = Species absent

recorded 42 species from Sahstradhara, Dehradun, out of which 18 species represented family Libellulidae; Prasad (2002) recorded 162 species from Western Himalaya, out of which 42 species represented family Libellulidae; Kumar (2002) recorded 109 species in Jharkhand state, out of which 40 species represented family Libellulidae; Vashishth *et al.* (2002) recorded 17 species in Rajaji National Park, out of which 9 species represented family Libellulidae; Kandibane *et al.* (2005) recorded 12 species of odonates in an irrigated rice field of Madurai, out of which 7 species represented family Libellulidae; Emiliyamma (2005) recorded 31 species of odonates in the Kottayam district, out of which 18 species represented family Libellulidae; Emiliyamma *et al.* (2005) recorded 137 species of odonates from Kerala, out of which 56 species represented family Libellulidae and Sharma and Joshi (2007) recorded 30 species of odonates from Dholbaha Dam, Punjab, out of which 17 species represented family Libellulidae.

The family Nymphalidae, represented by 10 species was the most dominant followed by

Pieridae (5 species), Papilionidae and Noctuidae (each 4 species), Arctiidae and Crambidae (each 2 species) and Geometridae, Lycaenidae, Lymantriidae and Saturniidae each having 1 species. Unlike bees, butterflies feed entirely on nectar, which they obtain through their long proboscis from flower. Thus pollination, a crucial link in the survival of ecosystem, is one such factor that needs to be well understood to develop appropriate strategies for conservation of the biodiversity.

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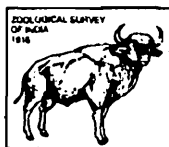
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STUDIES ON THE REPRODUCTIVE BEHAVIOUR OF *PSEUDAGRION RUBRICEPS* SELYS (ODONATA : ARTHROPODA) AT GYAN SAROVAR, MOUNT ABU, RAJASTHAN, INDIA

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INTRODUCTION

Odonates (Damsel flies and Dragonflies) demonstrate well developed complex behavioural patterns, of which the reproductive behaviour is a significant one. Reproductive behaviour of odonates has been studied extensively by several workers including Acharya (1961), Corbet (1962, 1980, 1999), Bick and Sulback (1966), Furtado (1972, 1974), Consiglio (1974), Sakagami *et al.* (1974), Jurzitza (1974), Ubukata (1975), Bick *et al.* (1976), Kumar and Prasad (1977), Hassan (1978), Rowe (1978), Doerksen (1980), Bick and Bick (1980), Kumar (1980), Utzeri *et al.* (1983), Miller *et al.* (1984), Banks and Thompson (1985), Srivastava and Babu (1985a & b), Waage (1988), Miller (1988), Alcock (1989), Cordero (1989), Meskin (1989), Prasad (1990, 1991), Srivastava *et al.* (1994), Copper *et al.* (1996), Mitra (1996) and Cordero *et al.* (1997). In the present study some observations are being highlighted on various aspects of the reproductive behaviour of *Pseudagrion rubriceps* Selys recorded at hill stream, Gyan Sarovar, Mount Abu, Rajasthan.

MATERIALS AND METHODS

The reproductive behaviour of *Pseudagrion rubriceps* Selys was studied at hill stream, Gyan

Sarovar, which is located 24°33'0"N, 72°38'0"E in Mount Abu, district Sirohi, Rajasthan in one of the oldest mountain ranges of India, the Aravalli range during September, 2008. Field binocular (30 X 25 DCF) and stop watch have been used for taking observations. Identification of adult individuals was carried out using identification keys provided by Fraser (1933).

RESULTS AND DISCUSSION

The reproductive behaviour of *Pseudagrion rubriceps* has been studied three times at study site on dated 19.09.08, 20.09.08 and 21.09.08. The conspicuous sexual dimorphism with a bright orange face of male, while much paler in females made easy to keep a close watch on a species. The observations on different activities, their duration and variabilities in the reproductive behaviour of *Pseudagrion rubriceps* were recorded as below.

(a) *Territoriality*: The males of *Pseudagrion rubriceps* arrived at the rendezvous during 9.00 to 10.30 a.m., while the females appeared from the surrounding vegetation late during 10.45 to 11.15 a.m. The males after arrival perched on nearby vegetation. The perch forms the centre of a circular territory with a radius of 1-

2 meters, which was defended by the resident male from the intruding intra or some inter specific males. The resident male showed chase and an aggressive abdomen raising display or by wing vibration against the conspecific and heterospecific male intruders.

(b) *Before wheel tandem*: As soon as the female arrived in the territory, the male started following her and after a short dual flight, got success to bind her in tandem link, catching hold her prothorax by its anal appendages. The pair in tandem flew to some nearby vegetation, where the male anchored the plant and the female hanged vertically. The pair in tandem changes perch 2-3 times to nearby vegetation. The before wheel tandem lasted for about 8-12 minutes. This was the time when intramale sperm translocation, from the gonopore to the vesicula spermialis took place 2-3 times of 21-48 seconds duration at an interval of 2-3 minutes.

(c) *Copulatory wheel position*: After the completion of intramale sperm translocation, the male relaxed its abdomen and in tandem rest for 30-40 seconds, after this the male started bending its abdomen and also forced female to bend her abdomen to initiate process of wheel formation. The female then tried to interlock its vulvar region with the secondary copulatory apparatus of male by curling her abdomen forward to form the copulatory wheel. After 2-3 attempts, the spectacular courtship wheel was formed. The duration of the wheel position varied from 4-8 minutes. At the starting of the wheel position, an upward and downward motion of the male's abdomen has been noticed. Whenever other conspecific males interfered during the wheel position, the male in courtship vibrated its wings vigorously to drive it away from the mating site. Sometimes the pair changed the perch. If the wheel breaks in the process, the pair in tandem formed the wheel again.

(d) *After wheel tandem*: After breaking of the wheel, the male lowered the female and the female also grasped some vegetation by her legs. After a rest of 4-6 minutes, the post copulatory flight was observed over the aquatic

vegetation to choose the suitable spot for oviposition and it lasted for 7-12 minutes.

(e) *Oviposition* : The female of *P. rubriceps* oviposited endophytically among the aquatic plants. The eggs were laid in the tissue of leaf, petiole and stem. During oviposition the female hold the perch plant and the male, just stayed in the air, balancing upon the prothorax of the female. The surface oviposition process lasts for about 1-2 minutes. Then the female started ovipositing underwater and within 1-2 minutes, the female was underwater except its wings which remain partially exposed. After 1 minute the female was completely underwater and the 6th-10th abdominal segments of the male were also submerged. Finally, only the first four abdominal segments of male were above the water, and the upright tandem posture was maintained throughout. Soon after this, the male release the grip on female prothorax and hovers around the ovipositing site. The female remain underwater and oviposits endophytically. This underwater oviposition may be continued for 5-8 minutes and the total duration of oviposition process lasts for 10-16 minutes. The female moves to the surface after oviposition and floats before emerging from the water. After a struggle for about, 2-3 minutes the head, thorax and forewings of the female may be out of the water and female continue to try to reach a suitable support to rest. After taking rest on vegetation for about, 3-4 minutes, the female took flight to nearby vegetation during this entire process the male hovers around the female, to defend her from intruding intra or inter specific males.

Darwin (1859) stated in the "Origin of Species", that sexual selection, "depends, not on a struggle for existence, but on a struggle between the males for possession of females, the result is not death to the unsuccessful competitors, but few or no offspring" In odonates many different reproductive tactics have evolved to optimize the number of opportunities to successfully reproduce with females and the territorial behaviour, copulation and oviposition are carried out within or near the territory (Conrad and

Pritchard, 1992). Several variation of the ovipositing behaviour exists in odonates, but the male has become territorial of these oviposition sites respective to its species (Corbet, 1962).

The phenomenon of male territoriality amongst Zygoptera, is exhibited well in the damselflies of family Coenagriidae (Srivastava and Babu, 1985a; Utzeri *et al.*, 1983), Calopterygidae (Kumar and Prasad, 1977; Waage, 1988) and Protoneuridae (Srivastava and Babu, 1985b). Corbet (1980) observed that aggressive behaviour of mature male odonates at the rendezvous was directed predominantly towards conspecific males, but in *Pseudagrion rubriceps* males demonstrate aggressive behaviour against both conspecific and heterospecific males. During present study in *Pseudagrion rubriceps* the range of their territory is 1-2 meters is more as that of *Ceragrion coromandelianum* and *Pseudagrion rubriceps* 30-80cm (Prasad, 1990) and in *Pseudagrion rubriceps* 40-70cm (Mitra, 1996). The duration of wheel position was 4-8 minutes, which is quite same to the duration 3-8 minutes recorded for the same species (Prasad, 1990; Mitra, 1996) and the mating behaviour was similar to that of other zygopterans (Corbet, 1962; Rowe, 1978; Bick *et al.* 1976).

The exploratory flight in tandem just after breaking of the wheel in *P. rubriceps* lasted for 7-12 minutes which is quite same in same species 7-14 minutes (Prasad, 1990; Mitra, 1996)

and slight shorter than the duration in *P. decorum* (18-30 min) (Srivastava *et al.*, 1994). The endophytic oviposition by the female and the upright tandem posture adopted by the male during oviposition was quite similar to that described by Furtado (1972), Sakagami *et al.*, (1974), Srivastava & Babu (1985), Prasad (1990), Srivastava *et al.* (1994) and Mitra (1996) for same and other species of Zygoptera. The upright tandem posture adopted by the male during surface as well as underwater oviposition is similar to that described by Jacobs (1955), Eriksen (1960), Furtado (1972), Srivastava and Babu (1985a) and Mitra (1996) for same and other species. Hence, it reveals that the time period during reproductive activities observed for a particular event during present and previous studies may relatively changes with the inter or intraspecific interference, according to habitats or by various environmental factors.

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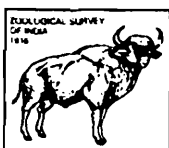
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INSECT CONSERVATION AND PEST MANAGEMENT STRATEGY : SOME PERSPECTIVES FOR THE CONTROL OF BRINJAL PEST, *LEUCINODES ORBONALIS* GUEN

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INTRODUCTION

The insects are 'Conquerors of Land', and represent one of the most important forms of life on this planet. Insects are keystone organism as pollinators and as ecosystem engineers with varied ecological interactions and stand as a special case in "Conservation Biology". However, with the torpid change in landscape, insects are facing conservation risk. As "pests" these have to be kept under economic loss zone rather than to annihilate the species. Among the pest attacking brinjal crops, *Leucinodes orbonalis* Guen. which is also known as Brinjal shoot and fruit borer, is the most noxious and destructive. It remained a major pest of brinjal since two decades. It belongs to the order Lepidoptera, family pyralidae. It is active throughout the year at places having moderate climate. This pest starts damaging the crop soon after transplanting of seedlings and continues till harvest. The insect pest has great economic significance for India, particularly in Rajasthan where the ecological conditions seem to be more favorable for its rapid multiplication. There is a need to draw the attention of cultivators to the fact that better irrigation facilities not only increase the production by promoting better growth of the

plants, but also favors pest to attack the crops. Subsequently, when agriculture developed and greater areas of land were utilized for farming, pressure from insect population increased disproportionately making insect pest control a major preoccupation. Approximately half of all known insects are plant feeders, our greatest number of insect problems involve plants. The main difficulty in evolving a suitable control measure against this pest is that it belongs to one of the most serious categories of insect pest internal feeder. Once the larva bores into petiole and midrib of leaves and tender shoots, it causes dead hearts. In later stages, it also bores into flower bud and fruits. The inside of the fruit is damaged considerably and the fruit becomes unfit for human consumption. Appearance of wilted drooping shoots is the typical symptom indicating damage by this pest. The pest causes fruit infestation upto 40.45-42.19 percent (Singh, 2000 and Sharma and Chhibber, 1999).

In view of the aforesaid havoc played by the *L. orbonalis*, man has been trying to combat it with many control measures and management programme. Successful control is the regulation of this insect pest level to low ebb. Control operation should be long lasting

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from the insect pest problem with a maximum safety to man. Development of the *L. orbonalis* inside the shoot and fruit of brinjal is one of the fascinating facts of nature. This fact is the trump card of the shoot and fruit borer by the virtue of which it aborts all the attempts on its life evading all the possibilities of using insecticides of high potential like organochlorides and organophosphorus.

MATERIAL AND METHODS

Leucinodes orbonalis Guen (Lepidoptera : pyralidae), commonly known as the fruit and shoot borer is the most destructive insect pest of brinjal (*S. melongena*). The non feeding adults of this holometabolus species perform the sole function of reproduction throughout their short life span of 27-33 days. The larval stage of this insect feed voraciously on the shoot and fruit of brinjal where they live in as well. This peculiar mode of feeding also renders a secure living space for the various development stages of the shoot and fruit borer, inside the shoot and the fruit of brinjal. Field studies under IPM modules included the following phases:

- Field survey and study area.
- Study of Varietal resistance.
- Efficacy of different control treatments under IPM package.

Study area

The study area, Umren, is 5 Kms away from Alwar district Rajasthan

Field preparation

The land was thoroughly ploughed and levelled. The seeds were sown at the rate of 400gm per hectare in raised nursery beds with all proper care and cultural operations. Healthy seedlings of brinjal were selected from the nursery and transplanted in the well-prepared field maintaining 50 × 50 cm² spacing between rows and plants, respectively. There were 4 rows of 5 plants each per plot i.e. 20 plant per plot. Seeds for raising nursery were treated with fungicide, Captan at the rate of 2g per kg seeds.

Nitrogen, Phosphorus and Potassium fertilizers were applied as basal dose before transplanting at the rate of 50, 60 and 60 kg hectare respectively. The remaining dose of 50 kg Nitrogen was applied in two split doses as top dressing. On both sides of experimental rows, buffer rows were left to avoid drift of insecticides. All the recommended agronomical practices for raising a good crop were followed and standard nutritional intercultural and water management were followed. Irrigation was given frequently as and when required. The entire crop was maintained weed free throughout the crop season.

Varietal susceptibility

Layout for varieties resistance

Design	: RBD (Plate 3)
Plot Size	: 3 × 3 m ²
Spacing	: 50 × 50 cm ²
Rows per plant	: 4
Treatments	: 16
Replications	: 3

The experiment was conducted to study the response of 16 cultivars and lines of brinjal against the damage caused by major insect pest of Umren region. The crop was left for natural infestation of *Leucinodes orbonalis*. Data were recorded from the time of first occurrence of the pests. The percent damage in shoots and fruits was taken as the parameter for assessment of losses and degree of resistance in all the selected varieties. The total number of shoots damaged due to attack of *L. orbonalis* was counted on five tagged plant in each plot. The observations on total number of fruits and number of borer infested fruits were recorded at each harvesting. Six pickings were done during the crop period. The fruits showing visible holes of any size were considered as borer infested and the remaining fruits were cut open to see the infestation. The percent damage in fruits was worked for each variety and subjected to statistical analysis. Following the grade of Subbaratnam and Butani (1981) the relative tolerance was estimated on the basis of incidence of number of insect pest /5 plants

for shoot borer. The fruit infestation was calculated in terms of percent damage. On this basis the grading index considered is given here.

Grade Index

Grade	Shoot borer	Fruit borer
Tolerant (T)	<2.0	<15%
Moderately tolerant (M)	2.1-3.0	16-25%
Susceptible (S)	3.1-5.0	25-35%
Highly Susceptible (H)	>5.0	>35%

Losses due to shoot and Fruit borer, *L. orbonalis* in some promising brinjal varieties

V ₁	Pusa purple long (47)
V ₂	Pusa purple long (74)
V ₃	Pusa purple cluster
V ₄	Pusa kranti
V ₅	Pusa purple round
V ₆	Pusa anmol
V ₇	H - 4
V ₈	P - 8
V ₉	T - 1
V ₁₀	Pant ritu raj
V ₁₁	BR - 112
V ₁₂	Sandhy (257)
V ₁₃	Navneet
V ₁₄	Pusa - hybrid 6
V ₁₅	Navkiran
V ₁₆	Krishna

Efficacy of different control measures

Details of field experiments

The details of field experiment for two seasons are described below.

Layout for treatment groups

Design	: R.B.D.
Plot size	: 3 × 3 m ²
Spacing	: 50 × 50 cm ²
Rows per plot	: 4
Treatments	: 9

Replications : 3

Variety : Pusa Purple Cluster

Field evaluation of Insecticidal schedules against brinjal shoot and fruit borer

As it is evident from earlier reports, under agro-climatic conditions of Alwar (Rajasthan), the shoot and fruit borer, *L. orbonalis* is considered as major pest during the crop period. So, a study was designed to evolve a suitable control schedule with 4 treatments consisting of both Biological & chemical control (Synthetic pyrethroid- Cypermethrin, Biological control measure-*Bacillus thuringiensis* and *Trichogramma chilonis*, Biological and chemical together with Cabaryl and Endosulphan) using RBD (Randomized Block Design) with 3 replications for each.

Timing and method of application

In all treatments, there were 6 foliar sprays in each season, starting after 15 days of transplanting and repeated at 15 days interval. A knapsack sprayer was used for spraying and insecticides were applied at the rate of 500-700 liters of spray fluid per hectare according to the growth stage of plants. Care was taken to avoid drifting of insecticides to neighboring plots.

Observations and recording of data

For two seasons, pre-treatment and post-treatment observations were recorded on randomly tagged 5 plants from each plot. The post-treatment observations were recorded at 1, 3, 7, 10 and 14 days interval.

In case of shoot and fruit borer, the infestation was recorded for the damage of shoots as well as fruits. While recording shoot infestation, total number of shoots on the plants and number of infested shoots were recorded; so that percent shoot infestation could be worked out. Infestation of fruits was recorded at the time of each picking. All the marketable fruits in each plot were plucked separately and examined carefully. The fruits showing exit holes and those fruits, which were subjected and confirmed to be damaged after dissection,

were separated. After sorting out, the damaged and marketable (healthy) fruits were counted and weighed separately to work out the percent fruit infestation.

Statistical analysis

The data recorded were subjected to arc sine percentage transformation. These transformed values were statistically analyzed by adopting the procedure given by Panse and Suckhtame (1978) to obtain Critical Difference (C.D.), so that the efficacy of different treatments against pest could be compared to each other and their relative efficacy could be adjudged. Percent infestation in shoot and fruit was separately subjected to the same procedure of analysis of variance, so that differential percent infestation in different varieties could be assessed appropriately. Data was analysed by using the different statistical computer software (SPSS 10.0 and STATISTICA 5.0).

RESULT AND DISCUSSIONS

Leucinodes orbonalis Guen is the most serious pest and a major limiting factor in brinjal cultivation. The present information integrating on the use of the chemicals with the partial varietal resistance for different pests can go a long way in the economic management of the brinjal pest. Navkiran and Pusa purple long-74 were among the tolerant group in respect to shoot infestation. Our results are in conformity with Krishna *et al.* (2001) who reported Pusa

purple long variety to be less susceptible. Br-112 and Navneet were found to be most susceptible variety in the present study. Senapati (2003) also reported lowest percentage of shoot infestation in Pusa purple long variety. For fruit infestation on number basis Pusa purple cluster was found to be among tolerant group while Pant ritu raj, Navkiran, Pusa purple long-74 varieties were found to be significantly superior with least infestation.

Studies were initiated to evaluate the efficacy of different control measures/IPM modules under prevailing ecological conditions in the study area (Table 1) Brinjal shoot and fruit borer is considered as an important insect pest limiting the quality and quantity of brinjal (Oomen *et al.*, 2002). The incorporation of biopesticides and IPM technologies is also gaining importance in recent years (Sardana *et al.*, 2004 and Bajpai *et al.*, 2005). It was observed that *Trichogramma chilonis* 6 was most effective for the control of shoot infestation only. Our studies have also revealed that Synthetic pyrethroid, Cypermethrin (0.007 per cent) gave min. infestation of 3.9% in shoot and 7.3% in fruit and proved to be superior to the rest of treatment groups while field application of *Bacillus thuringiensis* alone was least effective against shoot & fruit infestation. Similar results were also given by Jat and Pareek (2001).

When Bt was used in combination with endosulphan and carbaryl the efficacy was increased. This might be due to the fact that

Table 1. Efficacy of different insecticidal groups against *L. orbonalis*

Group no.	Treatment Group	Mean %Shoot infestation	Mean % Fruit infestation Number basis	Mean % Fruit infestation Weight basis
I	Synthetic Pyrethroid (Cypermethrin)	3.92 (11.37)	1.24 (6.28)	7.31 (15.66)
II	Biological control (<i>Bacillus thuringiensis</i>)	10.74 (19.06)	10.54 (18.90)	18.24 (25.28)
III	Biological+Chemical (Bt.+ Carbaryl) (Bt.+ Endosulfan)	6.34 (14.52) 3.58 (10.85)	6.72 (14.96) 14.08 (22.01)	4.35 (12.03) 15.09 (22.82)
IV	<i>Trichogramma chilonis</i> 6 release@1lac/ha	2.23(8.15)	10.45(18.83)	13.55(21.57)

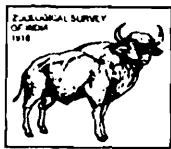
chemical insecticides act as a stressor and are frequently synergistic when combined with microorganism such as *Bacillus thuringiensis*. Single use of biopesticides seems to be insufficient to control this pest as it is an internal feeder. It is also observed that IPM practices could not stop pesticide use but able to reduce it substantially. (Mandal *et al.*, 2008) Therefore information dissemination through mass media should be undertaken on the use of IPM modules (Rashid *et al.*, 2008)

With the emerging Bt brinjal variety and owing to the unique behaviour as 'internal

feeder' *Leucinodes orbonalis* Guen draws its attention on both insect conservation and management issues. The issue of insect conservation in pest management has many conflicting aspects. It is desirable to conserve a pest residue in order to maintain natural enemy population and it is imperative to conserve natural enemies. Conservation of native pest thus depends to a large extent on whether the species is a direct pest of high value crop or an indirect pest with an acceptable economic injury level. Integrated Pest Management strategy therefore defines in terms of sustainable agriculture and conservation of biodiversity.

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PARASITOID FAUNA ASSOCIATED WITH PESTS OF AGRICULTURAL CROPS IN TWO NORTHEASTERN DISTRICTS OF TAMIL NADU

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INTRODUCTION

The modernization of Indian agriculture by means of introducing high yielding crop varieties, novel agronomic practices, pest management through novel synthetic chemicals and replacement of traditional crops with new type of crops has made an impact on the insect diversity in agroecosystem. The use of synthetic chemicals is detrimental to the beneficial arthropods and affects the natural balance between entomophagous insects and pest insects. In agroecosystems, hymenopteran parasitoids are important biological control agents of several groups of insect pests. The hymenopteran insects are the most diverse in number of described species and are the second largest group next to the Coleoptera (Askew, 1971). Suborder Apocrita includes maximum species of parasitic hymenoptera. According to Clauson (1940) hymenoptera is the dominant order among the entomophagous insects, both as regards the number of species and in the effectiveness with which they attack the insect pests. The earliest contributions to our knowledge of parasitic hymenoptera in India were by Ramakrishna Ayyar (1928) who studied South Indian Braconidae. At present the identification of efficient indigenous parasitoid is in great demand. To understand

the host specificity of parasitoids the host-parasitoid relationship in the field should be extensively studied. Previously many investigators have published lists of parasitic hymenoptera of agroecosystems especially from a single crop system like rice (Mohanraj *et al.*, 1995; Ambikadevi, 1998; Kumar and Kaul, 1998; Beevi *et al.*, 2000). Through the studies on host-parasite relationship, the potential parasitoid of a particular pest insect can be identified and the information can be useful for the augmentative biological control. With this background the present work was undertaken to record the parasitoid fauna associated with host insects in six localities in the northeastern zone of Tamil Nadu.

MATERIALS AND METHODS

Study site and study area

The survey of hymenopteran parasitoids was carried out in six localities viz., Dhandarai, Kakillapettai, Padappai, Parivakkam and Vayalanallur in Kanchipuram (11°00' to 12°00' N; 77°28' to 78°50' E) and Tiruvallur (12°15' to 13°15' N; 79°15' to 80° 20' E) districts and Nungambakkam (13°3'38" N; 80°14'4" E) in Chennai city. In Nungambakkam the survey was conducted at Entomology Research Institute garden (1 acre) in side the Loyola

College campus. The agroecosystems in Kancheepuram and Tiruvallur districts were of heterogeneous, i.e. composed of different types of crops. In each locality, approximately one acre field area was surveyed

Collection of parasitoids

Parasitoids were collected from January 2004 to December 2007 from their natural host insects. The life stages of host insects, egg, larva and pupa, were first collected randomly every month from crops such as paddy, groundnut, brinjal, bhindi, snakegourd and maize. Host insects found in the border crops or intercrops such as cow pea, black gram, *Sesbania*, raddish and castor were also randomly collected. Whitefly nymphs and aphids were collected along with the leaves or branches. At Entomology Research Institute garden, the sampling was done on cotton, curry leaf, bhindi, castor and brinjal. In groundnut, bhindi, brinjal, cotton, maize, snakegourd and castor plants, randomly chosen 10 plants were considered for host insect collection. Identity of the host insects was made by comparing with identified specimens maintained at the Entomology Research Institute and with the use of published literature. Parasitism in ladybird beetle eggs, larvae and pupae was also recorded. Eggs were maintained in glass vials (15 ml) plugged with cotton and other immature stages of larvae were reared in plastic containers (100 ml) covered with muslin cloth. Larvae were fed daily with fresh host plant leaves. Emergence of hymenopteran parasitoids from the host insects was examined daily. In the case of whitefly nymphs the percent parasitism was recorded by counting the parasitized nymphs in 1 cm² area under stereo microscope.

Identification of Parasitoids

The parasitoids that emerged from the host insects were collected, preserved in 70 per cent ethanol and identified to the lowest possible taxon, usually up to genus or species with the help of experts.

Percent parasitism

Totally 20 types of host insects in different stages were collected throughout the study

period. The number of parasitized individuals of each insect group was counted after each sampling and the percent parasitism was calculated. The mean percent parasitism was calculated and the maximum percentage of parasitism by each parasitoid was found out.

RESULTS

Parasitoid fauna

The hymenopteran parasitoids collected from their host insects are listed in Table 1. Totally 27 parasitoids including two hyperparasitoids were recorded from 18 different pests and two ladybird beetle species. Three parasitoids, one species from each of braconidae, encyrtidae and ichneumonidae family, were not identified up to genus level and many of the species in the present study have been identified only up to genus. All the collected parasitoids were grouped into 12 families: Aphelinidae, Bethyidae, Braconidae, Chalcididae, Dryinidae, Encyrtidae, Eulophidae, Eupelmidae, Ichneumonidae, Pteromalidae, Scelionidae and Trichogrammatidae. Among the different families collected, family Braconidae showed maximum representative species (8 species), which was followed by family Chalcididae (5 species). *Apanteles* sp., *Bracon* sp., *Cotesia* sp., *Dolichogenidia* sp. and *Glyptapanteles* sp. emerged from groundnut leaf miner (*Apraerema modicella* Dev.), *Helicoverpa armigera* (Hubner), *Spodoptera litura* Fab., *Pericallia ricini*, *Pelopidas mathias*, *Leucinodes orbonalis* and *Melanitis leda*, which are considered to be major pests. During the study period two hyperparasitoid species were also recorded. These hyperparasitoids were identified as *Pediobius foveolatus* and *Ooencyrtus* sp.. *P. foveolatus* is a well known biocontrol agent of the serious pest *Epilachna* spp. In the present study also it was recorded from *E. vigintioctopunctata* in brinjal with 31.6 and 24.3 per cent parasitism in grubs and pupa respectively. However it was identified as a serious limiting factor of the population build up of *Cotesia* sp. and *Dolichogenidia* sp. in which it recorded 47.5 and 43.7 per cent hyperparasitism respectively.

Parasitoid-host stage association

The parasitoids collected in the present study were grouped into egg, larval and pupal parasitoids. Larval parasitoids were predominant (15 species), which accounted for 55.5 per cent of the total species collected (Fig. 1). Nine species were found to be pupal parasitoids and five species were recorded as egg parasitoids. *Pericallia ricini* larvae and pupae were attacked by three braconid and one ichneumonid parasitoids respectively. Among the larval parasitoids, one was solitary and two were gregarious parasitoids. In the case of *Pelopidas mathias*, all immature stages (egg, larva and pupa) were attacked by parasitoids.

Percent parasitism

The mean percent parasitism calculated for the entire study period is presented in table 1. *Anastatus* sp., an egg parasitoid, recorded the maximum parasitism of 69.2 per cent on Coreid bug eggs. Another egg parasitoid *Telenomus* sp. parasitized 54.6 per cent *S. litura* eggs. *Neoplatycerus* sp. parasitized 62.5 percent population of the mealy bug *Pseudococcus affinis*.

DISCUSSION

A dynamic equilibrium exists between parasitoids and predators and their hosts in natural ecosystems, which is otherwise known as natural balance. This natural balance does not exist in agroecosystems due to the influences of agronomic conditions, crop varieties, cultivation cycles and agronomic practices (Ketippearachchi, 2002). As a prerequisite to understand the impact of these influences on beneficial insect fauna, studies on host-natural enemies interaction is very essential. Approaches to crop protection based on a thorough understanding of host-parasitoid relationship will be more effective and economic with fewer adverse environmental side effects. The present study adds some information on host-hymenopteran parasitoid association in the northeastern zone of Tamil Nadu. In the present study, there were no collecting devices used to collect the parasitoids. When we use collecting device such

as sweeping net and light trap, the information on host insect and host stage will be missing. Hence in this study the parasitoids emerged from the host insects were observed and recorded and the potential parasitoids were identified.

In the present study, 27 parasitoid taxa were recorded from 20 host insects. Among them, larval parasitoids were predominant. Ahmad and Rajendra Singh (1995) have recorded 13 species of parasitoids from 25 species of aphids in terai belt of northeastern Uttar Pradesh during 1990-1992. In a survey conducted in Peninsular Malaysia, Van Vreden and Ahmadzabidi (1986) reported 97 parasitoid species belonging to Hymenoptera. In Andaman and Nicobar Islands, India, eight species of parasitoids belonging to Braconidae, Eulophidae, Trichogrammatidae and Scelionidae were reported by Mohanraj *et al.* (1995). Beevi *et al.* (2000) have reported 84 hymenopteran parasitoid species belonging to 60 genera and 21 families from three locations in Kerala. In this study five egg parasitoids and nine pupal parasitoids were recorded. The chalcidid parasitoids *Brachymeria* sp. and *Epitranus* sp. were entirely pupal parasitoids. Many Chalcidid parasitoids are important primary parasitoids of several insect pests of agricultural importance (Narendran, 1989). According to Orr (1988) the egg parasitoids are suitable for biological control program since they have high search and reproductive rates, synchrony with host development, the possibility of mass production and the absence of hyperparasitoids. Hyperparasitism is a major limiting factor in biological control programmes with parasitoids. In this study two hyperparasitoids were recorded. The parasitoid *P. foveolatus* of epilachna beetles is an important limiting factor of *Cotesia* sp. in *P. ricini* management (Paulraj and Ignacimuthu, 2007). Hyperparasitism is due to the continuous availability of a particular parasitoid and non-availability of host to the hyperparasitoid.

Many of the parasitoids are self perpetuating and continue to produce their control effects without human assistance. Many parasitoids

are specific for one or few host insects and this restricted host range can add to their effectiveness in the control of a particular pest (Norris, 1968). In the present study 12 parasitoids were recorded from host insects that were collected from intercrops/border crops. Intercrops/border crops will support hymenopteran parasitoid complex by providing nectar, pollen, shelter and breeding place for adult parasitoids. Crop diversity management and reduced use of chemical pesticides may encourage natural parasitism in agroecosystems.

CONCLUSION

The present study can add some new information to parasitoid fauna of northeastern part of Tamil Nadu and their association with

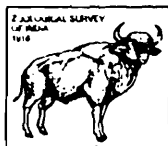
host insects. It was found that *Telenomus* sp. was a good candidate for the suppression of *H. armigera* and *S. litura* larvae at the egg stage. *Neoplatycerus* sp. can be used as biocontrol agent against *Pseudococcus affinis*. Several parasitoids were collected from border crops and intercrops, which could explain that more crop diversity could enhance the parasitoid activity. Detailed studies focusing on the impact of synthetic pesticides on hymenopteran parasitoid complex associated with pests are necessary in the future

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DESCRIPTIONS OF NEW TAXA IN THORONINI (SCELIONINAE : PLATYGASTRIDAE : HYMENOPTERA : INSECTA) FROM INDIA

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INTRODUCTION

The egg parasitoids of the subfamily Scelioninae (Platygastridae) are abundant and diverse worldwide. They attack a wide range of arthropods, including araneid spiders and insects of the orders like Heteroptera, Orthoptera, Odonata and Mantodea. A number of genera of Scelioninae are associated with aquatic habitats, with the females searching for hosts near or even under water (Johnson, 2004). Tribe Thoronini, of Scelioninae, is such a group, whose members are known to be endoparasitic on the eggs of the Odonata and aquatic Heteroptera, viz. Gerridae and Nepidae. They possess specialised characters like strong semi-erect bristles on vertex and dorsal mesosoma, which are presumably used in the formation of an air plastron for diving (Masner, 1972). The group is generally poorly represented in collections, largely due to the cryptic niches in which the adult wasps are encountered and also due to lack of adequate collecting techniques in such situations (Masner and Huggert, 1979). However, yellow pan traps and malaise traps placed on edges of gently flowing fresh water streams, have been successful in collecting them. Of the existing 6 genera under Thoronini, species under *Microthoron* Masner

only has been described to date from India (Johnson, 1992).

As a part of assessing the diversity of Platygastroidea of South Western Ghats, India (Rajmohana, 2007a, and 2007b), collections were made from banks of forest streams using yellowpan traps and malaise traps. This yielded a rich assemblage of Thoronini not encountered hitherto. On the basis of newly collected material, this paper describes one genus and five species, new to science. Two genera namely *Tiphodytes* Bradley and *Tanaodytes* Masner are reported for the first time from India. The new taxa described are *Narendraniola flagellata* gen. et sp. nov., *Tiphodytes gracilis* sp. nov., *T. minutus* sp. nov., *T. crassus* sp. nov. and *Tanaodytes elongatus* sp. nov. A key to genera of Thoronini from India and also a key to species of the world is provided under each genus.

Studies were made using Leica MZ16 stereomicroscope. Digital images were captured using Leica DFC420 and series overlayed by Combine Z (Hadley, 2006). The terminology follows as of Masner (1980). All the Types mentioned in this study are deposited in Western Ghats Regional Centre, ZSIC.

Acronym : ZSIC-Zoological Survey of India, Calicut.

Key to genera of Thoronini

1. First segment of metasoma much longer than wide (Fig. 20); propodeum elongated; apical metatarsal segment along with claws longer than combined length of preceding 3 tarsal segments *Tanaodytes* Masner
 - First segment of metasoma transverse (Fig. 4, 5, 7); propodeum normal; apical tarsal segment distinctly shorter than preceding metatarsi combined 2
2. Female antenna with 7 segments between scape and clava (Figs. 6, 11, 14) *Tiphodytes* Bradley
 - Female antenna with 4-5 segments between scape and clava (Fig. 1) 3
3. Female metasoma short and broad, <1.5x as long as wide; first tergite (T1) nearly 3x as wide as long (Fig. 5); in female antenna, 4 segments between scape and clava; fourth antennal segment not enlarged; antennal clava compact and swollen, wider than A4 *Microthoron* Masner
 - Female metasoma more or less slender, nearly 2x as long as wide; first tergite only about 2x as wide as long (Fig. 4); in female antenna, 5 segments between scape and clava; antennal clava subcompact (with visible traces of segmentation), sub equal to or narrower than A4 (Fig. 1) *Narendraniola* gen. nov.

New Descriptions

Narendraniola gen. nov.

Description : Female : General habitus almost similar to *Microthoron*. Short and plump; body nearly smooth and shiny.

Minute in size (0.6-0.7 mm). Head and body black; head distinctly transverse, with short semi-erect bristles on frons; vertex non-carinate, bluntly rounded to occiput; eyes large, with dense minute hairs; lateral ocelli very close to inner orbit; frons entirely smooth, malar sulcus fine, with a few short fan-like striae lower to malar sulcus near mandibular articulation; clypeus spiniform, pointed apically; antenna

appearing 7 segmented, but actually 10 segmented; 5 segments between clava and scape; clava abrupt and subcompact; the four segments of clava closely adpressed and difficult to distinguish; clava without lateral medial bulge; A4 enormous and with a median constriction, longer than scape as well as clava; A3, A5 and A6 small; antenna covered with long bristle. Mesosoma, arched dorsally, with numerous adpressed hairs and a few semi erect setae; in lateral view skaphion forming a less acute angle with horizontal axis of mesosoma; forewings with marginal, stigmal and postmarginal veins; pleurae with crenulate borders; mesopleural carina indicated. Metasoma elongate, nearly 2x longer than wide and with 7 tergites; T1 transverse; without a hump, less than 2x as wide as long; laterotergites broad, submarginal groove absent; third tergite largest; apical tergite with two pairs of long bristles curved upwards.

Male : Unknown

Host : Unknown

Etymology : The genus is named '*Narendraniola*' to honour Prof. T.C. Narendran, the renowned taxonomist from India, for his significant contributions towards the taxonomy of Parasitic Hymenoptera. The gender is female.

Narendraniola gen. nov. is most similar to *Microthoron* Masner. Both the genera occur side by side and are collected simultaneously in yellow pan traps and malaise traps. In the present study, the genus was collected from 3 different areas of South Western Ghats. The two genera share in common many morphological characters like general habitus, a reduction in the number of female antennal segments and a spiniform clypeus. But the two may be separated easily by a combination of characters, namely-the nature and shape of metasoma, the length to breadth proportion of first metasomal tergite, as well as by the details of female antennomeres. In the new genus, metasoma is comparatively slender, elongated and nearly 2x as long as wide, while in *Microthoron*, it is short and plump and even less than 1.5x as long as wide. Presence of 5 segments instead of 4, between scape and clava

of female antenna, an unusually enormous A4 and a subcompact clava, which is narrower than A4, also serve to distinguish this new genus from *Microthoron*.

Narendraniola flagellata sp. nov.
(Figs. 1-4)

Diagnosis : Female : Length = 0.68 mm. Head and body black; antenna with 7 segments, with 5 segments between scape and clava; clava abrupt and subcompact; fourth antennal segment unusually enormous, 1.7x length of clava; gena with a few short fan-like striae below malar sulcus, arising from mandibular articulation; central keel on frons incomplete; notauli absent; longest marginal ciliae of forewing extending to less than one-third of maximum wing width; metasoma as well as first tergite nearly 2x as long as wide.

Description :

Holotype. Female. Length = 0.68 mm. Head and body black; legs including coxa, with exception of tarsal segments brownish black; antennae brownish black through out; radicle, mandibles and tarsal segments, yellowish brown. Wings infuscated; veins brown; *basalis* slightly darker; eyes silvery white.

Head : Transverse dorsally (55 : 30); vertex smooth and rounded; antenna appearing 7 segmented; A4 of enormous size, longer and wider than scape or clava and with a feeble constriction medially, about 1.7x length of clava, but a little narrower than A4 (Fig. 1). A1-A6 with length/width ratios being 24:4.5, 9:4.5, 4:3, 34:8, 3:4, 3:5, 20:7. radicle elongate, one-third length of scape; setae on antennae as long as 0.8x width of A4; clypeus spine-like and pointed apically; mandibles tridentate, teeth acute; compound eyes large and rounded, sparsely setose; malar sulcus a bit wider towards orbital margin; gena with a few short fan-like striae below malar sulcus, arising from mandibular articulation; central keel on frons incomplete, extending only half way; minimum distance between orbital margin on frons, 1.3x maximum eye width; lateral ocelli very much close to orbital margin; ocelli arranged in a

wide triangle; OOL : OD : POL= 0.5 : 1 : 8.5; temples visible only as a short strip beneath large eyes dorsally; occipital carina complete head smooth and shining lacking microsculpture except for a small coriaceous area medially on occiput; setae denser towards vertex and occiput.

Mesosoma : Subequal to width of head; skaphion well developed, vertical, smooth and glabrous; mesoscutum coriaceous and setose; notauli absent; scutellum almost semicircular in outline, disc smooth, shining with deep crenulae flanking apical margin; both mesoscutum and scutellum bearing a few long setae; mesopleural carina indicated, not flanked by crenulae; dorsellum moderately expanded; propodeum simple dorsally, lateral face of propodeum aerolate rugose and densely setose; forewing with marginal vein thick, longer than stigmal; postmarginal shorter than both stigmal and marginal; longest marginal ciliae of forewing extending to less than one-third of maximum wing width (Fig. 3).

Metasoma : Smooth and shiny and slightly elongate; 1.9x as long as wide. T1 trapezoid, transverse, 1.5x wide as long (25 : 10), with two long lateral setae and with longitudinal striae extending through out (Fig. 4). T2 a little longer than T1; striae on T2 reaching only nearly its three-fourth; T3 longest, apically setose; T4-T7 setose; metasoma without a distinct submarginal ridge; laterotergites wide, not closely articulated to sternites; apical tergite with two long bristles, curved upwards.

Male : Unknown

Etymology : The species is named '*flagellata*' due to the unusually large second flagellar segment (A4).

Material examined : *Holotype* : Female (Reg. No. ZSI/INV/3000), INDIA : Kerala: Ernakulam: Thattekkad Bird Sanctuary (160 feet msl, Lat. 10°7.39'N and Long. 76°45.095'E), coll. Mohana on 3/xii/2006 in Yellowpan trap.

Paratypes : 2 females, (Reg. No. ZSI/INV/3001) INDIA : Kerala : Palghat: Parambikulam Wildlife Sanctuary: Thellikkal, at an elevation of 1809ft msl, 10°26.967'N Lat and 76°44.468'E

Long, coll. Mohana on 12/xii/2007 in Yellowpan trap and (Reg No. ZSI/INV/3002), INDIA: Kerala: Kannur: Aralam Wildlife Sanctuary (150 feet msl; 11° 58.078' N and 75° 48. 53' E), coll. Mohana on 3/iii/2006, in malaise trap set on the bank of a forest stream.

Genus *Tiphodytes* Bradley, 1902

Limnodytes Marchal, 1900.

Hungaroscilio Szabó, 1957.

Diagnosis : Minute size, ranging from 0.6-1.2 mm; body deep brown to black; smooth shiny, unsculptured body, with reflecting surfaces; antenna 12 segmented in both sexes, female antenna with 7 segments between scape and clava; clava stout and prominent with hardly differentiated segments; strong and distinct semi erect setae on vertex of head and dorsum of mesosoma; skaphion well developed; metanotum and propodeum, smooth, shiny, not sculptured except crenulate borders; pleura with crenulae bordering sutures; metasoma somewhat elongated and without a submarginal groove; third tergite broadest; females with 7 tergites and 6 sternites, while males are of 8 tergites and 7 sternites; longitudinal striae distinct on first and second metasomal tergites; basal margin of forewing often with an angular process; marginal fringe well developed.

As per the available biological data (Marchal 1901 and Notton, 2007) *Tiphodytes* species are confined to aquatic and its nearby habitats and are known to parasitise the eggs of heteropteran water-striders (Gerridae). An interesting fact on the group observed by Marchal, (1901), was that *T. gerriphagus* (Marchal), a widespread holarctic species could use its wings equally for flying as well as for swimming under water.

A key to world species of *Tiphodytes*, is provided including the three new species described here.

Tiphodytes gracilis sp. nov. (Figs. 6-10)

Diagnosis : Length : 0.93 mm-1.06 mm; head and body black; funicle and clava brownish

black; radicle, scape, pedicel, mandibles and legs including coxae honey brown; eyes with sparse bristle-like setae; notauli abbreviated; forewing with a distinct postmarginal vein; longest marginal ciliae as long as half of maximal width of forewing; metasoma gracile, slender and spindle shaped, >2x as long as wide, longer than combined length of head and mesosoma.

Description : *Holotype* : Female. Length: 0.93 mm-1.06 mm

Head and body black; funicle and clava brownish black; radicle scape, pedicel, mandibles and legs including coxa honey brown; wings very slightly infusate, with a faint band of basalis; stem of stigmal unpigmented.

Head transverse (24:14), entirely smooth and reflecting, with dense semi-erect bristles on vertex, eyes with sparse and long setae, erect as that of bristles on vertex, setae only half as long as bristles; eyes very large, inner orbital margin feebly emarginated; lower margin angular; maximum eye width about 1.6x minimum interorbital space on frons; as seen dorsally eye as wide as interocular space or even larger; temples bulging laterally in dorsal view; eye width 2.2x length of temples in dorsal view; clypeus with a very feeble emargination on lower margin, mandibles large and broad, not acutely incised at tip, instead very finely serrated, anterior most serration, towards clypeus most prominent; ocelli arranged in a wide triangle; OOL: OD: POL=0.5:1:7.2; malar sulcus distinct; antennal segments in proportions being 15:3; 5:3, 4:2.5; 3.5:2, 2.5:2, 2:2, 2:2; 14:5. clava 3x as long as wide, 2.5x width of A8.

Mesosoma wider than head; skaphion large, bare and smooth; mesonotum with rows of long bristles; notauli abbreviated, indicated posteriorly as short impressions; trans scutellar sulcus crenulate, wider laterally; scutellar margins crenulate; metanotum bordered by crenulae at upper and lower margin with a bunch of decumbent setae at meson; metanotum and propodeum as a smooth shiny

strip, without any carinae or ridges; meso and metapleuron without any setal fields; marginalis, stigmalis and postmarginalis in proportions 7:13:7.5; longest marginal ciliae longer than half of maximal width of forewing.

Metasoma longer than combined length of head and mesosoma (21 : 19); spindle shaped; gracile, nearly 2.6x as long as wide 34 : 13, widest at about middle; first tergite distinctly transverse (14 : 10) fully striate, second tergite trapezoid, striae restricted to basal area; , hardly as long as striae on T1; third tergite transverse, following tergites narrow, and sparsely hairy; apical tergite triangular.

Male : Length -1.05 mm No variation from females except in details of antenna and body proportions (Fig.10).

Material examined : Holotype : Female. (Reg. No ZSI/INV/3005) : INDIA : Kerala : Palghat : Parambikulam Wildlife sanctuary: Thellikkal, (1809ft msl, 10°26.967'N Lat and 76°44.468'E Long) coll. Mohana, on 12.xii.2007, in yellowpan trap, set on the banks of a forest creek.

Paratypes : 7. 3 females. with (Reg Nos: ZSI/INV/3006-3008) and 2 males (Reg Nos: ZSI/INV/3009-3010) with same data as that of the holotype.

1 female, (Reg. No ZSI/INV/3011) INDIA, Kerala, Idukki, Chinnar Wildlife sanctuary (1400ft msl, 10 ° 21.130'N Lat and 77 ° 14.189'E Long), coll. Mohana on 13.xii.2006 in yellowpan trap and another female, (Reg No ZSI/INV/3012) INDIA, Kerala, Ernakulam: Thattekkad Bird sanctuary, (10 07.392'N. Long. 76° 45.096'E, 162 ft, msl) coll. Mohana on 3.xii.2006 in yellowpan trap.

Etymology : The species is named '*gracilis*' due to its gracile metasoma.

Conclusion : *T. gracilis* sp. nov. species come close to *T. gerriphagus* Masner, due to the presence of an abbreviated notauli. In *T. gerriphagus* post maginal is absent, while in *T. gracilis*, a distinct post marginal is seen. The two differ in proportions of antenna and also that of metasoma.

***Tiphodytes minutus* sp. nov.**
(Figs. 11-13)

Diagnosis : Female. Length = 0.6 mm. Head and body black; antennal segments, mandibles, legs including coxae honey brown; gena and temples with an unusual bulge; apical clava, towards A8 not gradually tapering; eyes with sparse bristle-like setae; notauli absent; metasoma less than 1.5x as long as wide, shorter than combined length of head and mesosoma; forewing with a distinct postmarginal vein; longest marginal ciliae almost half as long as maximal width of forewing.

Description : Holotype : Female. Length = 0.6 mm

Head and body black; antennal segments, mandibles, legs including coxae honey brown; wings very slightly infuscate, with a very faint band of *basalis*; stem of stigmal unpigmented. ocelli arranged in a wide triangle; Resembling *T. gracilis* in characters except the ones described below.

Eyes small, with a few long stiff setae on eyes; Gena and temples with a significant bulge; eye width: temples = 7 : 5; dorsally eyes stretched towards mid occiput more than usual, angular rather than smoothly rounded, here eye width: occiput = 7 : 3.2; OOL: OD: POL = 0.5 : 1 : 8.2; maximum eye width about 1.35x minimum interorbital space on frons; in front view eye width: malar sulcus= 7: 4; antennal proportions: 15:3.5, 6:3.5, 5:3, 3:2, 3:2, 3:2, 2:2, 2:2, 17:7; base of antennal clava towards, A8 not gradually tapering, 2.4x as long as wide, clava with more than 3x width of A8.

Notauli absent; median mesonotum with dense short bristles; transcutellar sulcus very narrow, margins not crenulate Forewing with marginal vein much prominent; stigmal vein subequal to marginal; post marginal longer than stigmal; marginal ciliae on forewing longer than half maximum width of forewing.

Metasoma shorter than combined length of head and mesosoma (48 : 55) and nearly about 1.6x as long its maximum width; when viewed dorsally, metasoma spindle shaped and with a

distinct median lateral bulge. T1 2x long as wide; striae on T2 not as long as that on T1.

Male : Unknown.

Etymology : The species is named '*minutus*' because of its small size.

Material examined : Holotype Female (Reg. No: ZSI/INV/3013), INDIA : Kerala : Idukki : Chinnar Wildlife Sanctuary, (at an elevation of 1400ft msl, 10° 21.130'N Lat and 77 ° 14.189'E Long), on 13.xii.2006, in Yellow Pan Traps along the banks of a forest stream.

Paratypes : 2 Females. (Reg. Nos: ZSI/INV/3014-3015) with data same as that of the Holotype.

Conclusion : This species is minute in size, unique with a robust metasoma, only 1.6x as long as wide, with length well shorter than combined length of head and mesosoma. The bulged out, gena as well as the temples, a robust clava which is not tapering gradually towards A8 and presence of a much denser bristles on dorsal mesosoma make this species easily distinguishable from *T. gracilis*. Eyes are peculiar, that dorsally, they are stretched towards mid occiput more than usual, here eye width: occiput is 7: 3.2, where as eye width: temples is 7: 5. In *T. gracilis* eyes are normal, gena and temples are not unusually bulging.

Tiphodytes crassus sp. nov.
(Figs. 14-17)

Diagnosis : Female. Length = 0.7 mm; Head and body black; antennal segments, mandibles, legs including coxae honey brown to black; wings faintly infusate. Eyes with fine pubescence; A5 longer than A4; notauli absent; forewings, with postmarginal vein; marginal ciliae more than half of maximum length of forewing; metasoma 2x as long as wide, length subequal or longer than combined length of head and mesosoma.

Description : *Holotype* : Female Length : 0.72 mm. Head and body black; antennal segments, mandibles, legs including coxae honey brown to black; wings faintly infusate.

Only those characters which need special mention are stated here, rest of the characters are common to the genus.

Head distinctly transverse, (16:8); OOL: OD: POL 0.5:1:8.5, in a wide triangle, malar sulcus fine, body with semi-erect setae; eye width: temple= 7.5:4; eyes large and rounded, finely hairy but without bristle-like setae; temples moderately bulging; gena not with any unusual bulge; proportion of antennal segments being: 9:2, 3.5:2, 3:1.8, 2.3:1.1, 2.7:1, 2:1, 1:1, 1:1, 10:4 A5 longer than A4; clava 2.5x as long as wide; notauli absent; mesosoma a little wider than head, mesoscutum with numerous semi erect bristles; longest marginal ciliae on forewing longer than half of maximum width of forewing; metasoma not spindle shaped, not tapering gradually towards the posterior; metasoma subequal or longer than combined length of head and mesosoma; postmarginal present; metasoma 2.2x as long as wide; T1 2x as long as wide; striae on basal T2 not as long as striae on T1.

Male : Unknown

Etymology : The species is named '*crassus*' (= robust) to denote the robust body.

Material examined : Holotype female (Reg. No. ZSI/INV/3016), INDIA : Kerala : Ernakulam : Thattekkad Bird sanctuary, (10 07.392'N. Long. 76 45.096'E, 162 ft, msl), coll. Mohana, on 3.xii.2006 in yellowpan traps along the banks of a forest stream.

Paratypes -1 female (Reg. No. ZSI/INV/3017) with data same as that of the Holotype.

Conclusion : This species differs from *T. minutus* sp. nov. in having a larger and more robust body, dense and finely pubescent eyes; instead of having long stiff setae, gena and temples without an unusual bulge, and metasoma more than 2x as long as thick, compared to one less than 1.5x as long as wide in *T. minutus*. *T. crassus* can atonce be distinguished from *T. gracilis* sp. nov. by the absence of notauli and also by the finer eye pubescence, in contrast to long setae in eyes of the latter, as well as the shape of metasoma.

A key to world species of *Tiphodytes* Bradley
(Modified from Masner, 1972)

1. Hind margin of forewing straight, without an angular process; legs yellow; wings clear, *T. setosus* (de Stefani)
- Hind margin of forewing with an angular process enabling better coupling of the two pair of wings 2
2. The longest ciliae of forewing distinctly longer than the maximal width of the wing; Fore and hind wings very narrow, almost strip-like; legs and antennae uniformly dark brown; eyes white; first segment of metasoma rather broad *T. mymar* Masner
- The longest marginal cilia of forewing distinctly shorter than maximal width of wing 3
3. Legs and antennae dark brown to black. 4
- Legs including coxae bright yellow, scape and pedicel yellow 7
4. Notauli present 5
- Notauli absent 6
5. Post marginal distinct; metasoma slender, long and gracile, more than 2x as long as wide *T. gracilis* sp. nov.
- Post marginal absent *T. gerriphagus* (Marchal)
6. Metasoma 2x as long as wide, length nearly equal to or longer than combined length of head and mesosoma *T. crassus* sp. nov.
- Metasoma distinctly less than 1.5x as long as wide, shorter than combined length of head and mesosoma; *T. minutus* sp. nov.
7. Post marginal vein distinct, shorter than stigmalis, the latter distinctly elongate, much longer than marginalis; notaulices well impressed posteriorly; longest marginal ciliae as long as one third of maximal width of forewing *T. godavari* Masner
- Postmarginal vein vestigial, stigmalis

shortened, only a little longer than marginalis; notaulices almost wanting; longest marginal ciliae as long as ½ of maximal width of forewing *T. selangor* Masner

***Tanaodytes* Masner, 1972**

Diagnosis : Head and body black; almost entirely smooth and shiny; head distinctly transverse, with short semi-erect bristles on non-carinate vertex; eyes large, with dense minute hairs; lateral ocelli very close to inner orbits; frons entirely smooth, malar sulcus fine, clypeus convex at lower margin, mandibles broad, serrated at tip; antenna 12 segmented in males, segments long and cylindrical; where as in females though appearing 9 segmented, antenna actually with 12 segments; clava abrupt and subcompact, with indistinct segmentation; mesosoma arched dorsally, with numerous adpressed hairs and a few semi-erect setae; in lateral view skaphion forming a slightly less than 90° angle with horizontal axis of mesosoma; prothorax with varying sculpture; propodeum elongated with two keels medially forming an inverted V-shaped field; forewing with distinct bristles either throughout subcosta or restricted on its apical one fifth and with marginal, stigmal and postmarginal veins; legs with apical tarsal segment elongated; along with claws, longer than combined length of almost three preceding segments; metasoma elongate and pedunculate, nearly twice longer than wide; males with 8 tergites; females with 7 tergites and 6 sternites; T1 without a hump, longer than wide; both first and second tergites with longitudinal striae; laterotergites broad, submarginal groove absent.

***Tanaodytes elongatus* sp. nov.**
(Figs 18-22)

Diagnosis : Male length = 1.85 mm. Body ebony black; all coxae, trochanter and femur whitish yellow, tibia and tarsi brownish black; notauli extending more than half way on mesonotum; Prothorax without any longitudinal wrinkles, but with leathery granulose area towards fore coxa; first tarsal

segment unusually long; apical tarsal segment along with claws, longer than preceeding 3 segments; metasoma elongate and pedunculate; more than 2.5x longer than wide; first and second metasomal tergites with striae;

Description : *Holotype* : Male : Length = 1.85 mm. Body ebony black; all coxae, trochanter and femur whitish yellow, tibia and tarsi brownish black; antennal scape, radicle and mandibles pale brown (paler than femur); flagellar segments concolorous with tibia and tarsus; eyes whitish; wings faintly infuscated brown.

Head : Smooth and shiny; transverse (62 : 32); eyes with fine dense setae; lateral ocelli slanting, separated on its lower side by more than half its diameter from eye margin; OOL : OD : POL = 1 : 2 : 6; eyes large and rounded; occipital carina and flange distinct; frons bare, except for a row of very sparse setae along inner orbital margin from mid height onwards; vertex and occiput with scattered erect setae; clypeus broad; lower margin convex, lateral borders not pointed; mandibles large and broad, not incised at tip, instead finely serrated at tip, anterior most serration, towards clypeus most prominent; malar sulcus distinct; gena distinctly bulging, smooth without any traces of striae; eye width double distance between lateral ocelli (32:16); maximum width of eyes in front view 1.5x minimum distance between its orbital margin; A5 modified; antennal shelf finely raised; proportions of antennal segments being 13: 5, 4: 3, 8:3, 7:3, 8:4, 7.5:3, 7.5:3, 5.5:3, 5.5:3, 5.5:3, 8.5:3 (Fig. 18).

Mesosoma : Narrowly wider than head, with scattered erect setae; skaphion smooth and shiny, trisinate at posterior margin; notauli deep, extending more than halfway on mesonotum; transcutellar sulcus and crenulae wide laterally; scutellum also with crenulae at lower margin; metanotum as a smooth plate, but with tuft of setae medially, best visible in lateral view; propodeum margined by sharp lateral carinae and two keels medially forming an inverted V-shaped field; with irregular sculpture; prothorax with a trace of a longitudinal wrinkle beneath scutal suture and with dense, leathery, granulose sculpture along

anterior edge, near fore coxa, whereas finely granulose towards upper corner in front of tegula; median area smooth and reflecting; mesopleuron and metapleuron smooth, without any setal fields; metapleural carina distinct; Legs with apical tarsomere elongated and along with claws, longer than combined length of three preceding metatarsal segments. Forewing with distinct setae, even on proximal 4/5th of subcosta (Fig. 21); stigmal vein not abruptly knobbed; post marginal reduced to a stump; longest marginal ciliae, less than maximum wing width

Metasoma : Elongate and pedunculate; more than 2.5x longer than wide. T1 1.6x as long as wide (22 : 13), striate till apex and with many lateral setae; T2 (24 : 31) fully striate medially; T3 (23 : 36) transverse, plain and smooth without striations; apical tergites also smooth and with dense pilosity; T8 visible. S2 striated medially almost to its lower margin.

Female : Unknown

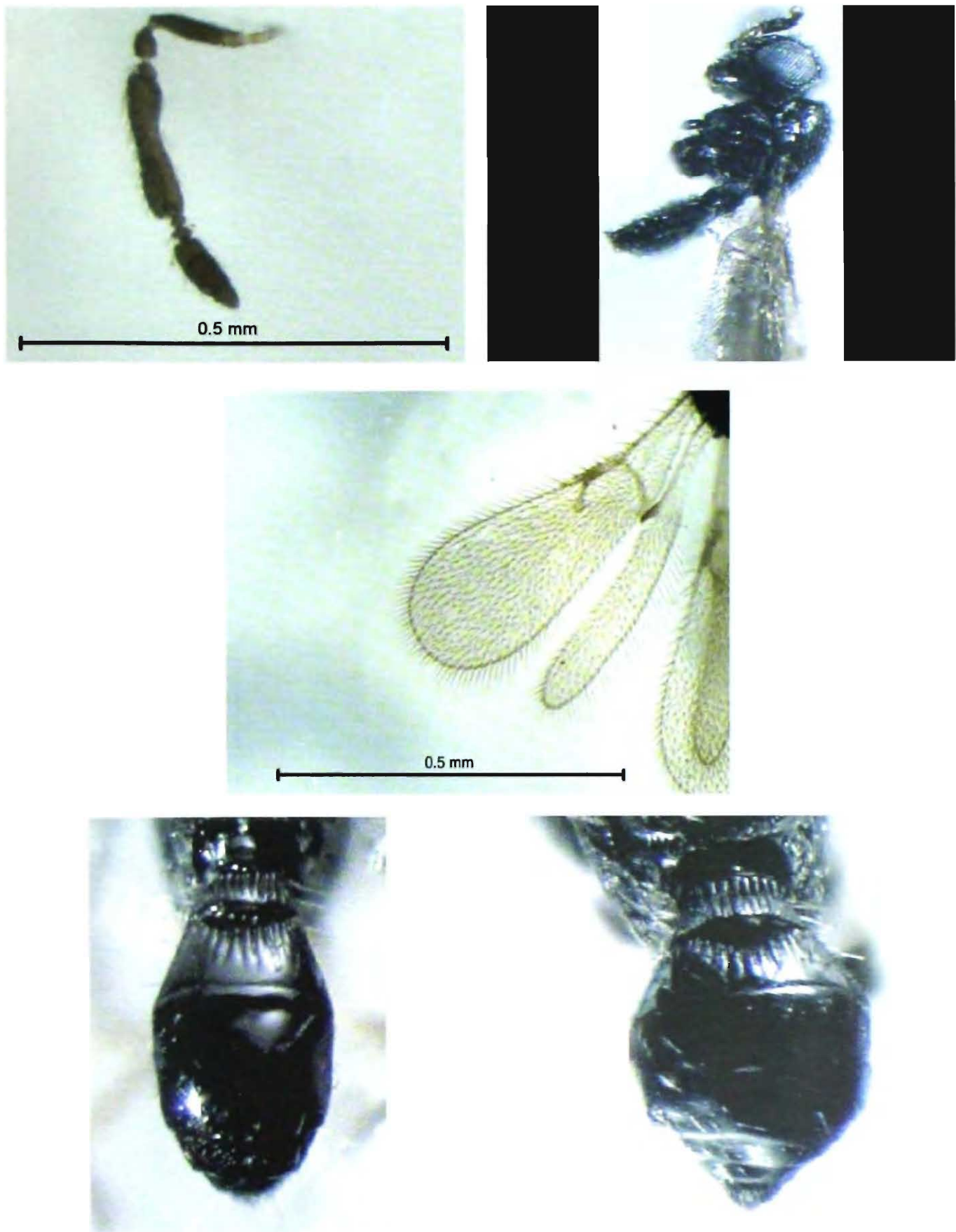
Etymology : The species is named '*elongatus*' due to the elongate metasoma of the species.

Material examined : *Holotype* : Male. (Reg. No. ZSI/INV/3004), INDIA : Kerala : Idukki: Chinnar Wildlife Sanctuary, (1400 ft msl, 10° 21.130'N lat and 77°14.189'E long.), coll. Mohana, on 13/12/2006, in yellowpan trap.

Conclusion : Genus *Tanaodytes* Masner is known only from the Oriental Region, with just two described species, viz., *T. longipes* Masner and *T. soror* Masner. *T. elongatus* sp. nov. forms the first male to be described in this genus.

The extremely long first and fifth tarsal segments, the elongate propodeum and the pedunculate metasoma of *T. elongatus*, justify the placement of this species under *Tanaodytes*. As in *T. longipes*, here too the lower margin of skaphion is trisinate. Absence of a prominent longitudinal wrinkle-like sculpture on sides of prothorax, which is specific to *T. longipes* and the presence of bristles all along the subcosta, makes this species distinct. The comparative measurements of the veins in forewing and the proportion of the length of marginal cilia to maximum width of forewing also vary

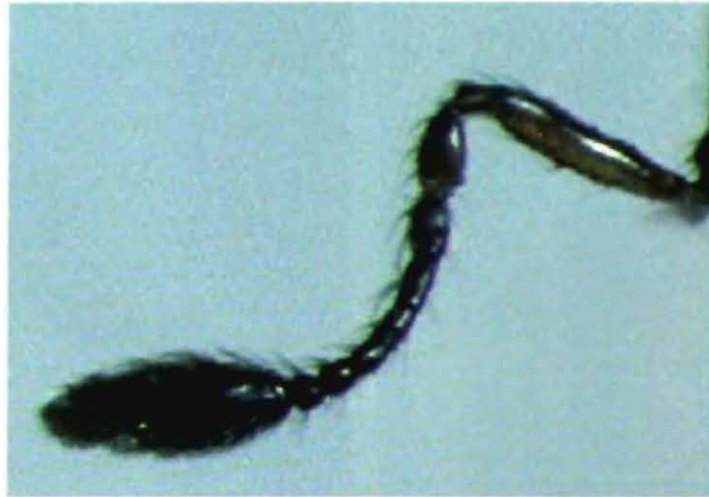
Plate 1



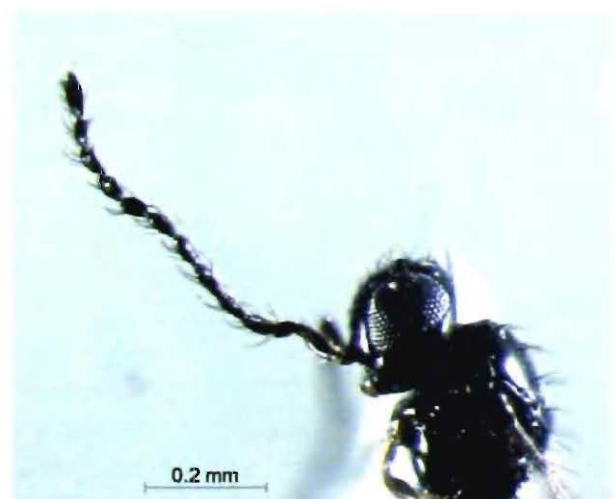
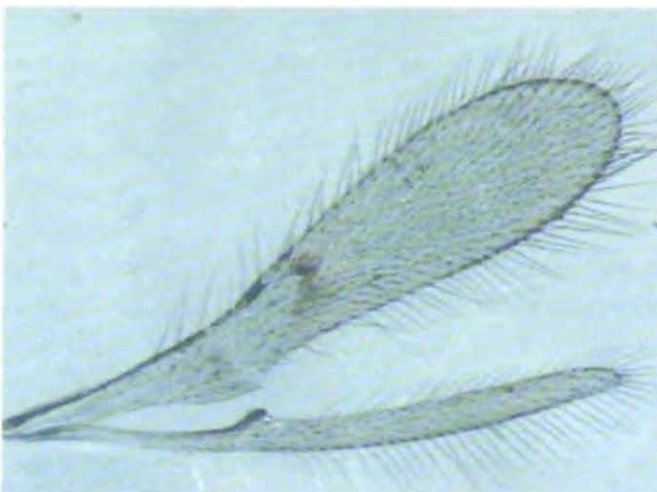
Figs. 1-4. *Narendraniola flagellata* sp. nov. Female. 1. Antenna, 2. Body Profile, 3. Wings, 4. Metasoma dorsal view

Fig. 5. *Microthoron* sp. Female, Metasoma dorsal view

Plate 2



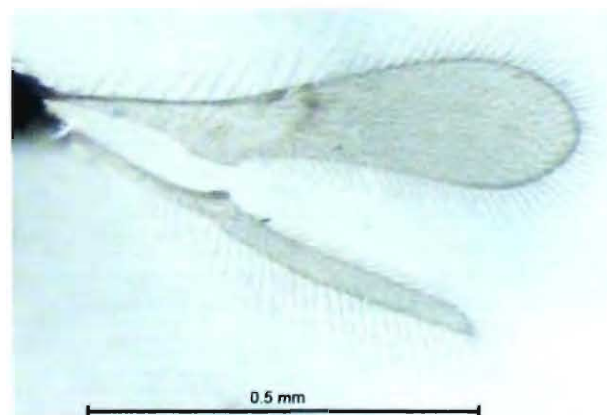
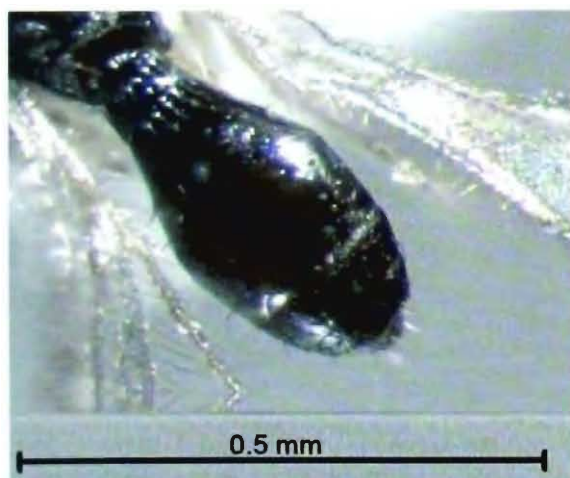
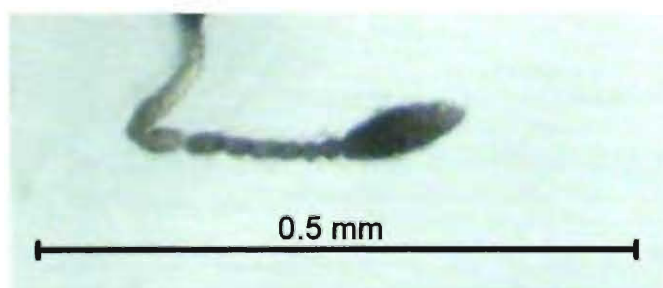
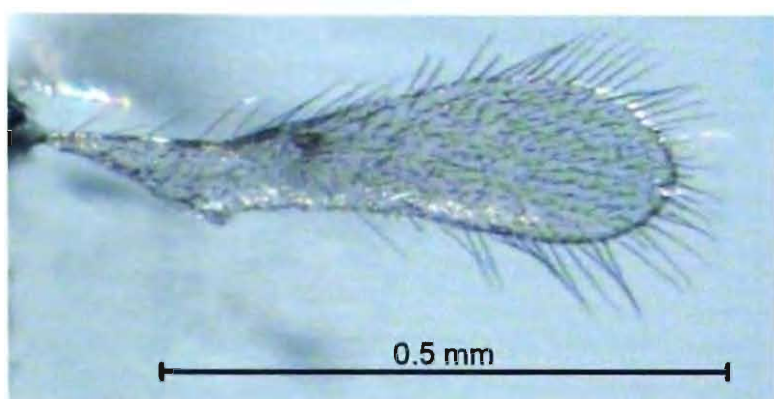
0.2 mm



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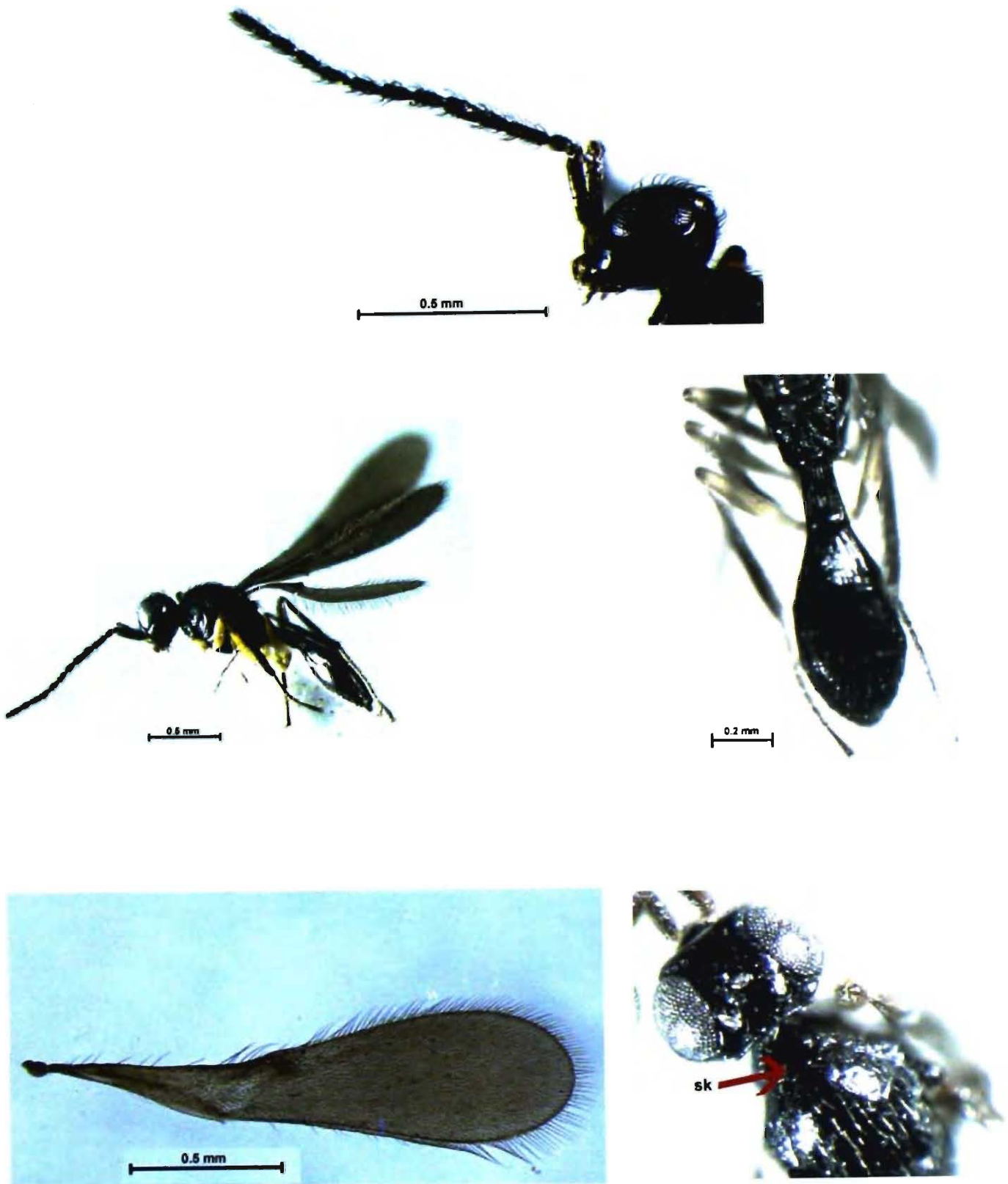
Figs. 6-9. *Tiphodytes gracilis* sp. nov. Female. 6. Antenna, 7. Body dorsal view, 8. Body profile, 9. Wings.
Fig. 10. *Tiphodytes gracilis* sp. nov. Male Antenna

Plate 3



Figs. 11-13. *Tiphodytes minutus* sp. nov. Female. 11. Antenna, 12. Metasoma Dorsal view, 13. Forewing
Figs. 14-17, *Tiphodytes crassus* sp. nov. Female. 14. Antenna, 15. Body Profile, 16. Metasoma Dorsal view, 17. Wings

Plate 4



Figs. 18-22. *Tiphodytes elongatus* sp. nov. Male. 18. Head and antenna, 19. Body profile, 20. Propodeum and Metasoma Dorsal view, 21. Forewing, 22. Head and mesoscutum Dorsal view, S.K. Trisinate lower margin of skaphion

considerably between the species. In *T. longipes* (as per the illustration in Masner and Huggert, 1979, the forewings are very narrow and its longest marginal cilia is nearly half the maximum wing-width. In *T. elongatus* the longest marginal cilia is only one third, the maximum width of forewing (Fig. 21).

The forewings of both *T. longipes* and *T. soror* lack setae on proximal 4/5th of subcosta. Since both the species were having an abbreviated marginal vein and a reduced stigmal, these characters were treated as generic traits by Masner 1972. But in *T. elongatus*, bristles are present all along the forewing margin on subcosta (Fig. 21) and both the marginal as well as the stigmal are moderately long. Considering these features and the male characters as well, *T. elongatus* has widened the limits of the genus. Hence diagnostic features of the genus are amended to accommodate the new species.

A key to world species of *Tanaodytes* Masner (Modified from Masner 1972)

1. Lower margin of skaphion trisinate (Fig. 22); T1 >1.5x as long as wide 2

- Lower margin of skaphion plain, not trisinate; T1 < 1.5x as long as wide
..... *T. soror* Masner
- 2. Sides of prothorax with longitudinal wrinkle-like sculpture; setae absent on proximal 4/5th on forewing subcosta
..... *T. longipes* Masner
- Sides of prothorax without any wrinkle-like sculpture; setae present all along forewing subcosta (Fig. 21) *T. elongatus* sp. nov.

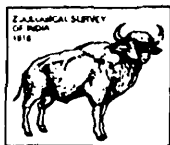
ACKNOWLEDGMENTS

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DEVELOPMENT OF SPECIES SPECIFIC MICROSATELLITE PRIMERS FOR FIVE AMPHIBIAN SPECIES OF WESTERN GHATS

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INTRODUCTION

Genetic analysis of natural populations has allowed biologists to ask a wide variety of questions which previously could only be answered by extensive observation of the group in question. A number of genetic markers have proven to be useful, including mitochondrial DNA, Major Histocompatibility Complex loci, allozyme loci, and Variable Number of Tandem Repeat (VNTR) markers. VNTR markers are characterized by a core sequence which consists of a number of identical repeated sequences. They can be divided into two categories based on the repeat length: a) minisatellites, 15-70 base pair (bp) repeats, which can be quite large, and microsatellites, 2-6 bp repeats, which seldom exceed 200 bp in total length. These sequences are regularly distributed throughout the genome and are found, on average, about every 10-20 kb in eukaryotes. At a given locus, there may be an important length polymorphism defined by the variable number of repeated motifs. They are usually flanked by conserved sequences which allow specific amplification of each microsatellite locus within a species.

This conservative DNA allows the development of specific primers for PCR reactions that allow one to specifically amplify the VNTR sequence between the conserved area on either side of the repeat.

PCR-based marker analysis requires primer sequences that target the marker regions for amplification. The task of microsatellite isolation can be quite involving in terms of effort and time because it traditionally consists of screening genomic libraries with appropriate primers. The number of positive clones (containing microsatellites) that can be obtained by means of this traditional method usually ranges from 12 per cent to less than 0.04 per cent. (Rassmann *et al.*, 1991). Therefore, several alternative strategies have been devised in order to reduce the time invested in microsatellite isolation and to significantly increase yield (Glenn and Schable, 2005). Within amphibians, it has been shown for Ranid frogs that cross-species amplification success rates are significantly lower than for birds and mammals. (Primmer and Merila, 2002). Hence we need to isolate microsatellite markers *de*

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novoo. In the present paper, we standardize a new protocol that skips all the blotting and radio active steps, and involves DNA isolation, restriction digestion, incorporation of a linker (super SNX linker) and hybridization capture for enrichment of microsatellites by dynabeads using biotinylated oligos, PCR recovery of enriched regions, transformation and sequencing. We have developed varying microsatellite repeat primers for the first time for five species amphibians of Western Ghats

MATERIALS AND METHODS

Genomic DNA of five frog species of Western ghats ie. *Hylarana temporalis*, *Clinotarsus curtipes*, *Nyctibatrachus major*, *Hoplobatrachus tigerinus* and *Fejervarya keralensis* were isolated from the toe clips (~25 mg tissue) and digested using the restriction enzyme, *Rsa* I. Resulting DNA fragments were then ligated to linkers, which provided a primer binding site for polymerase chain reaction (PCR). Ligated genomic fragments were then allowed to hybridize to a mixture of the biotinylated probes containing known microsatellite sequences. Following hybridization, the biotin on each probe was attached to streptavidin-coated magnetic beads (Dynabeads; Dynal Biotech). Magnetism was used to selectively retain microsatellite-containing fragments, and unbound fragments were discarded. PCR employing the linker priming site was used to increase the number of copies of each microsatellite fragment. These were ligated into pGEM-T Easy vectors (Promega), and transformed in *Escherichia coli* competent cells. Plasmid DNAs from individual clones were isolated and sequenced using BigDye version 3 and an ABI Prism 310 genetic analyser (Applied Biosystems). Sequences were viewed using Sequence scanner software (Applied biosystem) and microsatellite repeats were identified and designed primers using websat (Martins *et al.*, 2009).

RESULTS AND DISCUSSION

Of the 192 colonies screened for *Hylarana temporalis*, 27 microsatellite loci were identified with flanking regions sufficiently large to allow primer development. Of these, 19 appeared appropriate for population genetic work (i.e. the microsatellite repeat was the only repetitive sequence in the fragment). Primers were designed for these 19 loci (Table. 1). For *Clinotarsus curtipes*, 102 colonies were screened and obtained 9 microsatellite loci and designed primers for them (Table 2). 141 colonies were screened for *Nyctibatrachus major* and 193 colonies for *Hoplobatrachus tigerinus* of which 18 and 15 microsatellite loci were obtained respectively and developed primers (Tables 3 and 4). For *Fejervarya keralensis*, 124 colonies were screened and obtained 13 microsatellite loci and designed primers (Table 5).

Microsatellite DNA loci have become important sources of genetic information for a variety of purposes (Goldstein and Schlotterer, 1999; Webster and Reichart, 2004). To amplify microsatellite loci by PCR, primers must be developed from the DNA that flanks specific microsatellite repeats. These regions of DNA are among the most variable in the genome, thus primer-binding sites are not well conserved among distantly related species (Moore *et al.*, 1991; Pepin *et al.*, 1995; Primmer *et al.*, 1996 and Zhu *et al.*, 2000). Although microsatellite loci have now been developed for hundreds of species (indeed the journal Molecular Ecology Notes is largely devoted to their description), these loci have not yet been isolated from many additional species of interest such as amphibians of India and remain to be developed. We are interested in developing molecular methods for the identification of amphibian species for two reasons. Firstly such approaches should be more reliable than the variable morphological characters otherwise employed. Secondly apart from their high variability, DNA based markers

offer several practical advantages. DNA can be extracted from old (dried, alcohol or even formalin preserved) material such as that kept in museum collections. For any PCR based assay minute amounts of tissue are required allowing non-destructive sampling (amphibian DNA samples can be obtained by removing a toe).

Many different strategies for obtaining microsatellite DNA loci have been described. The simplest approach, cloning small genomic fragments and using radiolabeled oligonucleotide probes of microsatellite repeats to identify clones with microsatellites, was the first described and works well in organisms with abundant microsatellite loci (Weissenbach *et al.*, 1992). Unfortunately, this approach does not work well when microsatellite repeats are less abundant. Thus, new approaches have been used to overcome these limitations. The present work is a result of such a modification originally described by Glenn and Schable (2005).

Genetic considerations are probably most useful when incorporated early in a species conservation plan, when the existence of some

robust populations across a species range offers the possibility of a variety of creative solutions to conservation problems. Many amphibian species of our country suffer serious decline but are not yet exposed to the imminent risk of extinction, rendering molecular studies particularly timely. However, an increased knowledge of the population genetic structure alone is not sufficient to guarantee conservation, and new scientific findings based on high variation genetic markers will only help amphibian conservation when integrated into current and future action plans. Present study is expected to act as a starting point for generating an understanding about the genetic variation of amphibian fauna of Western ghats as well as the extent of endemism based on their genomic profile and eventually illuminate the biodiversity and bioprospecting potentials of amphibians.

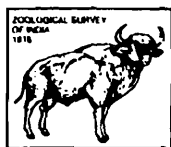
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IDENTIFICATION OF UNKNOWN TADPOLES USING DNA BARCODE SEQUENCES

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INTRODUCTION

The use of DNA barcodes has been proposed recently as a tool for identification of the species in many diverse groups of animals (Hebert *et al.*, 2003a; www.barcoding.si.edu, 2005). The mitochondrial gene cytochrome c oxidase subunit 1 (COI) is reported to be the most conserved gene for DNA barcoding owing to its advantages such as maternal lineage, lack of recombination, lack of indels and higher mutation rates (Hebert *et al.*, 2005; Hajibabaei *et al.*, 2006). One potential application of DNA barcoding in amphibians is certainly the species identification of larvae. Identification of tadpoles to species or even genus is an extremely time consuming task since it involves laborious rearing of eggs laid by well identified pair of adults or rearing of tadpoles collected from wild to juvenile stage and then to assign one of the species known to occur at the site (Vences *et al.*, 2005). DNA barcoding clearly overcome these problems and to offer identification tools and has been applied in several studies to successfully identify tadpoles (Thomas *et al.*, 2005). The present study is aimed to identify tadpoles collected from the wild by comparing COI gene sequences of both adult and tadpoles and to assess the usefulness of this method for rapid species identification at different life stages of an organism.

MATERIALS AND METHODS

Tadpoles were collected from Parambikulam wildlife sanctuary (10°20' and 10°20'N and 76°35' and 76°50'E) of Kerala. A non-destructive DNA sampling method was standardized for this purpose by clipping tailfin of the tadpole and used to extract high molecular weight genomic DNA. Tissue collections were made from the field itself and preserved in ethanol. Specimens were released immediately after the tissue collection. DNeasy kit (Qiagen) was used to extract DNA. The quantity and quality of the extracted DNA was determined through spectrophotometer and electrophoresis. The COI region of the mitochondrial genome was amplified using the primer pair LCO1490 and HCO2198 (Hebert *et al.*, 2003a). The PCR conditions are described elsewhere (www.barcoding.si.edu, 2005). To confirm successful amplification, 5 µl of the product was electrophoresed on a 1 per cent agarose gel stained with ethidium bromide. The amplified PCR products were purified using Exosap and products were sequenced with the forward primer using ABI PRISM Big Dye Terminator v 3.1 Cycle Sequencing Kit. The DNA sequences obtained were aligned with known COI sequences of adult frogs generated by our group by using *bl2seq* (NCBI).

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Sequences showed a high degree of homology (> 97 per cent) with adult species was selected for further analysis. The selected DNA sequences of both adult and tadpoles were subjected to alignment (Bioedit) and sequence similarities among individuals were quantified by using the Kimura two parameter distance model (Kimura, 1980). Based on this, tadpoles were assigned to corresponding species. A neighbor joining (NJ) tree of K2P distances was also created to provide a graphic representation of the clustering pattern among different species by using MEGA version 3.1 software (Kumar *et al.*, 2004).

RESULTS AND DISCUSSION

Tadpole sequences showed a high degree of homology (>97 per cent) within species when aligned with the adult COI sequences and thus could be confidently assigned to their corresponding species such as, *Fejervarya limnocharis*, *Clinotarsus curtipes* and *Duttaphrynus melanostictus*. The sequences were AT rich for the mitochondrial genome. The average AT content for 3 groups of frogs is found to be 55.70 while 44.30 being the G+C content. Table 1 showed the genetic distance (K2P) computed for three species of adult frogs with their corresponding tadpoles. The mean genetic distance computed for the three different species was found to be 0.2177. The NJ tree (Fig. 1) showed three species clusters reliably among the sequences studied, thus

identifying the tadpoles belonging to three species. The maximum intra specific K2P values recorded among the species clusters was for *Duttaphrynus melanostictus* (0.0151) followed by *Fejervarya limnocharis* (0.0059) and *Clinotarsus curtipes* (0.0000). The interspecific K2P values ranged from 0.2542 (*Fejervarya limnocharis* and *Clinotarsus curtipes*) to 0.3102 (*Clinotarsus curtipes* and *Duttaphrynus melanostictus*). It is already established that COI sequences provides ample nucleotide variability towards species identification and its conserved nature for higher orders of taxonomic strata (Hebert *et al.*, 2003a). The current study indicates the utility of cytochrome c oxidase subunit one gene toward identification of tadpoles stage of frogs since they cannot be easily assigned to an adult phase based on their morphology. The NJ tree and K2P distances computed was in general agreement with the taxonomy based on morphology as reported previously (Hebert *et al.*, 2003b; Vences *et al.*, 2005). The sequences for the COI gene of both adult and tadpoles were submitted to GenBank with accession numbers EF577512-577517.

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The authors are thankful to Director, RGCB for providing facilities. We thank Chief Wildlife Warden, Kerala for permission to do sampling. SVG and M K are thankful to DBT and KSCSTE respectively for financial support.

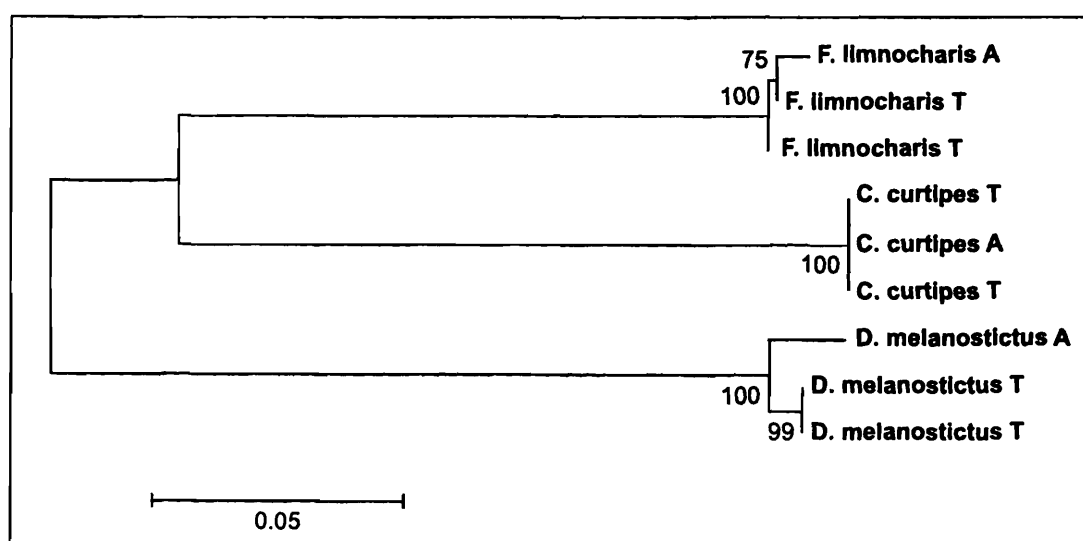


Fig 1. NJ phylogenetic tree based on Kimura 2-parameter genetic distances of the COI gene sequences of tadpole and adult frogs

Table 1. Kimura 2-parameter pair wise genetic distance based on CO I sequences of tadpole and adult frogs.

	1	2	3	4	5	6	7	8	9
<i>F. limnocharis</i> A*									
<i>F. limnocharis</i> T**	0.0089								
<i>F. limnocharis</i> T	0.0067	0.0022							
<i>C. curtipes</i> A	0.2574	0.2543	0.2510						
<i>C. curtipes</i> T	0.2574	0.2543	0.2510	0.0000					
<i>C. curtipes</i> T	0.2574	0.2543	0.2510	0.0000	0.0000				
<i>D. melanostictus</i> A	0.3100	0.2960	0.2996	0.3198	0.3198	0.3198			
<i>D. melanostictus</i> T	0.3064	0.2925	0.2960	0.3053	0.3053	0.3053	0.0226		
<i>D. melanostictus</i> T	0.3064	0.2925	0.2960	0.3053	0.3053	0.3053	0.0226	0.0000	

*A = Adult; **T = tadpole

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THE CONTRIBUTION OF CORAL REEF FISHES TO ANDAMAN FISHERIES PRODUCTION : GROUPER FISHERY AND ITS MONITORING AND IMPLICATIONS FOR MANAGEMENT

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INTRODUCTION

The Andaman and Nicobar Islands commonly known as Bay Islands comprise over 572 islands, islets and rocky outcrops of various sizes in Bay of Bengal situated between 6°45' and 13°45' N latitude and 92°10' and 94°15' E longitude in a North-South direction. The islands have a land area of 8293 km². Their total coast-line of 1962 km is about one-fourth of that of India. Of the 2 million km² of the exclusive economic zone of India, the area around the Andaman and Nicobar Islands comprise 30 per cent. Being oceanic islands, the continental shelf around them is narrow with an area of about 16,000 km² only. The limited shelf area is compensated by extension of marine habitats into numerous bays, creeks and inlets on the landward side of the islands.

From the fish and fisheries view point, Andaman and Nicobar Islands are the most interesting and fascinating owing to the diversity of Ichthyofauna occurring in the varied marine habitats, such as mangroves, creeks, rocky habitats, extensive sand beaches, muddy shores, coral reefs etc. A perusal of literature shows that since Blyth's (1846, 1863) time work on ichthyofauna of these islands have been done and

the most important contributions are those of Day (1870), Alcock (1899), Annandale and Hora (1925), Mukerjii (1935), Koumans (1940) and Herre (1939 and 1941). Subsequently several oceanographic and fishery expeditions by Challenger, Valdivia, Investigator, Galathea, Kistna, Anton Brun, Sagar Sampada etc. explored many areas of Andaman and Nicobar Islands and brought to light several new species and new records of fishes. In addition, scientists of Zoological Survey of India, Central Marine Fisheries Research Institute, Central Agricultural Research Institute and Fishery Survey of India and many other scientific organizations made valuable contributions to the knowledge of fish fauna of these islands.

MATERIALS AND METHODS

Samples of grouper fishes were collected from the fish landing centers in and around South Andaman and underwater observation were made using scuba gears. Three major kinds of natural reef system exist in the area. The most abundant and probably most important to fisheries, are the live bottom reefs which are scattered at depths of 20 to 100 m over the continental shelf from landfall island to Indira Point of the Nicobar group. Having

horizontal dimensions ranging from meters to kilometers, live bottom reefs usually are associated with out cropped sedimentary rocks, have relief ranging up to several meters and are richly over grows with macrobenthos; sponges, sea fans, soft and diminutive hard corals etc. True high relief, hermatypic coral reefs become common. The live bottom reefs, probably, due to area alone, all the most significant producers of commercial catch of reef fishes. Most are found in coral reefs and rocky coasts but some species inhabit in mangrove areas.

Diversity

Andaman coastal waters support high fish diversity. The study shows that 798 species (in 95 families) of reef associated fishes were known from these islands (Rajan, 2008 in press). Wrasses (family Labridae) are the best represented with 65 species, followed by damselfishes (family Pomacentridae-63 species), groupers (Serranidae-50 species) (Table 1). The number of Reef fishes so far reported from Andaman & Nicobar is the highest among

Indian reefs and this make up 72.5 per cent of the fish recorded in this region. About 400 sps. have been identified to have commercial value as food fishes under the major families Serranidae, Lutjanidae, Scombridae, Lethrinidae, Carangiidae, Carcharhinidae, Alopidae, Lamnidae, Clupeidae and Engraulidae, Leiognathidae, and Nemipteridae. Most abundantly available of these belong to families Serranidae, and Lutjanidae, attributed to their abundance in coral reefs.

Trophic ecology and fishers implications

From the perspective of fishery management, several aspects of the trophics of groupers are of interest. These fishes tend to occur at rather high levels in the trophical web. Traditional ecological wisdom would predict that large changes in their populations might significantly alter other components of the community. These predators and their prey organisms have a wide but patchy distribution. For most fishes, the distribution seems habitat, especially shelter. Hard bottom and high relief seem to be key elements, particularly for the

Table 1. Number of genera and species and percentage of species richness of major families of reef associated fishes.

Family	Genera	species	% of species richness of families
Labridae	23	65	5.07
Pomacentridae	18	63	4.91
Serranidae	8	50	3.9
Lutjanidae	9	45	3.51
Caranigdae	14	44	3.43
Blennidae	18	42	3.27
Gobiidae	19	32	2.61
Chaetodontidae	5	34	2.65
Apogonidae	9	33	2.57
Scaridae	7	31	2.42
Nemipteridae	3	30	2.39
Acanthuridae	5	25	1.95
Muraenidae	7	24	1.87
Lethrinidae	5	22	1.71
Syngnathidae	11	20	1.56

groupers, their habitat depending primarily on shelter rather than on prey distributions. There are probably no groupers so heavily dependent on such a narrow taxonomic range of prey that a major reduction in availability of one prey group would produce catastrophic effects on the predator population. The diet accepted by most species seems broad enough to permit shifts in feeding, even between rather diverse prey groups- pelagic fish, demersal fish, large or small benthic crustaceans and a variety of invertebrate nekton or plankton. It, therefore, seems unlikely that large movements of grouper populations would occur in response to changes in abundance of one or a few components of their diet. For the same reasons, these species are expected to be resilient to changes in abundance of feeding competitors. However, most of the major prey groups taken by most groupers are animals that must be hunted, captured and to some extent manipulated after capture. They typically are not uniform or diversely distributed nor extremely abundant. Thus, the rate of food consumption by the predators would be expected to show some direct functional response to prey abundance. The aggregate consumption of prey by groupers in a community may represent a significant source of mortality for these prey groups. If the predator populations are greatly reduced by fishing, the populations of fish that are their prey or that have diets that overlap theirs, might increase substantially. There also seems to be substantial predatory interactions among the groupers. There is considerable overlap of prey fish taken by the various species. Many benthic and some pelagic invertebrates are also shared. Considering the overlap and distributions seems likely. Because of the predators broad diets, it is probably diffuse and seldom severe. However the effects of competition for shelter or space might be more serious. There appears to be little or no direct evidence concerning the importance of food as a limiting factor in the growth, reproduction, or survival of wild populations of groupers. Groupers eat other groupers. The prey is usually rather young stages. However,

undoubtedly some predation by harvested species upon other exploited species occurs. Thus, it is possible that an active fishery for one species of grouper may directly change the populations of others through reduced predation.

Grouper fishery

The fishes of the Serranid subfamily, Epinephelinae, popularly, known as groupers, are among the most important benthic fishes of warm seas. The serranids are further classified into five sub families, namely Serraninae, Anthiinae, Nipponinae, Grammistinae and Epinephelinae. Most of the commercially important species belong to the subfamily Epinephelinae comprising about 110 marine species of the Indo-Pacific in 11 genera (Randall and Heemstra, 1991). The 11 genera are *Aethaloperca*, *Angperodon*, *Cephalopholis*, *Cromileptes*, *Dermatolepis*, *Epinephelus*, *Gracila*, *Plectropomus*, *Saloptia*, *Triso* and *Variola*. The more popularly known species belong to the genus *Epinephelus*. They are of moderate to large size. Most are shallow water species, but a few occur to depths as great as 300m. All are carnivorous, feeding mainly on fishes, large crustaceans, and occasionally, on cephalopoda. They are highly esteemed as food fishes, but some species, particularly those of the genera *Plectropomus*, *Variola*, and the large species of *Epinephelus*, have frequently been implicated in ciguatera fish poisoning. Groupers are generally at or near the top of food chains of tropical and subtropical marine habitats and thus play a major role in the population structure of the animal communities of these environments. 48 species of groupers are reported from the islands that support 43.63 per cent of grouper so far known to science. Fishing practices vary little with region, habitat, or species. In Andaman most of the commercial catch results from hook and line fishing. Bottom long lining is increasingly popular for deep reef fishing and produces most of the groupers.

Family SERRANIDAE (Groupers)

Subfamily EPINEPHELINAE

Aethaloperca rogae (Forsskal) MS

Anyperodon leucogrammicus (Valenciennes) MS
Cephalopholis argus Bloch & Schneider MS
Cephalopholis boenak (Bloch) SS
Cephalopholis cyanostigma (Valenciennes) MS
Cephalopholis formosa (Shaw & Nodder) MS
Cephalopholis leopardus (Lacepede) SS
Cephalopholis microprion (Bleeker) MS
Cephalopholis miniata (Forsskal) MS
Cephalopholis sexmaculata (Ruppell) MS
Cephalopholis sonnerati (Valenciennes) MS
Cephalopholis urodeta (Forsskal) SS
Cromileptes altivelis (Valenciennes) MS
Epinephelus areolatus (Forsskal) MS
Epinephelus bleekeri (Vaillant) LS
Epinephelus caeruleopunctatus (Bloch) LS
Epinephelus chlorostigma (Valenciennes) LS
Epinephelus coioides (Hamilton) LS
Epinephelus corallicola (Valenciennes) MS
Epinephelus erythrurus (Valenciennes) MS
Epinephelus fasciatus (Forsskal) MS
Epinephelus faveatus (Valenciennes) SS
Epinephelus flavocaeruleus (Lacepede) LS
Epinephelus fuscoguttatus (Forsskal) LS
Epinephelus hexagonatus (Schneider) SS
Epinephelus lanceolatus (Bloch) ELS
Epinephelus longispinis (Kner) MS
Epinephelus macrospilos (Bleeker) LS
Epinephelus malabaricus (Bloch & Schneider) LS
Epinephelus megachir (Richardson) MS
Epinephelus melanostigma Schultz SS
Epinephelus merra Bloch SS
Epinephelus miliaris (Valenciennes) LS
Epinephelus ongus (Bloch) MS
Epinephelus polyphkadion (Bleeker) LS
Epinephelus polystigma (Bleeker) MS
Epinephelus quoyanus (Valenciennes) MS
Epinephelus radiatus (Day) MS
Epinephelus sexfasciatus (Valenciennes) MS
Epinephelus spilotoceps Schultz SS
Epinephelus tauvina (Forsskal) LS
Epinephelus undulosus (Quoy & Gaimard) LS

Plectropomus areolatus (Ruppell) LS
Plectropomus laevis (Lacepede) LS
Plectropomus maculatus (Bloch) LS
Plectropomus pessuliferus (Fowler) LS
Variola albimarginata Baissac LS
Variola louti (Forsskal) LS

ELS (Extra large size) MS (Medium size) LS (Large size) SS (Small Size)

Groupers are captured in the Andaman Islands together with numerous other members of the highly diverse reef fish community in which they are typically important predators. Historical data on fisheries for reef species, however are scant compared to those for the more traditional demersal and pelagic fisheries. Reef fishing around the island has traditionally been of smaller scale and more artisanal. The fishing gears include traps, hook and line beach seines, gill nets, cast nets (Local fisherman), spears (Tribes) dynamite and poisons (foreign Poachers). In recent years bottom longlines and small travels have been used on shallow areas. Habitat suitable for colonization by groupers in the sea of Andaman Islands includes both well developed coral reefs and hard bottoms which consists of lower relief rocks ledges with minor scleractinian coral growth, sponges and octocorals. Thus exploited groupers in this region reside within a continental reef fish fauna. Among the serranid fishes of red groupers, black groupers have historically been the object of sustained high volume fisheries on the continental shelf. More recently groupers were taken for live trade in large numbers. The coral trout *Plectropomrus* sp are caught in greatest numbers.

Commonly Cultured Grouper species recorded from Andaman Islands

Groupers are coastal warm water fishes that are widely distributed in the world. Their characteristics such as good taste, hardness in a crowded environment and rapid growth, make them a good candidate for intensive aquaculture. Likewise, they are commercially important as a high value food fish. Their bulk of production comes mostly from capture

fisheries. However in the face of increasing consumer demand and depleting wild fish populations, the culture of groupers is becoming more important. The culture of several species of groupers has been tried with varying success. The following is an introduction to some of the main cultured grouper species in the Asian region. A brief summary of their common names, natural distribution and habitat is provided. *Cromileptes altivelis* also called the humpback grouper. Distributed through out the Indo-Pacific, East Indian Ocean, South Japan to New Caledonia. Thrives in coral, dead or silty reef areas, tidal pools to deep water. *Epinephelus areolatus* known as the orange spotted grouper. Distributed in the islands and coast of the Indo-West Pacific region, with in latitudes of 38° N to 38° S. lives in marine and brackish waters. *E. coioides* known as the orange spotted grouper. Distributed in the islands and coasts of the Indo-West Pacific region, with in latitudes of 38° N to 38° S. lives in marine and brackish waters. *E. lanceolatus* also called the giant grouper widely distributed in the Indo-Pacific region. Thrives in marine or coastal waters, near shore harbours, also in reef caves and also associated with wrecks. Both adults and juveniles are found in estuaries. *E. malabaricus* also commonly referred to as the malabar or estuarine grouper. Distributed in islands and continental coasts of the Indo-Pacific tropical and sub-tropical regions within latitudes of 35°N to 35°S. lives in marine, brackish water, coral, rocky reefs, sandy and muddy bottoms, tide pools, estuaries and mangrove areas. Juveniles are also found in shallow coastal waters and estuaries. *E. tauvina* also called greasy grouper. Distributed within the Indo-Pacific region, mainly in Oceanic islands within the latitudes of 35°N to 35°S. lives in marine, clear oceanic waters, coral reefs and hard bottoms. Juveniles are also found in reef flats and tidal pools. *E. fuscoguttatus* known as the brown marbled grouper. It occurs in the Indo-Pacific region, with in latitudes of 35°N to 38°S. also reported to be found in the Marshall Islands and Phoenix Islands to East Africa and the Red Sea. They live in marine, shallow coral

reefs, rocky bottoms and clear waters. Juveniles are found in sea grasses. *Plectropomus leopardus* also called the leopard coral trout. Distributed in the west pacific, South Japan to Queens land. Lives in coral reefs. *P. maculatus* known as the spotted coral trout. Distributed in Indo-Pacific. Lives in coastal reefs.

Resources

The EEZ of the around the Andaman and Nicobar Islands has an estimated fishery potential is 1.48 lakhs tonnes comprising 32000 tonnes of demersal fishes, 56000 tonnes pelagic, fishes and 60000 tonnes of oceanic fishes. The Pelagic resources include Anchovies, Sardines, Mackerels, Carangids, Ribbon fishes, Seer fishes, neritic tunas, Barracuda etc. The Demersal resources constitute Perches, Silver Bellies, Pomfrets, Scads, Scianids, Nemipterids, Shrimps and Lobsters. The Oceanic resources are Skipjack tuna, Big Eye tuna, Bill fishes (Sail fish, Marlin and Sword fish), pelagic sharks etc.

Fishing Capacity

Out of the islanders total population of 3.56 (2001 census), fisher population is 15320. Amongst the fisher population about 5617 are full time fishermen and 718 are part time fishermen engaged in marine fishing. They operate about 2808 fishing crafts of which 1524 are non motorized/traditional crafts, 1279 motorized crafts and 10 mechanized boats. The main fishing gears used are drift gill net (contribute to over 40 per cent of marine fish landings) other fishing gears commonly used are shore shine, hook and line, long line and cast nets etc. they contribute to the rest of the catch. To bridge the gap between the resources potential and the present level of exploitation, there is need for increasing fishing capacity and infrastructure for handling the resources. There are 57 beach landing centers (Table 2), 10 fish markets out of which 2 were submerged due to tsunami.

Present status of fishing

The present level of annual marine fish harvest in the islands is about 28855 MT, which is about 19.5 per cent of the total estimated

Table 2. Fish landing centers in Andaman and Nicobar Islands

Zone	Landing Centre	Total
North Andaman	Areal Bay, Smith Island, Laxmipur, Durgapur, Kalipur.	5
North/Middle Andaman	Mayabunder proper, Kalighat, Tugapur, Webi.	4
Middle Andaman	Rangat Bay, Yaratta, Kadamtala, Long Island, Betapur, Sabari, Bakultala.	7
South Andaman	Phoenix Bay, Haddo, Junglighat, Writmyo, Wandoor, Bambooflat, Hope Town, Baratang, Neil Island, Havelock, Chidiyatapu, Chouldari, Lohabarrack, Shoalbay, North Bay, Dunduspoint, Dignabad.	17
Little Andaman	Hutbay, Baludera, Vivekanandpur, Dugong Creek, Harminder Bay, R. K. pur.	6
Car Nicobar	Tee top, Malacca, Sawai, Pursa, Mus, Kimus.	6
Nancowry	Attabiak, Champion, Hitui, Tapong, Balubasti, Kamorta, Trinket.	7
Katchal	West Bay, Katchal, Kapanga, East Bay Katchal.	3
Great Nicobar	Campbell Bay, Vijaynagar.	2
	Total	57

Source : Fishery Department

potential. Out of the 1.48 lakh tonnes of fishery resources available in Andaman and Nicobar Waters, 64500 tonnes constitute tunas forming 44 per cent of the resources. The landing of tuna resources is negligible. There is wide gap between the present level of fish harvest and the harvestable potential, thereby providing vast scope for fishery resource exploitation from the island water.

From 0 to 12 Nautical Miles, fishing in Andaman and Nicobar Waters is regulated by the Union Territory of Andaman and Nicobar Islands, as per the Andaman and Nicobar Islands Marine Fishing Regulation. Near Shore Fishing Gear fishing gear of different kinds operated are **Gill nets** are made from a monofilament line. They are normally deployed in channels, seagrass beds, encircling mangrove islands on algal plains or near coral reef habitats. They are normally fished for an average of 5 hours. Possible impacts to habitat could include entanglement and breakage of hard and soft corals, trampling of seagrasses, and stirring up fine sediments. Occasionally nets are lost, causing ghost-fishing and fouling of the habitat from decaying fish entangled in

the lost net. **The longline/hook and line fishery** : targets reef fish in shallow and deep coral reef, seagrass lagoon, deep seagrass bed, and algal plain habitats. The main lines are typically 700 feet long with the attached hook line 99 feet long. Hook and line includes hand lines (1 to various hooks per line) and bottom lines (average 11 hooks) lifted either manually or with an electric winch. There is the possibility of fouling of habitat structure with lines and hooks. **Spear fishing** targets reef fish in coral reef, seagrass bed, and algal plain habitats. A potential impact of spear fishing in coral reef communities is the physical damage caused by firing spears underwater in coral habitats (breakage). There are no restrictions on who can spearfish or where (outside reserves). In addition, spearfishers typically target large fish, thus greatly impacting the older reproducing age classes of a population. For example, shifts in reproductive output and sex ratios could be expected among fish such as groupers. **Rod and reel and Hand Lines** target larger species including snappers, groupers, barracudas, pelagics, and other species. They have the potential to snag or hang on hard and

softcorals, rocks, and patchy corals over seagrass beds. There is the possibility of fouling of habitat structure with lines and hooks.

Andaman Market and production

Overall sea food market is well known for relatively high species based on local preference for a limited number of species of fresh fish. Included in this consumption bundle are a number of snappers, groupers and jacks, thread fin beam, emperors, mackerel, tuna of which *Pristipomoides* sp. *Lethrinus* sp. *Scombromorus* sp. are the most important. Retails sales to Andaman consumers include two components: regular purchasers within a households food budget and cultural demand includes events

such as weddings and birthdays. The regular household component can be served by small bottom and reef fishes. The price differential is substantial. The average price for bottom fish is \$ 2 per kg and for seer fish (King mackerel) alone, it is more than \$4. Restaurant demand for fresh fish is centered as fresh Seer fish and is based on catering to "Up Scale" tourist preferences. Successful market promotion and a fairly regular supply of this species in large sizes have led to its introduction on restaurant menus as a high quality item.

From the production side, the fish market is served by small fishing boats, mainly by traditional wooden dinghies fitted with motor. Relatively Small Size (5-10 m), 2-3 days full

Fishery Potential and Exploitation During 2003-04 to 2007-08 (Qtys. in mt.)

S. No.	Species/group	Potential yield	Exploitation (in tones)				
			2003-04	2004-05	2005-06	2006-07	2007-08
	Demersal Resource						
1	Elasmobranch	4200	329	257	52	2219	2234
2	Silver bellies	5000	747	982	255	2981	3000
3	Perches	8000	8920	6299	4367	5520	5530
4	Pomfrets	1900	322	214	278	309	314
5	Cat fish	1000	135	383	44	279	286
6	Thread fins (Polynemids)	400	17	12	9	50	50
7	Croakers (Sciaenids)	1200	58	17	39	890	895
8	Gerrids	1400				135	139
9	Goat fishes (Upenoids)	900				9	10
10	Silver grunt	100				8	13
11	Drift fish (<i>Areomaea indiea</i>)	300				0	0
12	Threadfin breams	500				247	254
13	Lizard fish	150				10	12
14	Flat fish	50				10	11
15	Bulls eye (<i>Priacanthids</i>)	100				0	0
16	Cephalopods	100				45	46
17	Penaeid shrimps	800	613	260	128	565	586
18	Crabs	1000	552	168	208	513	514
19	Deepsea lobster	120	38	65	53	0	0
20	Deepsea shrimps	110				0	0
21	Deepsea fishes	1970				0	0
22	Others	2700	2482	521	961	0	0
	Total	32000	14213	9178	6394	13790	13894

S. No.	Species/group	Potential yield	Exploitation (in tones)				
			2003-04	2004-05	2005-06	2006-07	2007-08
	Pelagic Resources						
1	Anchovies	6200	1161	1116	579	2339	2286
2	Sardines	8000	2988	2392	686	3600	3573
3	Hilsa shad	2500	251	143	100	153	168
4	Wolf Herring (Chirocentrids)	600	37	43		75	77
5	Mackerel	4500	1518	833	422	2000	2016
6	Round scads (Decapterids)	1300				175	173
7	Other carangids	6000	4571	1812	1675	1070	1082
8	Ribbon fish	1000	85	68	46	232	252
9	Half beaks & full beaks(Belonids)	600	79	51	22	294	232
10	Barracuda	2200	1249	350	547	611	508
11	Mulletts	2500	1325	768	405	938	944
12	Seer fish	1800	1679	456	547	1236	1238
13	Neritic tunas	18000	626	233	189	2076	2400
14	Others	800	741	155	287	0	0
	Total	56000	16310	8420	5505	14799	14949
	Oceanic Resources						
1	Yellowfin tuna	24000	97	36	29	2	2
2	Skipjack tuna	22000	88	32	26	0	0
3	Bigeye tuna	500	2	1	2	1	1
4	Bill fishes (Marlin, sailfish, swordfish)	2800	348	98	97	1	1
5	Wahoo	200				0	0
6	Pelagic sharks	7000				7	8
7	Dolphin fish	200				0	0
8	Barracuda	200	-			0	0
9	Flying fish	300				0	0
10	Oceanic squids	2000	-			0	0
11	Others	800				0	0
	Total	60000	535	167	154	11	12
	Grand total	148000	31058	17765	12053	28600	28855

Source : Fishery Department

time fishing dinghies ply the waters of the relatively distant (50-100km) North South islands. These dinghies have the capacity of 80 - 120 kg of fish at the conclusion of their 2-3 days trips, landing up to 120 kg of mixed pelagic and bottom fish, but their boats have not developed an effective market for required demand. Their fishing range size composition tends to allocate the larger fish of the catch to

restaurants and the smaller fish of the catch to the household market. The high demand for groupers in the market poses both a threat and an opportunity. The threat is represented by the lure of high profits, which induce poachers from the neighboring countries like Burma, Thailand and Indonesia, to engage in cyanide fishing or dynamite fishing, which is clearly detrimental to the environment.

Conservation

As the three district South Andaman, Middle and North Andaman & Nicobar shared, on the whole, similar habitats, and fishes, so they also share many of the same obstacles to achieving fishery management plans for reef fish. The foremost obstacles were lack of vital information. Fishery statistics were lacking or uninterpretable. Ostensible records of commercial catches for each area were fraught with flaws. Foremost among these was that the rewards presented location of landings rather than location of fishing. A second major flaw was that species separations were either lacking, improper or irregularly applied. No information on fishing effort existed. Finally almost no information on the economic and social aspects of the reef fisheries existed.

Twenty of World's 110 Grouper Species are Threatened With Extinction The first comprehensive assessment of the world's 110 species of groupers, a culinary favourite and important commercial fish, found that 20 are threatened with extinction unless proper management or conservation measures are introduced. Eight species previously were listed by the World Conservation Union (IUCN) as under extinction threat, and the new assessment proposes adding 12 more.

It is determined that the extinction threat facing groupers, which are the basis of the multimillion-dollar live reef food fish trade

based in Hong Kong and comprise one of the most valuable groups of commercial fishes in chilled fish markets of the tropics and sub-tropics. Around the world, consumers pay up to \$50 per kilogram for grouper. This shows that over-fishing could decimate another major food and economic resource for humans. The results are worrying and highlight the urgent need for fishery management, more effective marine protected areas (MPAs), and more sustainable eating habits for consumers of these fishes. It is identified that the need to protect outer reef areas and to manage spawning aggregations of many of the threatened grouper species is important. Outer reef areas are often not incorporated into MPAs, and spawning aggregations necessary for continued reproduction of many grouper species are rapidly eliminated by uncontrolled fishing. Increasing international trade to meet an insatiable demand for grouper poses a particularly major threat. The present need is for sustainable fishing and consumption of important fish species. The threatened groupers are naturally vulnerable to over-fishing, and the continued decline of fish populations can threaten food security and livelihoods in source countries. Their pending inclusion on the IUCN Red List of threatened species also reflects the widespread failure to successfully manage fisheries associated with coral reefs. Groupers are among the oldest fish on coral reefs, with some species reaching to more than 50 years

Table 3. Quantity of marine products exported (Qty.in kgs.)

Sl. No.	Year	A.F.L.		I.M.P.L.		OYA EXIM
		Fish (chilled different varieties)	Shrimp (chilled)	Fish (chilled different varieties)	Shrimp (chilled)	Fish (live grouper)
1	2000-01	48730	20	Nil	30155.6	—
2	2001-02	106000	Nil	81095	47332	—
3	2002-03	48000	Nil	9500	8500	4754
4	2003-04	40350	Nil	13000	9600	7572.300
5	2004-05	46176	Nil	Nil	Nil	10220
6	2005-06	47420	NIL	NIL	NIL	3010
7	2006-07	65701	NIL	31500	NIL	4173

Source : Fishery Department

of age. Several species only reach reproductive maturity later in life, making them particularly vulnerable to fishing before they mature. In addition, commercial fishing that targets reproductive gatherings of adults further hinders replenishment of unmanaged populations. The threatened groupers include two species of coral trout grouper, *Plectropomus areolatus* (Ruppell) *Plectropomus pessuliferus* (Fowler) which are mainstays of the chilled fish markets poses a significant threat in Andaman Islands. Both can be found in Andaman fish markets, but they face heavy and unmanaged fishing pressure that is rapidly reducing their populations.

Managing coral reef fisheries

The management of coral reef fisheries generally involves restricting fishers access to marine resources of economic value (food fish, edible invertebrates, fish for the aquarium, decorative shells for tourists, etc.) through licensing fishers and fishing vessels, restricting the use of certain fishing gear, setting catch limits, or designating waters as closed to all commercial and artisanal fishing short term or more permanently as is generally the case with marine protected areas. Given that coral reefs are of interest to multiple user groups whose interests vary considerably, from commercial and sport fishers to snorkelers, divers, researchers, glass bottom boat operators, and other stakeholders, managers are faced with the challenging task of addressing the needs of stakeholders, while protecting the biological richness of reefs. The establishment of marine protected areas that prioritize research and recreational uses is a widely used approach in the management of coral reef fisheries; such marine protected areas often promote tourism and species conservation but conflict with the livelihood interests of fishers. Fisheries management frequently affects not only the total volume of fish that reaches a market but also the timing and composition of supply. All three factors can affect the ex-vessel price of fish and thus commercial fishing incomes and through the marketing chain, whole sale and processor incomes and consumer budgets. Once

the nature of demand is determined, any management scheme can be evaluated with respect to its effect on prices and income. The hand line harvested product is treated with considerably more respect than trawl caught fish and receives appropriately higher prices. For example August 2003 whole sale prices for grouper at Port Blair market were in the range of \$ 0.5 to \$ 1 a kilogram now (2009) it goes to 6\$ per kg. The marine protected areas offer economic benefits via park entry fees and recreational services. Nonetheless, the income generated is rarely sufficient to offset the management costs (patrols, mooring buoys, educational placards and lifeguards) and an unfortunate reality is that most coral reef-based marine protected areas are undermanaged due to lack of funds. Managing coral reef fisheries is further complicated by the fact that the benefits from marine parks (jobs and recreational opportunities) tend to accrue to non-local people, whereas the costs in terms of lost livelihood opportunities tend to affect local fishing communities. Finally, many modern approaches to fisheries management do not support the informal management systems historically practiced by indigenous people, potentially fueling local fishers' discontent with marine protected areas. Local fishing communities receiving few benefits and experiencing notable costs due to the presence of marine protected areas often leads to the illegal extraction of resources, increased law enforcement costs, and ultimately the failure to achieve conservation aims.

Future Outlook

It is obvious that grouper farming is in its infancy. In order for grouper farming to grow substantially, more research and practical trials, especially in the nursery phase are needed before large-scale operations can be successful. With the high prices paid for groupers in certain markets, investors will focus on these species, and progress will be made. Total world production (capture and aquaculture combined) of groupers is today very low. Grouper is a luxury food product, which is sold at very high prices. When production mainly

Plate 1



Plate 2



Epinephelus caeruleopunctatus



Epinephelus chlorostigma



Epinephelus corallicola



Epinephelus erythrurus



Epinephelus fasciatus



Epinephelus flavocaeruleus



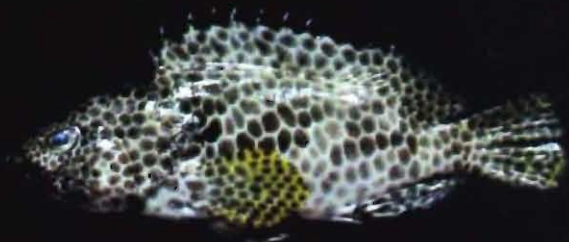
Epinephelus fuscoguttatus



Epinephelus longispinis



Epinephelus malabaricus



Epinephelus merra

Plate 3



Epinephelus ongus



Epinephelus polyphekadion



Epinephelus polystigma



Epinephelus quoyanus



Epinephelus undulosus



Plectropomus areolatus



Plectropomus laevis



Plectropomus maculatus



Variola albimarginata



Variola louti

from aquaculture is increased the luxury image will gradually wane and prices will come down. It will be very important for the grouper industry to plan for this occurrence.

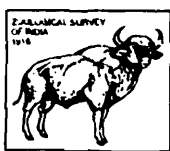
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GEOGRAPHICAL DISTRIBUTION PATTERN OF SEA TURTLES IN THE INDIAN SEAS

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INTRODUCTION

Sea turtles are widely but unevenly distributed throughout the circumglobal tropical and subtropical seas. They thrive not only in the coastal waters of the sea, but also in the offshore regions, and from the general oceanic to the specialized niches like coral reefs, seaweed beds and deep seas. After leaving the nesting beach as hatchlings, green turtles, loggerheads and hawksbills begin a pelagic phase that is believed to last for several years (Meylan and Meylan, 1999). They are often found at sea in association with the weed lines or drift lines that exist near frontal boundaries near major currents. Carr *et al.* (1978) discussed the concept of developmental habitats and defined them as places where immature sea turtles commonly occur, but where adults of the same species are rarely, if at all, found. These may consist of one or a series of habitats through which turtles pass as they grow to adult size. Estimates of growth rates in the wild individuals indicate typically slow growth, with age-to maturity ranging 15 to 50 years or more, depending on the species and geographical area (Balazs, 1982; Bjorndal and Zug, 1995). Adult turtles spend most of their lives in the adult

foraging grounds, an area usually separated from the nesting beaches. Adult foraging grounds may be fixed in space, such as sea grass beds, areas in the ocean with seasonably predictable blooms of jellyfishes or benthic invertebrates. During the reproductive seasons, adult turtles travel to the vicinity of the nesting beach, where they may remain for up to several months. Mating takes place along the migratory corridor, at courtship or breeding stations (Meylan and Meylan, 1999). India has a long coastline of 7516 km, about 5423 km area in the main land and 2094 km in the Andaman, Nicobar and Lakshadweep Islands. These coastlines are a combination of headlands, promontories, rocky stones, sandy spits, barrier beaches, open beaches, embayment, estuaries, inlets, bays, marshy land and offshore islands (Ahmed, 1972). Oceanography of the Indian coastal region is dominated by three seasons, viz. southwest monsoon (June to September), northeast monsoon (October to January) and fair weather period (February to May). The continental shelf along the east coast of India is narrow, as where along the west coast, the width of the shelf varies from about 340 km in the north to less than about 60 km in the south. Of the seven recognized species of sea turtles

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found worldwide, five species, the olive ridley, *Lepidochelys olivacea* (Eschscholtz, 1829), the green turtle, *Chelonia mydas* (Linnaeus, 1758), the hawksbill *Eretmochelys imbricata* (Linnaeus, 1766), the leatherback, *Dermochelys coriacea* (Linnaeus, 1766) and the loggerhead *Caretta caretta* (Linnaeus, 1758) occur in the Indian seas (Dash and Kar, 1990). All species of sea turtles are included in the International Union for Conservation of Nature and Natural Resources (IUCN) and Red List of Threatened animals (Baillie and Groombridge, 1996). While the hawksbill is considered as critically endangered, the loggerhead, green turtle, olive ridley and leatherback are listed as endangered. Except the loggerhead, all species are reported to nest along the mainland and the bay Islands (Choudhury, 2001). Sea turtles are considered highly evolved morphologically and have many adaptations for life in the sea. All species share features such as paddle-shaped limbs, in which all movable articulations between the distal bony elements are lost and three or four digits of the hand are markedly elongate. Lacrimal or tear glands are remarkably enlarged and modified to remove excess salts from body fluids, the salts are derived mostly from drinking sea water. Sea turtle shells are characterized by a reduced amount of bone. Sea turtles are also streamlined to various degrees, which improves their hydrodynamic efficiency an enlarged shoulder girdle with a markedly elongate coracoids serves as an attachment site for the well-developed pectoral muscles which are used for swimming (Meylan and Meylan, 1999). All the five species of turtles are highly migratory and visit parts of the coasts of mainland India and the Islands of Lakshadweep and Andaman and Nicobar for nesting during certain months. They are widely distributed and their migration extends throughout the world oceans. The mechanisms of sea turtle navigation have been the subject of intensive experimentation and speculation. Marine turtles are being studied for more than four decades with emphasis on their trade, nesting, tagging of mating pairs, general biology, fishery related mortality and other parameters. Unfortunately, there is a little

information on the offshore distribution of sea turtles in the Indian seas (Ram, 2000; Kannan and Rajagopalan, 2005). The distribution or pattern of different species of sea turtles may be categorized as inshore species, offshore species and oceanic migratory species. The offshore and migratory species frequent the Indian coastal areas during certain phases of their life cycle for breeding and nesting purposes. The purpose, season and duration of occurrence, assemblage and activities of different species in the Indian seas need to be properly documented. Therefore, the present study was aimed to study these aspects in the Indian coastal as well as in deep waters including the Island ecosystem by participating research cruises.

MATERIALS AND METHODS

Between 30.10.2003 to 8.11.2003 (north east monsoon) 21.7.2004 to 30.7.2004 (southwest monsoon) and 26.1.2005 to 15.2.2005 (fair weather) season, we conducted at-sea observations of sea turtles during the research cruises along the Arabian sea in west coast and Bay of Bengal in the eastern coast and Lakshadweep and Andaman and Nicobar Islands. Using Binoculars (Vanguard BR.7500, 7x50 mm field: 7.1), we searched the ocean surface for signs of sea turtles during day light hours (06:00-17:30). The night vision binocular Newcon-Optik BN-5, Magnification, X 2.4, Dimension mm 165x204x67 was also used during night hours for sea turtle observations. Each sighting was given a unique number and the following data were recorded: date and time of sightings, general locality (nearest land mark) latitude and longitude (by using cruise's GPS), sea conditions like size of waves, calm, rough, slightly sea swell, moderate sea swell and high sea swell), number of animals, how long was watch kept, duration of sightings including estimate of diving time, distance of sighting from observer, movement relative to observer; speed and heading of the ship, details of ship course, depth of the area, (m) (by using automatic recorders in the cruises) environmental parameters such as air,

temperature, weather conditions (wind speed, direction, sea swell and visibility). If sea turtle was sighted the following data were collected; species, number, size, sex if possible, details of behavior; presence of other species, reaction to observer or vessel. Photographs were taken wherever possible. Where and when no sea turtles of any kind were also recorded in the data sheets.

RESULTS

A total of 60 sightings representing 4 species of sea turtles were recorded in the Indian coastal and offshore waters. Most sightings were in the Arabian Sea followed by Lakshadweep and Andaman & Nicobar Islands and Bay of Bengal. Majority of turtles observed were olive ridleys 68.3% (n=41) while green turtles 20% (n=12), hawksbill turtles 6.7% (n=4) and leatherback 5% (n=3) were recorded (Table 1). Leatherback turtles were observed only in Andaman Island and Hawksbill turtles were in Lakshadweep group of Islands and Arabian Sea. Migration of olive ridleys were observed at the lat. 13°02.37' N long. 87°10.17' E, off Chennai, Bay of Bengal at a depth of 3100 m. Various activities like feeding, respiration, swimming, floating at the water surface without any movement and floating along with a wooden pole surrounded by fishes were noticed. Foraging green turtle on the water surface was observed at Lakshadweep Island. Sub adults *Lepidochelys olivacea*, *Chelonia mydas* and young leatherback turtles were noticed in the near shore as well as in deep waters during the cruise periods. There were no sightings of sea turtles in Nicobar group of Islands.

Balanoglossus attachments on the carapace of olive ridleys were seen. Harmful algal blooms were noticed at lat. 11°15.82' N long. 72°24.05' E, off Agatti Island, Lakshadweep at a depth of 1702 m.

DISCUSSION

Sea turtles occupy different ecological niches and the breeding areas are widely separated from the feeding areas. All sea turtles appear to exhibit migratory behavior at different times in their lives for food and breeding (Meylan and Meylan, 1999). The green turtle is herbivorous, distributed in the tropical and sub tropical areas near continental coasts and around Islands (Minton and Minton, 1973). According to Diez (1999), green turtles forage on sea grasses and algae. They nest sporadically throughout the year with the peak between June and September. To deposit their eggs, these animals undertake prolonged journeys over enormous distances often covering hundreds of kilometers of certain nesting beaches. Some of the marine habitats like Gulf of Mannar, Andaman and Nicobar Islands and Lakshadweep form the feeding grounds for green and hawksbill turtles. On the Indian main land, the coast of Gujarat in the west coast is a major nesting ground, where considerable numbers of green turtles lay their eggs (Venkatesan *et al.* 2004). Mukherjee (2001) and Kannan, (2008) mentioned that the Andaman Island is a feeding ground for green and hawksbill turtles and nesting grounds for green turtles, olive ridleys, hawksbills and leatherback turtles. Record of sub adult green turtles during the cruise periods indicated that, these

Table 1. Sea turtles and their relative (%) sightings in the Indian seas

Species	Arabian sea	Bay of Bengal	Andaman Island	Nicobar Island	Lakshadweep Island	No	Relative sightings (%)
<i>Lepidochelys olivacea</i>	23	7	6		5	41	68.3
<i>Chelonia mydas</i>	8				4	12	20.0
<i>Eretmochelys imbricata</i>	1				3	4	6.7
<i>Dermochelys coriacea</i>			3	-		3	5.00
Total	32	7	9		11	60	100.0

individuals probably feeding in shallow waters (Carlson, 1999). Leatherbacks are mainly oceanic medusae feeders and there are seasonal exceptions in some parts of the world. This species is not normally encountered in the coastal waters with the exception of gravid females in their inter-nesting habitat. Leatherbacks have been recorded over 30,000 miles from the point of tagging. The Leatherbacks, voyage to cooler latitudes may be related to its diet, as it feeds largely on jelly fishes and tunicates whose bodies are about 95% water. In the Indian coast, nesting grounds of this species are known in Nicobar Island and southern coasts of Ceylon (Deraniyagala, 1953). Mortimer (1982) stated that the leatherback sea turtle prefers a deep and unobstructed underwater access and a relatively steep beach profile. The leatherback (*Dermochelys coriacea*) distributions is correlated with dynamic nesting beaches adjacent to deep waters and prey availability, especially the Scyphomedusae and other epipelagic invertebrates (Pritchard, 1982). Sightings of leatherbacks in Andaman waters during the present study provide ample evidence of availability and food in the Andaman waters. Foraging sea turtles surface regularly during bouts of feeding (Diez, 1999). The hawksbill is a predominately tropical species whose foraging habitats have been determined to be coral reefs, where it preys on specific species of sponges (Meylan, 1988) and its distribution is associated with coral reefs and rocky outcropping in shallow coastal areas (Mortimer, 1982). Hawksbills routinely traverse shallow, coral strewn habitat to reach more heavily vegetated, low profile beaches for nesting.

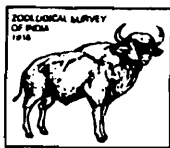
Although widely distributed, the hawksbill is believed to be more sedentary in its habits than the other sea turtles and less given to long journeys across the open ocean (Minton and Minton, 1973). Hawksbill sea turtles observed during the present study in Lakshadweep waters can be related to either breeding or feeding activity of the turtles in the adjacent shore waters where coral reefs and rocky habitats are found plenty in these Island ecosystems (Rajagopalan and Menon, 2003). Sea turtles spend most of the year scattered in the oceans and at mating time they all begin to move to the nesting sites, first gathering in small groups and then gradually merging until a great number are traveling together. Olive ridley is the smallest among all sea turtles, omnivorous with a penchant for crustaceans and mollusks. Olive ridleys are known to form huge reproductive congregations in habits a phenomenon popularly known as *arribada*. Every year at the beginning of the winter season, schools of turtles migrate *enmass* to reach the coastal waters of Orissa for mating and nesting. About fifty percent of the total world population and more than eighty percent of the total Indian population of olive ridleys nest in the Orissa coast (Patnaik and Kar, 2001). Usually the olive ridleys migrate *enmass* and not solitarily from the feeding ground. A number of small groups may migrate from different areas to the breeding ground, where they congregate in large numbers. Observation on the movements of olive ridleys in the Bay of Bengal during the cruise periods could be due to its reproductive migration of the sea turtle from the feeding grounds to nesting beaches.

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DIVERSITY OF OCEANIC FISHERY RESOURCES IN ANDAMAN & NICOBAR WATERS

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Fishery Survey of India Port Blair

INTRODUCTION

The Andaman & Nicobar groups of Islands are situated between Latitude 6°45'N and 13°41'N and Longitude 92°12'E & 93°57'E in the South East Bay of Bengal. The archipelago with 572 islands are fringed by lagoons and coral reefs and experiences both north east and south west monsoons and some Islands are blessed with perennial streams and rivers. The islands have a coastline of 1912 Kms, which is about one fourth of the total coastline of India. About 0.6 million, km² EEZ lies around these islands, which accounts for 30 per cent of the total EEZ of India. There is practically no continental slope in the Island group. The union-territory has a continental shelf of 16,000 km², which offers rich potential for coastal marine fisheries. The term biodiversity is the whole blotch of living things on earth or it can be also said as life on earth. It can be of floral or faunal diversity. The diversity includes all the living things in Terrestrial, Marine and other aquatic ecosystem. The diversity of marine fishery resources worldwide is about 24,618 species under 4,258 genera and 482 families. Similarly in India about 2,500 species were identified under 1,022 genera and 116 families. The oceanic diversity of these island group is very vast. The Andaman and Nicobar Islands marine ecosystem is known to harbour a large number of species *i.e.* 1200 species of fishes,

580 species of crustaceans, 900 species of molluscs and 300 species of echinoderms, out of 1200 fish species, about 350 species are commercially important at present (Krishnamurthy and Soundarajan, 1999). The marine fish landings in the islands can be divided into three groups namely the demersal, pelagic and oceanic. The demersal group consists of Elasmobranchs, Silver bellies, Pomfrets, Perches, Cat fish, Polynemids, Sciaenids, Prawns, Crabs and Other miscellaneous fishes. The pelagic and oceanic group comprise of fishes like Sardines, Thripos, Chirocentrus, Anchovies, Mackerels, Carangids, Mulletts, Hilsa, Ribbon fishes, Tunas, Bill fishes, Barracudas, deep sea sharks, Seer fishes and other miscellaneous varieties. The oceanic region of these islands provides vast scope for exploitation of oceanic resources such as tunas, bill fishes, sharks etc., The marine capture fisheries sector plays a significant role in the food and nutritional security, economy, employment generation and export trade. So, it is important to develop this sector by exploiting the vast potential of oceanic fishery resources for which one should have a clear understanding of the potential and bio diversity of the Oceanic resources in the Island waters. Thus this paper attempts to study the diversity of oceanic fishery resources in the Island waters based on the data collected by the departmental survey vessel MFV Blue

Marlin (OAL-35.76m) during the period from 2003-2007.

MATERIALS AND METHODS

The oceanic fishery resources survey was carried out by the Survey vessel MFV Blue Marlin, a tuna long liner (OAL 35.76m, GRT 310T) with an endurance of 20 days per month. The data collected during the period 2003-07 was utilized for the present study. During the survey period the vessel covered all the squares (Lat 1° X Long 1°) in the EEZ of Andaman and Nicobar Islands. The survey was carried out in the latitude 5°-15°N and Longitude 89°-96°E. The Fishing Gears operated by FSI for the exploitation of Oceanic resources are Tuna Long Line and pole and line for Tuna and allied resources, Drift long line using light sticks for Sword Fishes and Deep Long line for Big eye tuna resources. In the present paper an attempt has been made to study the abundance indices (aggregate hooking rate (per cent), the species richness measured by Shannon's index and also the Simpson's index was calculated to study the richness and evenness of the distribution

The Simpson's Index 'D' is calculated by using the formula

$$D = \frac{\sum n(n-1)}{N(n-1)}$$

'n' = The total number of organisms of a particular species.

'N' = The total number of organisms of all species.

After calculating the Simpson's Index the Simpson's Index of Diversity was calculated as 1-D and the Simpson's Reciprocal Index is calculated as "1/D"

The Shannon's Index was calculated as follows.

$$H^1 = -\sum \{P_i \times \ln (P_i)\}$$

Where H^1 = Shannon's Index

P_i = Percentage in the total population

i = No. of groups present

ni = No. of individual in the particular group.

RESULTS AND DISCUSSION

Biodiversity of Oceanic Resources

The oceanic fishery resources can be broadly classified into four groups viz. Tunas, Bill fishes, Sharks and other miscellaneous fishes. During the survey period 2003-07, about 34 species from 22 genera and 12 families were recorded. Among them 6 species belong to Scombridae, 4 species to Istiophoridae, 1 species to Xiphidae, 1 species to Coryphaenidae, 1 species to Sphyrnidae, 10 species to Carcharhinidae, 1 species to Lamnidae, 3 species to Sphyrnidae, 3 species to Allopidae, 1 species to Bramidae, 2 species to Gempylidae and 1 species to Molidae. The details of families, Genera, Scientific name and English name are given in Table 1.

Tunas : The tuna and tuna like fishes belonging to 6 genera, namely, *Thunnus*, *Katsuwonus*, *Euthynnus*, *Auxis* and the Bonitos i.e. *Sarda* and *Gymnosarda* are recorded from the Island's oceanic waters. The tuna fishery is mainly contributed by the coastal species viz. little tunny (*Euthynnus affinis*), long tail tuna (*Thunnus tonggol*), Oriental bonito (*Sarda orientalis*), Frigate tuna (*Auxis thazard*) and Dog tooth tuna (*Gymnosarda unicolor*) in A & N islands. Out of these 5 genera, mainly 3 genera and 5 species are recorded from oceanic region of A & N waters; these are *Thunnus albacares* (Yellow fin tuna), *Thunnus obesus* (Big eye tuna), *Thunnus alalunga* (Albacore tuna), *Katsuwonus pelamis* (Skipjack tuna) and *Gymnosarda unicolor* (Dogtooth Tuna). The oceanic species contributes very little to the tuna fishery of the islands. The fishing area for the coastal tunas extends mainly from the eastern part of Little Andaman to North Andaman (Lat 10°N to 15°N) up to the depth of 200m. This area is influenced considerably by both Southwest and Northeast monsoons. The coastal tunas from the waters of the islands are mainly caught by drift gill nets and hook and lines. The common species of tunas represented in the fishery and their common size range and maximum weight are given in Table 2.

Table 1. Oceanic species recorded by Fishery Survey of India

Family	Genus	Scientific name	English name
SCOMBRIDAE	<i>Thunnus</i>	<i>Thunnus albacares</i>	YELLOW FIN TUNA
		<i>Thunnus obesus</i>	BIG EYE TUNA
	<i>Katsuwonus</i>	<i>Katsuwonus pelamis</i>	SKIPJACK TUNA
	<i>Gymnosarda</i>	<i>Gymnosarda unicolor</i>	DOGTUOTH TUNA
	<i>Acanthocybium</i>	<i>Acanthocybium solandri</i>	WAHOO
	<i>Scomberomorus</i>	<i>Scomberomorus commerson</i>	NARROW- BARRED SPANISH MACKEREL
ISTIOPHORIDAE	<i>Makaira</i>	<i>Makaira mazara</i>	BLUE MARLIN
		<i>Makaira indica</i>	BLACK MARLIN
	<i>Tetrapterus</i>	<i>Tetrapterus audax</i>	STRIPPED MARLIN
	<i>Istiophorus</i>	<i>Istiophorus platypterus</i>	SAIL FISH
XIPHIDAE	<i>Xiphias</i>	<i>Xiphias gladius</i>	SWORD FISH
CORYPHAENIDAE	<i>Coryphaena</i>	<i>Coryphaena hippurus</i>	DOLPHIN FISH
SPHYRAENIDAE	<i>Sphyrna</i>	<i>Sphyrna jello</i>	BARRACUDA
CARCHARHINIDAE	<i>Galeocerdo</i>	<i>Galeocerdo cuvier</i>	TIGER SHARK
	<i>Rhizoprionodon</i>	<i>Rhizoprionodon acutus</i>	MILK SHARK
	<i>Scoliodon</i>	<i>Scoliodon laticaudus</i>	SPADE NOSE SHARK
	<i>Carcharhinus</i>	<i>Carcharhinus limbatus</i>	BLACK TIP SHARK
		<i>Carcharhinus albimarginatus</i>	SILVERTIP SHARK
		<i>Carcharhinus amblyrhynchos</i>	GREY REEF SHARK
		<i>Carcharhinus melanopterus</i>	BLACK TIP REEF SHARK
		<i>Carcharhinus macroti</i>	HARD NOSE SHARK
		<i>Carcharhinus sorrah</i>	SPOT TAIL SHARK
		<i>Carcharhinus longimanus</i>	OCEANIC WHITE TIP SHARK
LAMNIDAE	<i>Isurus</i>	<i>Isurus oxyrinchus</i>	SHORT FIN MAKU SHARK
SPHYRNIDAE	<i>Sphyrna</i>	<i>Sphyrna zygaena</i>	ROUND HEADED HAMMERHEAD
		<i>Sphyrna lewini</i>	SCALLOPED HAMMERHEAD
		<i>Sphyrna mokarran</i>	GREAT HAMMERHEAD
ALOPIDAE	<i>Alopias</i>	<i>Alopias pelagicus</i>	PELAGIC THRESSER SHARK
		<i>Alopias superciliosus</i>	BIG EYE THRESSER SHARK
		<i>Alopias vulpinus</i>	THRESSER SHARK
BRAMMIDAE	<i>Taractichthys</i>	<i>Taractichthys longipinnis</i>	BIG SCALE POMPFRET
GEMPYLIDAE	<i>Lepidocybium</i>	<i>Lepidocybium flavobrunneum</i>	ESCOLAR
	<i>Ruvettus</i>	<i>Ruvettus pretiosus</i>	OIL FISH
MOLIDAE		<i>Mola mola</i>	SUN FISH

Bill fishes : Four genera of Billfishes, namely, *Istiophorous*, *Makaira*, and *Tetrapterus* from the family Istiophoridae and *Xiphias* from the family: Xiphidae are recorded from the oceanic waters of the Islands. They are *Istiophorous platypterus* (Indo-Pacific Sailfish), *Makaira mazara* (Blue Marlin), *Makaira indica* (Black Marlin), *Tetrapterus audax* (Striped Marlin) and *Xiphias gladius* (Sword Fish). The common size range and maximum weight of bill fishes recorded in A & N water are given in Table 3.

Sharks : These are widely distributed species among all the marine fishery resources. These resources are highly predatory in nature. They belong to the Class: Chondrichthyes and Sub class: Elasmobranchii and form one of the important commercial fisheries of India. The shark meat and fins are having very good export value and widely used as food either in fresh or dried condition. During the study period 8 genera from 4 families of sharks were

recorded from the oceanic region namely *Alopias* (Family: Alopiidae), *Isurus* (Family: Lamnidae), *Carcharhinus*, *Prionace*, *Galeocerdo*, *Rhizoprionodon*, *Scoliodon* (Family: Carcharhinidae) and *Sphyrna* (Family: Sphyrnidae). The common size and maximum weight of few commonly occurring sharks recorded in A & N waters are given in Table 4.

Shannon's diversity index (Fig. 1 & 2) and Simpson's index (Fig. 3 & 4) were used to study the species richness and evenness in distribution. The species richness was more in the square 9°-90° where it was 1.82 followed by 1.71 in the square 13°-94° and 1.66 in the square 11°-94°. Similarly the Simpson's index was more in the square 8°-94° where it was 10 followed by 6.02 in the square 9°-94° and 5.78 in the 9°-92°.

Estimates on Fishery potential

The marine fishery potential of the islands has been assessed by various authors. The

Table 2. The common species of tuna, their common size range and weight

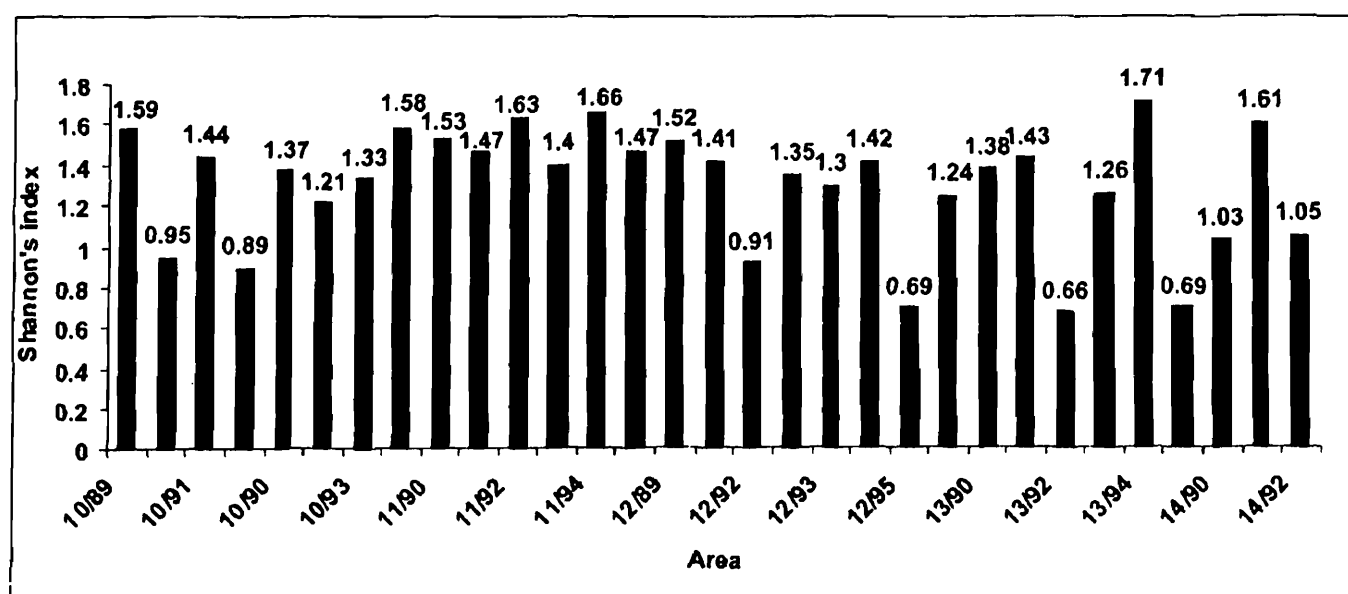
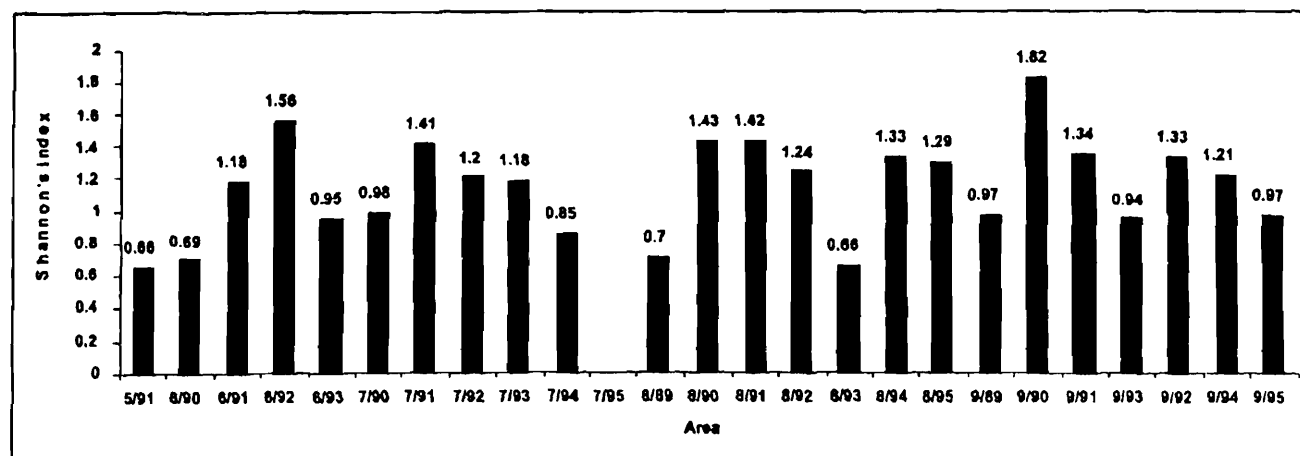
Name of the species	Common name	Common size (in cm)	Maximum Weight (in kg)
<i>Euthynnus affinis</i>	Little tunny	40-60	13
<i>Thunnus tonggol</i>	Long tail tuna	40-70	43
<i>Auxis thazard</i>	Frigate tuna	40-60	10
<i>Sarda orientalis</i>	Oriental bonito	30-50	06
<i>Gymnosarda unicolor</i>	Dog tooth tuna	40-60	130
<i>Thunnus albacares</i>	Yellow fin tuna	50-150	170
<i>Katsuwonus pelamis</i>	Skipjack tuna	40-80	34
<i>Thunnus obesus</i>	Big eye tuna	60-180	197
<i>Thunnus alalunga</i>	Albacore tuna	40-100	50

Table 3. The common species of Bill fishes, their common size range and weight

Name of the species	Common name	Common size (in cm)	Maximum Weight (in kg)
<i>Istiophorus Platypterus</i>	Indo-Pacific sail fish	131-230	100
<i>Makaira mazara</i>	Blue Marlin	141-230	820
<i>Makaira indica</i>	Black marlin	151-220	700
<i>Tetrapterus audax</i>	Striped marlin	151-200	230
<i>Xiphias gladius</i>	Sword fish	131-190	500

Table 4. The common species of Sharks, their common size range and weight

Name of the species	Common name	Common size (in cm)
<i>Carcharhinus sorrah</i>	Spot tail shark	61-220
<i>Carcharhinus limbatus</i>	Black tip shark	96-180
<i>Carcharhinus albimarginatus</i>	Silver tip shark	111-205
<i>Carcharhinus longimanus</i>	Oceanic white tip shark	61-180
<i>Carcharhinus melenopterus</i>	Black tip reef shark	101-160
<i>Galeocerdo cuvier</i>	Tiger shark	96-265
<i>Prionace glauca</i>	Blue shark	80-180
<i>Alopias spp.</i>	Thresher shark	71-180
<i>Sphyrna spp.</i>	Hammer head shark	121-200
<i>Isurus oxyrinchus</i>	Short fin mako shark	121-250
<i>Rhizoprionodon acutus</i>	Milk dog shark	35-45
<i>Scoliodon laticaudus</i>	Indian dog shark	33-60

**Fig. 1.** Shannon's index in the Andaman waters**Fig. 2.** Shannon's index in the Nicobar waters

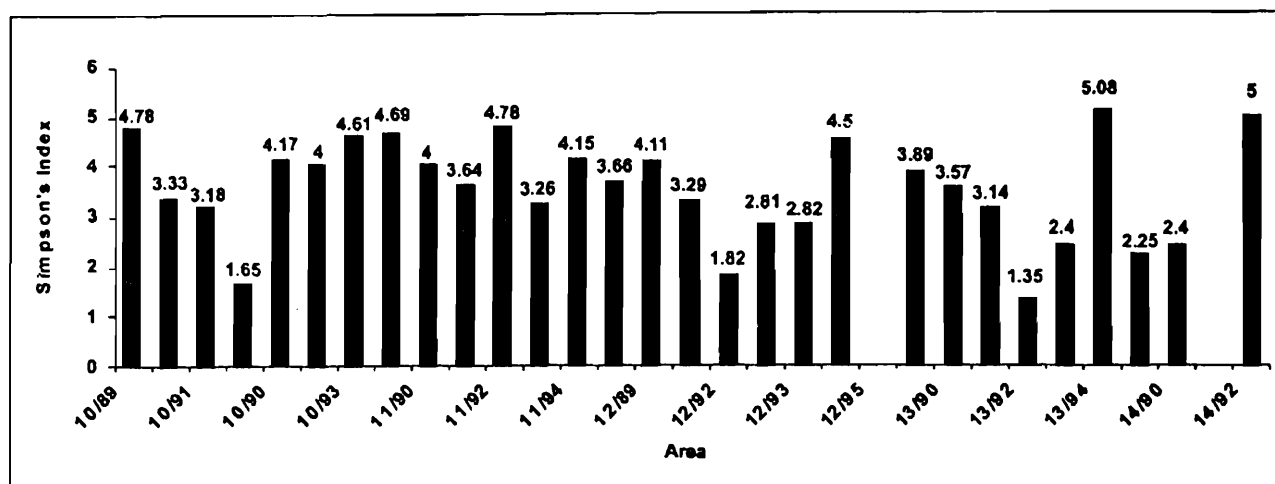


Fig. 3. Shannon's index in the Andaman waters

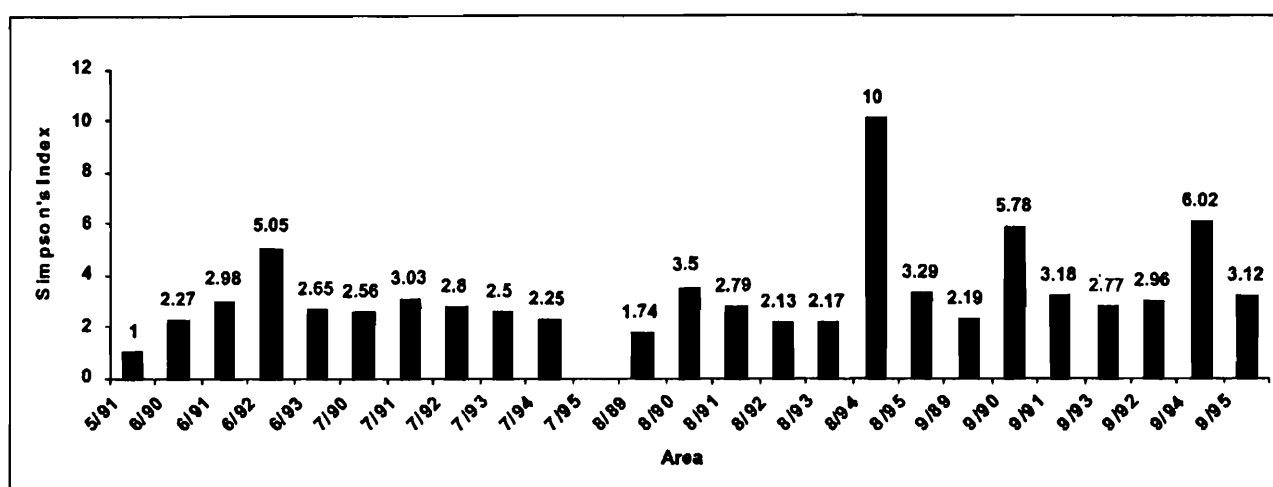


Fig. 4. Shannon's index in the Nicobar waters

estimates vary widely. Most of the estimates in Andaman Sea are based on primary/secondary/tertiary production and exploratory survey data. Jones and Banerji (1973) estimated the demersal resources as 4,000 tonnes and pelagic resources as 8,000 tonnes. Kumaran (1973) gave an estimation of 50,000 tonnes for both demersal and pelagic resources. George *et al.* (1977) estimated the coastal and oceanic resources as 1,60,000 tonnes. Sudarsan (1978) gave the estimate of demersal resources as 45,000 tonnes. Antony Raja (1980) estimated the coastal resources as 90,000 to 1,00,000 tonnes. Joseph (1985) gave an estimate for demersal and pelagic resources as 72,500 tonnes. Sudarsan *et al.* (1990) estimated the demersal, pelagic and oceanic resources as 2,43,500 tonnes. The marine fishery resource potential of Andaman and Nicobar EEZ estimated by FSI is 1, 48,000 tonnes which is comprised of

demersal resources (32,000 tonnes), Neritic-pelagic resources (56,000 tonnes) and Oceanic resources (60,000 tonnes). The aggregate potential yield of fishery resources in the EEZ around the Andaman & Nicobar Islands forms about 10% of the total projected fishery potential of the entire Indian EEZ. The aggregate potential yield of fishery resources in A & N Islands as per John *et al.*, 2005 is given in the Table 5. The major components of the oceanic resources are tunas (76.7 per cent),

Table 5. Total Marine Fishery Potential of A & N Islands

	Resources	Potential (in tones)
1.	Demersal	32,000
2.	Neritic-pelagic	56,000
3.	Oceanic	60,000
	Total	1,48,000

shark (11.7 per cent) and bill fishes (4.7 per cent). The potential yield of oceanic fishery resources estimated in the Exclusive Economic Zone around the Andaman and Nicobar Islands are furnished in Table 6.

The total marine fish production in the islands was characterized by wide fluctuations during the 05 year period 2003-2007 (Table 7). During the last seven years, the marine fish landings in the islands varied between minimum of 8615 tonnes in 2005 and a maximum of 30636 tonnes in 2003. The trend of total marine fish landings in the Islands was determined by the landings of demersal and pelagic resources viz., Sardines, Mackerel and Perches. The landings which was 30636 tonnes in 2003 decreased considerably to 8615 tonnes

in 2005 accounting for a decrease of 72 per cent just after the tsunami which struck this island group in 26th December 2004. But the landings gradually increased to 24085 tonnes and 27993 tonnes in the succeeding years i.e. 2006 & 2007 respectively. During this 05 years period the average landing of the islands was about 23647 tonnes. The oceanic fish production of last five years in A & N Islands contributes only 0.58 per cent to the total fish landing (Demersal, Pelagic & Oceanic) of 1,18,236 tonnes which is negligible. It shows that the oceanic resources are underexploited and efforts should be made to trap these resources to a sustainable level. The details of total fish production vis-à-vis Oceanic fish production during 2003-07 is given in Table 7. By analyzing the exploratory data

Table 6. Potential of Oceanic resources in A&N Islands

	Species / Group	Potential (in tonnes)
1.	Yellow fin tuna	24,000
2.	Skipjack tuna	22,000
3.	Big eye tuna	500
4.	Bill fishes (Marlin, Sail fish, Sword fish)	2,800
5.	Wahoo (<i>Acanthocybium solandri</i>)	200
6.	Pelagic sharks	7,000
7.	Dolphin fish (<i>Coryphaena</i> spp.)	200
8.	Barracuda (<i>Sphyraena</i> spp.)	200
9.	Flying fish (<i>Exocoetidae</i>)	300
10.	Oceanic squids	2,000
11.	Others	800
	Total	60,000

Table 7. Marine Fish Production in A & N Islands During 2003-2007 (in tonnes)

Sl. No.	Year	Total fish production (Demersal, Pelagic & Oceanic) (in tonnes)	Oceanic fish production (in tonnes)	% Contribution
1.	2003	30636	370	1.21
2.	2004	26907	182	0.68
3.	2005	8615	107	1.24
4.	2006	24085	11	0.05
5.	2007	27993	12	0.04
	Total	1,18,236	682	0.58

*Directorate of Fisheries, A & N Administration

of MFV Blue Marlin for the period 2003-08 it could be seen that the aggregate hooking rate was found to be more in Andaman waters (0.83 per cent) followed by Nicobar waters (0.69 per cent) (Table 8). The Abundance indices (Hooking rate) in Lat. 1° X 1° Long for all resources was more in the square 7°/93° (1.48 per cent) followed by 1.46 per cent in the square 10°/91° and 1.44 per cent in the square 5°/93°. Abundance indices (Hooking rate) in Lat. 1° X 1° Long of tuna resources was more in the square 12°/92° (1.26%) followed by 13°/92° (0.93 per cent) and 7°/93° (0.64 per cent). Similarly the abundance indices of bill fishes was more in the square 9°/89° (0.53%) followed by 12°/92° (0.49 per cent) and 13°/95° (0.40 per cent). The abundance indices of oceanic Shark was more in the square 8°/92° (0.97 per cent) followed by 5°/93° (0.80 per cent) and 9°/92° (0.70 per cent) (Fig. 5).

CONCLUSION

The Diversity of Oceanic fishery resources in Nicobar waters is more than Andaman

waters. During the Survey period 2003-2007 a total of 34 species belonging to 12 families were recorded. Among them 4 species of Tunas, 5 species of Bill fishes, 17 species of Pelagic sharks, 2 species of Seer fishes and one species each of Barracuda, Dolphin fish, Big scale pomfret, Escolar, Oil fish and Sun fish were present.

The study also revealed that abundance of oceanic resources are more in the EEZ of A&N waters but the exploitation level from the oceanic waters is very meager. It is observed from the study that the exploitation level of Oceanic fishery resources as compared to demersal fisheries in Andaman & Nicobar Islands is negligible which is due to lack of adequate knowledge and non availability of infrastructure facilities in the islands. Moreover the entrepreneurship temperament among the business community in the island is lacking as the deep sea fishing is capital intensive. So, keeping in view the vast potential of oceanic resources and their exploitation level, it is required to impart training on the deep sea

Table 8. Latitude-wise and Species-wise Hooking Rates (HR) obtained in exploratory survey in A & N waters during 2003-07

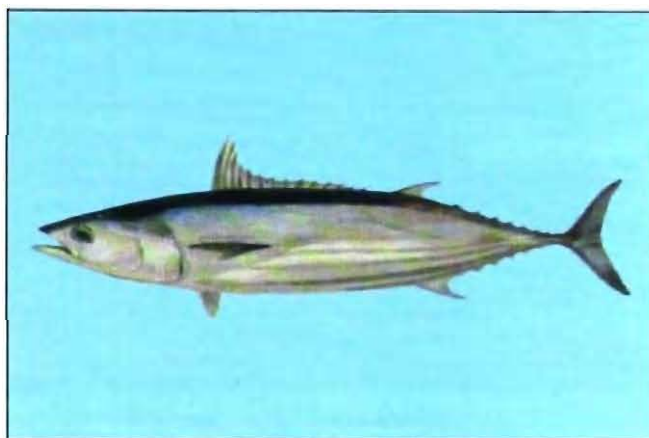
Area		Effort (in hooks)	Agg. HR (%)	Hooking rate (%)							
				YFT	SKJ	BET	SAI	SWD	MAR	SHK	OTH
N I C O B A R	5°	3135	1.02	0.06	0.03	—	—	—	0.03	0.51	0.38
	6°	16190	0.53	0.07	0.006	0.012	0.03	0.018	—	0.234	0.15
	7°	29665	0.67	0.19	0.006	0.006	0.03	0.03	0.003	0.24	0.17
	8°	35625	0.62	0.09	—	0.022	0.025	0.01	0.006	0.34	0.12
	9°	30000	0.83	0.14	0.01	0.05	0.02	0.06	0.01	0.37	0.18
Total		114615	0.69	0.12	0.01	0.02	0.02	0.02	0.03	0.01	0.31
A N D A M A N	10°	28125	0.92	0.22	0.004	0.007	0.05	0.07	0.02	0.37	0.18
	11°	58750	0.92	0.29	0.02	0.01	0.05	0.04	0.01	0.32	0.19
	12°	45510	0.77	0.34	0.013	0.004	0.05	0.02	0.01	0.19	0.15
	13°	46250	0.77	0.29	0.13	—	0.06	0.02	0.01	0.24	0.13
	14°	7500	0.61	0.36	0.05	—	0.03	0.03	—	0.09	0.05
Sub Total		186135	0.83	0.29	0.02	0.01	0.01	0.05	0.03	0.01	0.27
Grand Total		300750	0.78	0.23	0.012	0.012	0.043	0.03	0.008	0.29	0.16

Plate 1



Thunnus albacares, Yellow fin Tuna

Length range : 28-176 (cm)
Average Length : 121.08 cm
Average weight : 30.49 Kg.



Katsuwonus pelamis, Skipjack Tuna

Length range : 45-66 (cm)
Average Length : 56.3 cm
Average weight : 3.27 Kg.



Thunnus obesus, Big eye Tuna

Length range : 61-180 (cm)
Average Length : 125.4 cm
Average weight : 42.92 Kg.



Gymnosarda unicolor, Dog tooth Tuna

Length range : 54-174 (cm)
Average Length : 128.2 cm
Average weight : 35.45 Kg.



Xiphias gladius, Sword fish

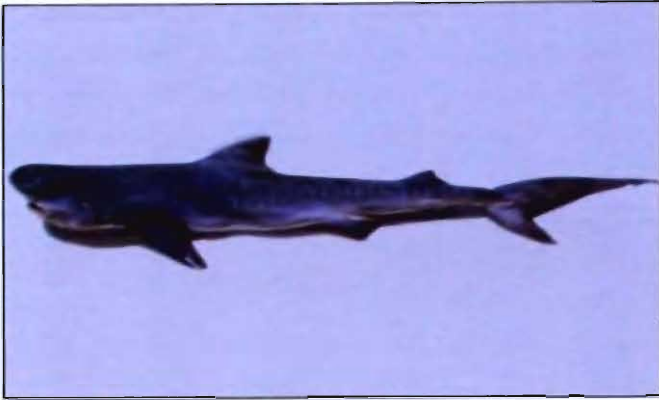
Length range : 134-220 (cm)
Average Length : 45.3 cm
Average weight : 39.56 Kg.



Makaira mazara, Indo-pacific Blue Marlin

Length range : 76-249 (cm)
Average Length : 186.3 cm
Average weight : 29.73 Kg.

Plate 2



Galeocerdo cuvier, Tiger Shark



Carcharhinus amblyrhynchos, Grey Reef Shark



Alopias pelagicus, Pelagic thresher Shark



Sphyrna lewini, Hammer headed shark



Taractichthys longipinis, Big Scale Pomfret



Sphyrna jello, Banded baracuda



Lepidocybium flavobrunneum, Escolar



Acanthocybium solandri, Wahoo

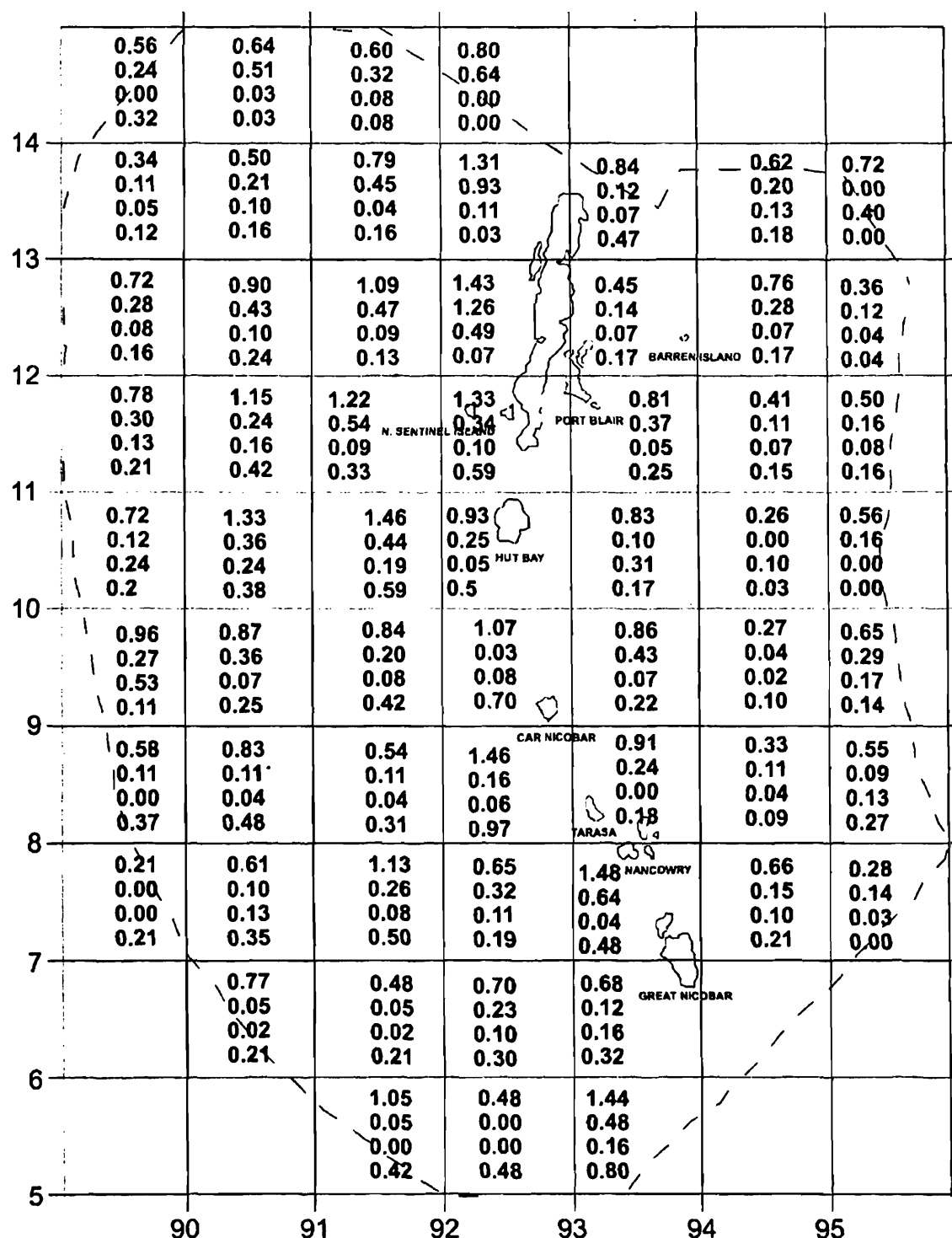


Fig. 5. Abundance indices (hooking rate) of Tunas, Bill fishes and Sharks in Lat 1°× long 1° during the period 2003-07

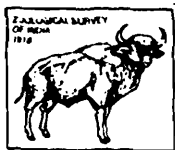
fishing and also to create awareness among the industry and the fishermen of the A&N Islands. In order to harvest the unexploited oceanic resources, efforts have to be made to introduce medium sized and larger size vessels which can go to the distant waters in the EEZ of the Islands to catch the highly migratory oceanic resources like Tuna and allied resources.

ACKNOWLEDGEMENTS

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BIOCHEMICAL STUDIES ON THE EFFECT OF PROFENOFOS IN *TILAPIA MOSSAMBICA* (PETERS)

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INTRODUCTION

Pesticides enter natural waters by various routes. First by discharge wastes from industrial plants (Duke *et al.*, 1970) secondly by the run off catchment's areas and sediment transport from treated soil (Nicholson and Hill, 1970) and lastly by aerial spraying of fields and accidental spill (Hsich *et al.*, 1972). Pesticides that are biologically active have a wide range of action; present a major danger to aquatic ecosystem. Pesticides affect the growth rate, survival, fecundity and reproductive activity of fishes (Park *et al.*, 2004; Singh and Singh, 2006). Pesticides are known to have the potential of disrupting endocrine system in aquatic life. This leads to abnormal thyroid function, reproductive alterations, poor hatching rates, decreased fertility and reduced growth in aquatic animals (Singh *et al.*, 1992; Pratt and Cairns, 1996).

The present investigation is an attempt to examine the following aspects of physiology of *Tilapia mossambica* under the stress of pesticides :

- Tolerance of fish exposed to the pesticide, Profenofos
- Effect of sublethal concentrations of pesticide on the biochemical composition and enzyme activities of the fish.

MATERIALS AND METHODS

Tilapia mossambica with the average weight of 28 ± 2 gms, length 12 ± 2 were collected from Hydrobiological Research centre, Chetpet, Chennai, Tamilnadu. The animals were maintained in large aquarium tank for a period of 15 days. During these days they were fed with formulated feed and water was exchanged everyday in order to remove the nitrogenous waste. Profenofos 50 per cent EC (O - 4 - bromo - 2-Chlorophenyl O-ethyl S-Propyl Phosphorothioate) was widely used in cotton field and it is also an antidote. The LC_{50} was determined following the procedure of Finney (1971). Based on the results of the acute toxicity study, doses of $1/10^{th}$ value were selected for sub acute studies (Desai *et al.*, 1985). *Tilapia mossambica* was placed in five different plastic tubs containing 0.03, 0.04, 0.05, 0.06 ppm of profenofos and the last tank as control. Experiments were carried out in triplicates.

For biochemical study 10 fishes each were placed in different sublethal concentration of Profenofos and animals were sacrificed at 10th and 20th day of the experiment. Protein in muscle were estimated by Lowry *et al.*, (1951), carbohydrate by Roe (1955) method. Enzyme activities include acid and alkaline phosphatases (Bergmeyer, 1963) were analyzed in the liver of fishes.

Statistical Analysis

Data collected from various biochemicals and enzymatic activities were subjected to mean and standard deviation. Students' *t* test was conducted to find out the significant between the control and experimental fishes.

RESULT

Acute study-Assessment of LC_{50}

The assessment of toxicity was based upon the percentage mortality of *T. mossambica* in different concentrations of Profenofos. It was found that LC_{50} (50 per cent mortality at 96 hours) is 0.2 ppm. The acute sign of poisoning appeared rapidly. The fishes exhibited restlessness. Loss of balance was followed by abnormal posture ultimately leading to death.

Subacute study

1/10th of LC_{50} such as 0.03, 0.04, 0.05 and 0.06 ppm was chosen for subacute study. Mortality was not observed in any of the subacute treatment group.

Protein

Changes in the level of total protein of *Tilapia mossambica* exposed to Profenofos and the result was presented in table 1. A decline in total protein of the treatment fish when compared to that of control was observed. Decline of protein was highest at 0.06 ppm of Profenofos 20th day of experiment. A significant difference ($p < 0.001$) in total protein was observed in all treatment.

Table 1. Changes in total protein (% mg) in *T. mossambica* exposed to sublethal concentration of Profenofos

Exposure period	Control	Pesticide concentration (% 96 hr LC_{50})			
		0.03 ppm	0.04 ppm	0.05 ppm	0.06 ppm
10 th day	8.10 ± 0.02	7.11 ± 0.08**	6.77 ± 0.17**	6.09 ± 0.13**	5.85 ± 0.52 **
20 th day	8.23 ± 0.07	6.13 ± 0.26**	6.01 ± 0.46**	5.77 ± 0.19 **	4.02 ± 0.31**

**Significant at 1% level

Carbohydrate

Carbohydrate content was lower in treatment when compared to that of control (table 2). Decline in carbohydrate content was found to be at 0.06 ppm concentration at 20th day. There was a significant ($p < 0.001$) decline in carbohydrate content of all treatment groups when compared to that of control.

Lipid

Lipid content also decreased in treatment when compared to that of control (table 3). Maximum impact was found in the longest exposure period and the highest test concentration. A significant ($p < 0.001$) decline in lipid content was observed when compared to that of control on all experimental days.

Table 2. Changes in carbohydrate (% mg) in *T. mossambica* exposed to sublethal concentration of Profenofos

Exposure period	Control	Pesticide concentration (% 96 hr LC_{50})			
		0.03 ppm	0.04 ppm	0.05 ppm	0.06 ppm
10 th day	4.19 ± 0.02	3.73 ± 0.17**	3.57 ± 0.13**	3.19 ± 0.03**	2.05 ± 0.45**
20 th day	4.56 ± 0.07	3.53 ± 0.33**	3.07 ± 0.15**	2.45 ± 0.71**	2.09 ± 0.38**

**Significant at 1% level

Table 3. Changes in total lipid (% mg) in *T. mossambica* exposed to sublethal concentration of Profenofos

Exposure period	Control	Pesticide concentration (% 96 hr LC ₅₀)			
		0.03 ppm	0.04 ppm	0.05 ppm	0.06 ppm
15 th day	1.10 ± 0.02	1.01 ± 0.21**	0.97 ± 0.12**	0.79 ± 0.43**	0.68 ± 0.16 **
30 th day	1.23 ± 0.07	0.77 ± 0.22**	0.61 ± 0.42**	0.57 ± 0.18**	0.42 ± 0.32**

**Significant at 1% level

Enzyme activities

Acid Phosphatase

Acid phosphatase activity in the liver was presented in Fig. 1. Enzyme activity decreases when compared to that of control. There is a dose dependent decrease in acid phosphatase activity on all experimental days was observed.

Alkaline phosphatase

The activity of alkaline phosphatase is shown in Fig. 2. Alkaline phosphatase activity decreased on all experimental days when compared to that of control. There is a significant difference ($p < 0.001$) between sublethal concentrations to that of control on all experimental days.

DISCUSSION

Intensive use of organophosphorous pesticides in public health, agricultural and forestry are responsible for the rapid decline in the production of fish because fishes are most vulnerable to pesticides. In the present investigation the impact of Profenofos on the

physiology of the *Tilapia mossambica* with special reference to biochemical components varied according to the concentration of the pesticide. Acute toxicity studies suggest that the susceptibility and pesticide concentrations are directly related. Mortality of the fish may be due to physiochemical alteration such as decrease in dissolved oxygen, increase in total solids, chlorides as chlorine and conductivity that is induced by Profenofos, and loss of homeostasis. Physiological and biochemical mechanisms in poikilotherms aid them to adapt to a range of environmental factors (Grant and Schoettger, 1972).

Alterations in the biochemical parameters in fish have the potential to detect acute or chronic damage from pollutants (Neff, 1985). Body biochemical composition such as protein, carbohydrate and lipid play a vital role in tissue construction and energy production.

Variety of environmental pollutants has been shown to alter protein metabolism in fish and invertebrates. In the present study, concentration and exposure period of

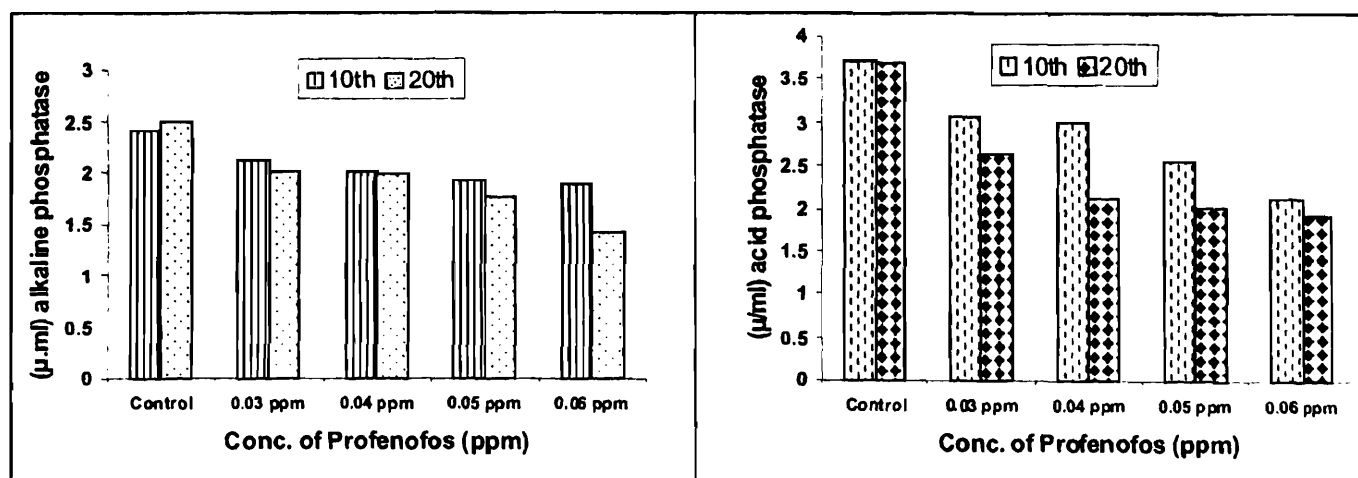


Fig. 1a & 1b Effect of Profenofos on acid and alkaline phosphatase activity in *T. mossambica*

profenofos will decrease the total protein content of *T. mossambica* which was similar to the findings of Devaraj *et al.*, (1992); Singh *et al.*, (1993) and Tilak *et al.*, (2005). The decrease in protein content may reflect an increased energy cost of homeostasis, tissue repair and detoxification during stress.

In the present investigation total carbohydrate was found to decline in all the test concentrations for both the exposure periods. This result coincides with the finding of Murthy and Devi (1982) and Yasmeen *et al.*, (1989) under the stress of pesticides. This decline in carbohydrate may be due to the utilization of immediate energy under stress condition. Lipid forms an important fuel reserve stored in large quantities and it is an essential component of protoplasm and even during extreme starvation considerable amount could be extracted from tissues (Hoar, 1984). In the present study, lipid content decreased in treatment when compared to that of control. Similar results were observed by Jayachandran and Chockalingam (1987); Shanker and Verma (1989) and Athiya Jabeen *et al.*, (2008). Depletion

of lipid may be due to the increased uptake of lipid by the tissues and lipolysis.

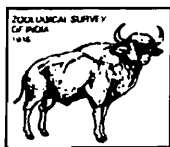
Acid & Alkaline phosphatase activity in the present study showed a decline when compared to that of control. Sastry and Sharma (1980) also found a similar trend in *Channa punctatus*. The reason for decrease in acid and alkaline phosphatase may be due to the leakage of the enzymes into extra cellular compartments or inhibition of normal membrane transport and uncoupling of oxidative phosphorylation leading to an alteration in enzyme system (Gill and Hema, 1990).

Minor fluctuations in the biochemical and enzyme activity may reflect redistribution of components further the maximum depletion encountered at the highest test concentrations and the longest exposure period. So to conclude the homeostatic system of fish are continuously stressed by the altered aquatic habits by pesticide. Fish constitutes one of the primary sources of cheap nutrition for man; alteration in their biochemical and enzyme composition would certainly reduce the nutritional value (McLeay, 1973) of the fish.

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FISHERIES AND ECONOMICS

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INTRODUCTION

This section of the report aims to both review the fisheries related economic material published which is specific to the study area, and to introduce other subjects relevant to the topic. It represents an introductory stage in the process of evaluating existing work on the subject. The notion that economic study should be useful to the people involved in the activity of the fisheries has been used as general guideline in the collection and compilation of the material. The subjects introduced here include: placing value on fish and fishing, a review of the statistical estimations of these, government involvement in fisheries economics, a review of one community initiative and a brief discussion of applied research and institutional research on the topic.

The traditional tasks involved in the fisheries have been essentially those of harvesting, processing, and selling fish. The activity of

“primary fishing” represents private enterprise utilizing a natural resource to generate financial profit (Mandale, 1998). It must be said, however obvious it may seem, that economics pertaining to fisheries goes much further than an analysis of this primary activity. It is important not only to describe the “indicators” of an ongoing relationship between the resource, producer and consumer but also to understand the dynamics of a large number of influencing factors.

The economic value of fish and of fishing

What is the value of fish, fishing and the activities associated with the fisheries? This is not an easy question to answer. The federal government Department of Fisheries and Oceans (DFO) maintains detailed records of the volume of fish landed at each port. This also includes the landed value of the fish at the port (Table 1). Such information is vital to economic analysis.

Table 1. Fisheries Statistic by County, 1995

Fish Landing	Weight (metric tons)	Value (\$000)	Fishermen 1995	Vessels 1995
Inverness County	6,695	36,984	1,118	374
Antigonish County	1,793	9,034	409	141
Totals	8,488	46,018	1,527	515

Source : compiled by the Nova Scotia Department Finance, Statistics Division, 1998

Original source : DFO

Collected data represents fact, qualified by collection terms and procedure. The economic significance of these facts lies in their use as indicators in the analysis and evaluation of a larger matrix of economic activity. Also, depending on their purpose and motivation different people may feel qualified to draw a variety of different conclusions from the same data.

For example, the reader can observe that the volume of lobster landed at Ballantyne's Cove, in Antigonish County, declined between 1993 and 1994 (Table 2). Also, they can see that this decreased volume saw an increase in the value of the landed lobster. What can be said about this? It would seem, apparently, to be a simple matter of scarcity in supply producing an increase in market value.

The answer to what these changes in landed catch size and value represent may be significantly different depending on who you ask. A fisherman at the wharf, a buyer with an independent purchasing license or large company with provincial market influence may each have a different view of the same facts. The value of lobster or any other fish does not end at the wharf. The process in "added value" is an important topic. This is essentially any activity or process which adds commercial value to the fish after it leaves the wharf and before it is sold to the consumer. This includes, transportation, fish processing, and product development, distribution, marketing and sales.

After carrying out an initial search it appears that there are no published evaluations of the added value and ultimate consumer destination of fish landed at the ports in the study area. This topic should be examined in-depth in the future. At the provincial level a recent report

indicates that, "Fish and fish processing combined are consistently Nova Scotia's single biggest source of export earnings, exceeding other well-known provincial products like forestry products, Michelin tires, or Volvo motor cars." (Mandale, 1998) It is not possible, using the data provided by Mandale (1998), to determine how much of the cited export earnings are contributed from within the St. Georges Bay study area. This statement does, however, characterize the importance of the industry.

Statistical Determination of Employment Levels

There are problems with the use of published statistical data in the estimation of employment level in the fisheries. A variety of published sources cite the number of people employed within different but related Statistics Canada occupational classifications which cover the fisheries within the study area. There are some problems associated with drawing accurate conclusions from compilations of such data. The Census of Canada occupation classification in "Labour Force by Sex" lists "fishing and trapping" combined. The occupation classification in "Experienced Labour Force", lists "fishing, hunting, trapping and related" combined. These grouping of employment type create problem for fisheries analysis.

Furthermore, there seems to be several errors in the presentation of calculations for 1981 data, when the males and females for "fishing and trapping" in the "Labour Force by Sex", were added together the results came out to be $(200 + 15 = 235)$ (Table 3). The same addition of sexes for "fishing, hunting, trapping and related", in the "Experienced Labour Force" table, resulted in $(220 + 20 = 235)$ (Table 1-3).

Table 2. Example of Lobster Volume and Value Ratio (1993-1994)

Ballantyne's Cove Landings	1993	1994
Volume	163,866 (metric tons 000)	142,958 (metric tons 000)
Value	1,111,813.25 (\$000)	1,183,954.10 (\$000)

Source : DFO Moncton

Table 3. Labour Force, 15 Years and Over, By Sex, Showing Industry Divisions Antigonish County 1981

	Antigonish County			% of Total Labour Force	
	Male	Female	Total	Antigonish Co	Nova Scotia
Agriculture	285	65	350	4.8	2.3
Forestry	225	30	225	3.5	1.3
Fishing and Trapping	200	15	225	3.1	2.0
Mines, Quarries and Oil Wells	65	-	70	0.9	1.8
Manufacturing	555	150	705	9.6	15.0
Construction	575	35	615	8.4	6.5
Transportation, Communication & Other Utilities	355	30	380	5.2	8.0
Trade	630	525	1,150	15.7	17.4
Finance, Insurance and Real Estate	75	100	180	2.5	4.4
Community, Business & Personal Services	1,215	1,170	2,980	40.8	29.2
Public Administration	245	155	405	5.5	12.1
Total Labour Force	4,430	2,880	7,305	100.0	100.0

Labour Force : By place of residence excludes persons looking for work who last worked prior to January 1, 1980, and who never worked.

This sample in original format includes their unexplained total. For example, see the line for Fishing and Trapping. 200 plus 15 provides a total of 225. Source : The Nova Scotia Department of Finance has compiled data in many different formats. In 1986, they produced County Profiles for both Antigonish and Inverness from Statistics Canada, Census of Canada data. When examining a work force of 7,305 people the cumulative effect of these variations in compiled totals may represent a significant factor. Any attempt to create a profile, over time, becomes problematic. The occupational classification for the 1996 Census of Canada changes to "Occupations Unique to Primary Industry." Combining occupations in broad categories makes assessment of the fisheries difficult through the use of this census data.

Samples of this publicly available Statistics Canada data are shown in Tables 3, 4, 5, 6 and 7.

There are other sources which selectively cite

levels of employment without qualification of their data sources. For example, in the estimation the Antigonish Regional Development Authority; "The fishery represents a small but vital part of the Antigonish economy. In 1993, there were 374 fisherman in Antigonish County, of this total, 100 obtained over 75% of their income from the fishery." (Anonymous, 1995b). This provides a number of fisherman for one year without considering the state of the fishery during that year relative to other years. In order to show trends over time other means of deriving accurate levels of employment in the fishery must be utilized. The Nova Scotia Department of Finance currently produces information which documents fish landing volume and value, number of fishermen and the number vessels by county (Table 1). The Finance Department's 1998 publication uses 1995 data, supplied to them from Fisheries and Oceans Canada. They have not compiled this over time to provide a comparison of years.

Table 4. Experienced Labour Force by Occupation Groups Antigonish County, 1981

	Antigonish County Labour Force			% of Total Labour Force	
	Male	Female	Total	Antigonish Co	Nova Scotia
Managerial, Administrative & Related	405	115	525	7.2	7.3
Natural Sciences, Engineering & Math	160	05	165	2.3	2.8
Occupations in Social Sciences & Related	70	65	135	1.8	1.5
Occupations in Religion	20	30	45	0.6	0.3
Teaching & Related Occupations	275	320	600	8.2	4.7
Occupations in Medicine & Health	105	320	425	5.8	5.2
Artistic, Literary, Recreational & Related	40	55	90	1.2	1.2
Clerical & Related	165	865	1,025	14.0	16.5
Sales Occupations	320	265	585	8.0	9.2
Service Occupations	325	615	940	12.9	14.6
Farming Horticulture & Animal Husbandry	270	65	340	4.7	2.3
Fishing, Hunting, Trapping & Related	220	20	235	3.2	2.4
Forestry & Logging	165	20	185	2.5	1.2
Mining & Quarrying	40		40	0.6	1.0
Processing Occupations	180	45	230	3.1	5.0
Machining & Related Occupations	160		160	2.2	1.6
Product Fabrication, Assembly & Repairing	290	5	295	4.0	6.1
Construction trades	705	10	715	9.8	7.6
Transport Equipment Operating	275	15	290	4.0	4.4
Materials Handling & Related	65	15	85	1.2	2.2
Other Crafts & Equipment Operating	80		80	1.1	1.2
Occupations Not Elsewhere Classified	95	25	115	1.6	1.7
Total Experience Labour Force	4,430	2,880	7,310	100.00	100.00

Government Initiative

The utilization of fisheries resources is "regulated" and "managed" by different levels of government. The Federal Department of Fisheries and Oceans plays a key role in these efforts. Part of this department's mandate is to ensure the health of fish stocks. The information which they produce that is economic in nature often keeps the task of "conservation" as its focus. There have been some unsuccessful attempts to introduce social and economic analysis into fisheries management research. The Canadian Atlantic Fisheries Scientific Committee (CAFSAC) has met with little

success attempting an interdisciplinary approach to integrate biology and socio-economics. "The main reason for their failure are lack of committed input from economists, apparently due to the lack of manpower, and resources, and a reluctance to divert the effort of CAFSAC assessment biologists into the study of fishery economics" (Mahon, 1986).

There does not seem to have been any independent assessment of their attempts or any current publication pertaining to more recent efforts. Perhaps the present organization of the "Policy and Economics" DFO branch is an outcome of this earlier CAFSAC work. The

Table 5. Experienced labour force by occupation groups

Antigonish County	1981	1991
Managerial, Administrative & Related	525	710
Natural Sciences, Engineering & Math	165	105
Occupations in Social Sciences & Related	135	155
Occupations in Religion	45	65
Teaching & Related Occupations	600	570
Occupations in Medicine & Health	425	580
Artistic, Literary, Recreational & Related	90	130
Clerical & Related	1,025	1,265
SALES OCCUPATIONS	585	680
Service Occupations	940	1,365
Farming Horticulture & Animal Husbandry	340	330
Fishing, Hunting, Trapping & Related	235	235
Forestry & Logging	185	265
Mining & Quarrying	40	
Processing Occupations	230	295
Machining & Related Occupations	160	230
Product Fabrication, Assembly & Repairing	295	420
Construction trades	715	810
Transport Equipment Operating	290	285
Materials Handling & Related	85	35
Other Crafts & Equipment Operating	80	20
Occupations Not Elsewhere Classified	115	165
Total Experience Labour Force	7,310	8, 745

Labour Force : Excludes persons looking for work, who prior to January 1, 1980 and January 1, 1990 or who never worked.

Source : N.S. Department of Development and N.S. Department Finance (Original source: Statistic Canada, Census of Canada)

Policy and Economics Branch pronounces purpose in research related to the fisheries management. They state that "Management policies and regulation routinely affect economic performance in the private sector in a variety of ways. In the fisheries, for example, they can affect fishing revenue, harvesting cost, and the cost of managing the fishery. The type of fisheries management system used will influence how profitable the industry will be and how much the taxpayer must pay for fisheries management" (Anonymous, 1999f).

The Branch also states that it will have a role in helping to design regulatory programs,

contributing to the development of annual fishing plans, providing advice on financial assistance proposals, collecting and analyzing commercial data, design and delivery of ground fish adjustment programs, cost recovery, revenue generation, and industry partnerships. They also plan to direct "attention" to programs formerly provided by the Coast Guard (Anonymous 1999f). These activities in economic research and analysis cover a lot of territory. The government would seem to be motivated by a perceived need to address issues which are fundamentally economic in nature in order to take a more active role in promoting growth in the economy.

Table 6. Population by Occupation

Antigonish County	1996
Management Occupations	755
Business, Finance and Administrative Occupation	1,200
Natural and Applied Sciences and Related Occupations	295
Health Occupations	560
Occupations in Social Sciences, Education, Government Services and Religion	805
Occupations in Art, Culture, Recreation and Sport	170
Sales and Service Occupations	2,520
Trades Transport and Equipment Operators and Related Occupations	1,430
Occupations Unique to Primary Industry	1,035
Occupations Unique to Processing, Manufacturing and Utilities	350
Total employed labour force 15 years of age and over	8,165

A common opinion, which will only be mentioned once here within the study area context, is that the government department responsible for fish quota allocation hinder the economy by allowing over fishing or by not allowing enough fishing. The Canadian Institute for Research on Regional Development included the following in its review of the areas fishery. "The fish plant in Arisaig, Antigonish County, has suffered from what its owner regards as unnecessary cuts in herring-stock allocations, which in the fall of 1996 resulted in severe loss of income for both fishermen and the 110 workers" (Arseneault, Beaudin, *et al.*, 1997). There is no discussion of the owners comment. This issue is mentioned here in passing because it characterizes an element of "popular" opinion pertaining to the governments impact on the economics of the fishery.

An Example of Government Intervention-Environmental Emergencies

DFO maintains a Gulf Region Environmental Emergencies Response Plan. This region includes the St. Georges Bay study area. The plan is to be used as a reference during emergencies. It states that, "DFO will plan for preemptive interventions in the fishery, such as the restriction or closure of fisheries and aquaculture operations and purchase or quarantine of contaminated catches, and will implement these plans upon the decision of

the Regional Director General" (Anonymous, 1993b). The reader may wonder what this has to do with economics. In the event of an emergency in which a fishery is jeopardized there should be a clear understanding of what the potential losses would be. The plan also makes provision for making "information available" on an optional cost recovery basis, if restitution claims are made against a polluter for damages or loss.

Impact of Reductions in Stock Allocation and Closures

The Cheticamp Development Commission produced a report in 1994 titled, Impact of the Fisheries Crisis in Northern Inverness County. This report presents the results of a study which had goals to, "...determine the impact of the fishing crisis in Cheticamp and surrounding communities. It is to identify the direct and spin off effect of the present situation due to the quota reduction and closure of fish plants." (Aucion-Grace and Aucion, 1994). The report documents the displacement of approximately 400 workers. Through an interview process the commission developed what they felt to be a representative sample of opinion regarding the communities relationship to the changes in fisheries resulting from stock closures. The study resulted in a number of recommendations. Most of them focused on a need for greater government support in the

Table 7. Population by occupation 1996

Antigonish and Inverness Counties	Antigonish County 1996	Inverness County 1996
Management Occupations	755	690
Business, Finance and Administrative Occupation	1,200	1,160
Natural and Applied Sciences and Related Occupations	295	250
Health Occupations	560	380
Occupations in Social Sciences, Education, Government Services and Religion	805	595
Occupations in Art, Culture, Recreation and Sport	170	55
Sales and Service Occupations	2,520	1,460
Trades, Transport and Equipment Operators and Related Occupations	1,430	1,610
Occupations Unique to Primary Industry	1,035	1,275
Occupations Unique to Processing, Manufacturing and Utilities	350	620
Total employed labour force 15 years of age and over	8,165	8,095

Source : Statistic Canada, Census of Canada 1996

form of projects that would stimulate both economic benefit from fish habitat enhancement and projects that would encourage locally driven diversification of the areas economy. Some discussion is made pertaining to the demographics of the Cheticamp area. This issue was important in context to older people facing the prospect of starting over on new "careers"

Cheticamp harbour development

A marine services centre and industrial park market study was completed in 1987 for the Cheticamp area. While this report now dates back 13 years, it is mentioned because of the in-depth approach to assessing the local fishery economy. By way of example, the authors describe a rapidly growing fishery with an increase of over 300 fishermen within the DFO statistical districts 12 and 13 of Inverness County from 1980 to 1986. In 1985 they accounted for 385 vessels registered in the County and an additional 63 from outside of the area using ports in the County.

Other issues

The First Nations fisheries are an important topic for which no study area specific

information was found. Also, cooperative organization within the fisheries is important within the study area. In view of the history and number of co-ops in the area this subject should be reviewed further at later date. Due the time constraint on the current report no mention is made of boat building, maintenance, storage and hauling. It should be noted that an extensive review of the economics associated with fisheries for the entire province is made in *Estimating the Economic Value of Coastal Ocean Resources : the Case of Nova Scotia* by Maurice Mondale (1998). This publication may be of some use in sorting out sources of useful data relevant to the St. Georges Bay study area.

Research and development

While this a broad topic for discussion, one case specific to the St. Georges Bay study area is reviewed here. In 1992 the Nova Scotia Department of Fisheries carried out a study to determine if existing whelk populations in the Gulf region of Cape Breton would support "already defined markets" The study area included Mabou, Pleasant Bay and Bay St. Lawrence.

This project was supported by the Technology and Inspection Division of the Nova Scotia Department of Fisheries. The intended "by-products" of the study included,

1. determining if a certain trap design excelled in catching performance.
2. determining if catch rates were related to bottom type.
3. determining size frequency distribution of whelks in the area sampled.

The economic benefits of this research are not estimated. The development of under utilized species may, however, have rewards for fisherman who are looking for new opportunities. The report states that the positive feed back they received from potential buyer suggests a large market for whelk meat (Moffatt, 1992). While this study may not have resulted in direct economic benefit for the region it does raise the issue of potential value to the industry in research and development. To this end, there does not seem to be any recorded assessment of the industries or individuals needs for such work within the St. Georges Bay study area. There is an important question raised here. How does the institutional research within the study area benefit the economy. For example, there are a number of departments and programs at St. Francis Xavier University which conduct research relevant to the fisheries economics. What direct productive impact do these activities have on the fishery economy? There are limited connections between this research and the community. In view of this fact, current initiatives such as the Interdisciplinary Program are underway which aim at better integrating research with the needs of people involved in the fisheries.

The St. F.X. Extension Departments has a long history of working with community members on matters of cooperative economic organization. Their relationship to the Coastal Communities Network would seem, also, to represent a partnership with the community. The scarcity of published material addressing a scale relevant to the study area, which pertain to the subject on fisheries economics suggests

that there are opportunities for the formation of further productive partnerships between the communities and existing institutions.

SUMMARY

Fisheries economics is an important component of the study area economy. While the Department of Fisheries and Oceans collects and records fish landing volumes and values an important task remains to evaluate the impact of fishing and the resource brought to market on the economy of both the area and the province. Employment, within the broad definitions of the fisheries and related occupations, is significant. An improvement in the documentation of employment patterns could provide a better understanding of how much the sector contributes to such economic indicators as house hold income and generated tax revenue. While government policy regulation and legislation have impacts on the study area, little economic research has been conducted addressing the specific details and long term consequences at the study area level. When the government solicited public opinion in the wake of the "fisheries collapse" some communities expressed a desire to participate in fisheries work which would contribute to the protection and rejuvenation of fish and fish stocks. Some fisheries related research and development exists in the study area. Given public desire for contribution to an improvement in the fisheries and institutional character of the area, there an opportunity for increased community partnerships as the research and development sector matures.

Aquaculture and economics

Published material specific to the economics of aquaculture in the St. Georges Bay study area does not exist. However, there has been a number of academic papers, industry publications and government documents produced which are relevant to the study area. Overall, in the province of Nova Scotia, economic study has not kept pace with the actual economic activity of aquaculture operators. The production of material by the government follows a pattern of re-action. A

common starting point has been the notion typified by editorial comments made in the April, 1996 issue of the Nova Scotia Business Journal. "With decline of the commercial fishery over the past several years, aquaculture is considered to be a viable alternative for coastal communities to generate jobs and new wealth" (Anonymous, 1996c)

Aquaculture Development Strategy

In 1993, the same year as a moratorium on cod came into effect, that the provincial government set about to develop an "aquaculture development strategy" The finished product was intended to be, "...a document which sets out two primary goals : 1. to develop a economic and regulatory environment in which aquaculture can flourish, and 2. to establish strict guidelines which will ensure environmental integrity is maintained." (Anonymous, 1996c). The document Aquaculture Development Strategy has not been acquired or reviewed here.

A Revised Act

In February of 1996 a discussion draft for a revised provincial fisheries act was released. In its support for aquaculture the draft went as far as to recommend that the Department of Fisheries be called "Fisheries" and "Aquaculture" The revised "Fisheries and Coastal Resource Act" came into being later in 1996. The Act not only sets out the terms, conditions and guidelines for resource management, it also attempts to include "provisions" aimed at addressing broader topics, including the initiation of economic study and the amelioration of community concerns.

Aquaculture and the Greater Community

There has been a history of conflict between different members within communities where applications for aquaculture licenses are made. There are always many different expressions of interest. Perhaps foremost among these concerns is the, "Privatization of the commons" (Baily, 1995). Coastal bodies of water such as bays and harbours have been popularly viewed

as property common to all people in the community. In order for a private aquaculture operator to carry out their occupation they must hold licensed rights to the water they use. This issue, however, is only a starting point. As John Phyne puts it in (Baily, 1995), "The conflict over aquaculture has far reaching implications for the residents of coastal communities." He also expresses a passing concern about who has control over the invested capital and their commitment to the community, and then goes on to say that, "...participatory co-management is a pressing need for the members of coastal communities." While not necessarily what this author had it mind, some steps in direction of co-management have been made.

Regional Aquaculture Development Advisory Committees

The Nova Scotia Fisheries and Coastal Resources Act has optional provision for community participation. As a result there are now a number of "Regional Aquaculture Development Advisory Committees" (RADAC) in existence. They were formed, "In an effort to facilitate economic development while simultaneously providing information to the local area, the concept of community-based decision making was initiated" (Anonymous, 1996c). This expression of purposes provide opportunity for a degree of community participation. In the end decisions regarding the issue of aquaculture licenses rest with the Fisheries and Aquaculture minister and his office The Fisheries and Coastal Resources Act states that the RADAC recommendations "may" be acted upon. "The idea was to establish a way for the Department of Fisheries and Aquaculture to receive advice from affected communities on aquaculture development" (Anonymous, 1996c). The process of determining how these committees work and what role they play in the decision making is ongoing. The people involved are not paid. They volunteer out of an expression of interest within the community. Ultimately, "The goal is for this approach to help screen applications while ensuring local support and awareness of aquaculture projects" (Anonymous, 1996c).

There is currently no RADAC in the Antigonish County area. The existence and status of an Inverness RADAC county is unknown.

Published Economic Studies

Cold-Water Aquaculture in Atlantic Canada is a text produced by The Canadian Institute for regional Development which contains a section which addresses economic, social and environmental issues. This text has not been reviewed.

Nova Scotia Aquaculture: Comparative Analysis of Development Issues and Species Economic Potential is a 1998 report produced by Gardner Pinfold consulting Economists for the Nova Scotia Department of Fisheries and Aquaculture. This document has not been reviewed. However, John Odenthal of the Nova Scotia Department Economic Development and Tourism states in his summary of the study, "...the study implies that current expectations about the economically sustainable size and scope of aquaculture in NS may be unrealistic." He also says, without identification, that there are some important policy implications. This report should be reviewed in context to the St. Georges Bay study area. In the Aquaculture, Supplement to the August 1997 issue of the Nova Scotia Business Journal comments pertaining to economic issues are made without qualification. Marli MacNeil, president of the Nova Scotia Aquaculture Association, states that, "The association estimates that with every direct job created in finfish aquaculture, one job is created in related spinoff industry. Every 10 jobs created in shellfish aquaculture creates 6 spinoff jobs."

The spinoff estimates provided here, without information regarding source, are followed by

a number of additional articles giving brief review of: fish food production, underwater camera systems, equipment, research and educational "markets" The 1995-96 ACOA Roundtables Initiative, Roundtables Report summarizes roundtable discussions pertaining to the current state of Research and Development. Some points are raised regarding the need to address R&D funding. The specific relationship between R&D and economic environment is not discussed (Anonymous, 1996e).

Aquaculture Statistics

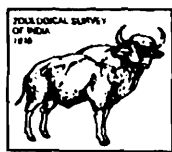
Department of Fisheries and Aquaculture statistical record of the value of aquaculture production at the county level do not represent an accurate account of activity for the study area. The record of production has been combined for 3 species. The only county for which this information may be of some use would be Antigonish. The other data include significant aquaculture operations in Inverness County which are outside of the St. Georges Bay study area.

Access to Aquaculture Information

With reference to the Nova Scotia Fisheries and Coastal Resources Act 1996, Part II Administration, section eight, sub-section three, "(3) Subject to the *Freedom of Information and Protection of Privacy Act*,

(a) all information under the control of the Department is accessible to the public; and

(b) the Minister shall ensure that information under the control of the Department is shared with other government departments and agencies. 1996, c. 25, s 8."



IMPACT OF TSUNAMI ON MARINE FISH PRODUCTION IN ANDAMAN AND NICOBAR WATERS AND MEASURES FOR SUSTAINABLE FISHERY

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Fishery Survey of India, Port Blair

INTRODUCTION

The Andaman and Nicobar group of Islands are located in the southern Bay of Bengal between the Latitude 06°45' N & 13°12'E and Longitude 92°12'E & 93°53'E. There are about 572 Islands out of which 38 are inhabited. The total coastline of A & N Island group is 1912 km which is about 1/4th of total coastline of India. The Exclusive Economic Zone (EEZ) around the Islands encompasses an area of 0.6 million sq. km forming about 30 per cent of the Indian EEZ. As per the latest estimated annual exploitable stock by Fishery Survey of India, Andaman and Nicobar waters has 1.48 lakh tones of fish which comprises of 32,000 tons of demersal fishes, 56,000 tons of pelagic fishes and about 60,000 tons of oceanic resources. More than 90 per cent population of the Islands consumes fish. About 25,000 of the local inhabitants either or partially depend on the fisheries sector for livelihood. Fishery Survey of India conducted the marine fisheries census in this Island during 2005 and reported that the total fishermen population in this Island is about 15,320 and they reside in 97 fishing villages with 3,274 fishermen house hold in this emerald group of Islands. Due to the vast scope and high potential, fishery sector is recognized as a thrust area after forestry for the development of the Island. The natural

calamity "Tsunami" which ravaged the Island groups caused severe damage to the life and property of the Islanders and the worst hit group was the fishermen as they stay near to the coastal area. The annual marine fish production of Andaman and Nicobar Island varies between 8,635 tons in 2005 to 30,636 tons in 2003 during last six years (Anon, 2006) which indicate that before Tsunami the landing was at its peak and after Tsunami the catch has declined drastically. The present paper deals with the impact of Tsunami on Marine fish production and the measures for revival of the industry.

MATERIALS AND METHODS

For the above study the data on the fishermen, fishing crafts and gears, and fishery infrastructure before and after tsunami was analyzed. The fish landing data before and after the tsunami was also analyzed for the above study. The above data was collected from the A & N administration. The oceanic fishery resources data collected by the vessel MFV Blue Marlin for the period 2003-2006 was utilized to study the seasonal abundance and distribution of various oceanic species. The study was carried out for the Andaman & Nicobar Sectors. Sector I is Andaman Waters (Lat 10°- Lat 15°N) and Sector II, Nicobar Waters (Lat 05°-Lat 10°N).

RESULTS AND DISCUSSION

Status before Tsunami

Fishing in the Island is mainly artisanal. About 4,000 active marine fishers used about 1,300 traditional fishing crafts and 523 motorized crafts before Tsunami. The catches brought from sea are landed in 57 fish landing centers which were scattered through out the Island groups. The major fishing gears used were gill nets, hand lines, long lines, cast nets, beach seines, trammel net and anchor net etc. The main species, which contributes to the total landings are Sardines, Carangids, Perches, Silver bellies, Mackerels, coastal tunas etc. The fish landed are basically consumed fresh and in dried form. From the infrastructure point of view it is seen that 3 ice plants, one each at Port Blair, Hutbay and Campbell Bay, 5 cold storages one each at Hutbay, Campbell Bay and 3 at Port Blair and one ice plant and one cold storage were under construction at Rangat. The fish markets were constructed by the Department of Fisheries in various places for domestic purpose.

The fishing units in operation before Tsunami was about 523 motorized crafts and 1,334 country crafts. About 2,348 Nos. of gill nets, 2,101 Nos. of cast net, 11,381 Nos. of hooks and lines and 98 other gears were in operation before Tsunami. The above number of fishing units landed a catch of 26,920 tons of fish during 2004 and 30,636 tons in 2003.

The Fishery Survey of India, Port Blair, which conducts tuna long line operation in Andaman and Nicobar EEZ registered hooking rate of 0.52% in Nicobar waters and 0.89 per cent in Andaman waters before Tsunami. It is evident from Table 1 that though comparatively very less effort was put in Nicobar waters than Andaman waters the hooking rate for all fishes is quite encouraging in Nicobar waters. The hooking rate of Yellow fin tuna is 0.17 per cent: Shark (0.2 per cent), Sailfish (0.08 per cent), Marlin (0.02 per cent), Skipjack tuna (0.01 per cent) and Others (0.04 per cent); Where as in Andaman waters the hooking rate of shark is 0.31 per cent followed by Yellow fin tuna (0.27 per cent) Others (0.18 per cent), Sword fish (0.08 per cent), Skipjack tuna (0.02 per cent), Sail fish and Big eye tuna (0.01-per cent each) and Marlin (0.006 per cent). But while reviewing the data on catch per unit effort (CPUE) and resource distribution during 1989 to 2002 it is clear that the overall hooking recorded in the survey was 1.85 per cent. Shark yielded the highest hooking rate of 0.83 per cent followed by Yellow fin tuna (0.62 per cent) and Sailfish (0.10 per cent). High degree of annual variability was observed in the catch indices with the highest hooking rate of 3.48 per cent during 1994. A decline in hooking rate was observed after the mid nineties and reached a lowest level of 0.62 per cent in the year 2000. Subsequently a marginal increase in catch rate was observed during 2001 and 2002. Seasonal changes in resources

Table 1. Sector wise and species wise hooking rate obtained during survey

AREA	Pre/Post tsunami	Effort	Agg.	YFT	SKJ	BET	SAI	SWO	MAR	SHK	OTH
Nicobar waters (5°-10° N)	Pre tsunami (2003 & 2004)	18750	0.52	0.17	0.01		0.08	-	0.02	0.2	0.04
	After tsunami (2005 & 2006)	21875	0.59	0.19	0.009	0.05	0.03	0.05	0.009	0.23	0.04
Andaman waters (10°-15° N)	Pre tsunami (2003 & 2004)	48525	0.89	0.27	0.02	0.01	0.08	0.01	0.006	0.31	0.18
	After tsunami (2005 & 2006)	72,575	0.86	0.41	0.025	0.005	0.06	0.015	0.015	0.23	0.010

YFT : Yellow fin tuna, BET : Big eye tuna, SKJ; Skip jack tuna, MAR : Marlin, SAI : Sail fish, SWO : Sword fish, SHK: Shark

availability was found to be very pronounced with high hooking rates (2.2 to 2.6 per cent) during November to February. The variability with respect to the abundance of different species is given in Table 2. Yellow fin tuna was registered highest hooking rate of 1.32 per cent in January and two different periods, December-February and June-July were found to yield relatively higher hooking rates. These species formed over 50 per cent of total catch during January and June.

According to John and Somavanshi (2000), Andaman waters were found to yield higher abundance index of Yellow fin tuna. The availability of Big eye tuna was found to be relatively higher in Nicobar waters. While analyzing the data for the period 2003-2006, latitude wise an aggregate hooking rate of 0.795 per cent was obtained which indicates that the resources has taken a declining trend.

Impacts of Tsunami

The Tsunami of 26th December 2004 which was triggered by an earthquake with a Richter

scale magnitude of about 9.3 in Indonesia created havoc in Andaman and Nicobar Islands system. The epicenter of the earthquake was at 3.7°N and 95°E at a distance of 30 km off the Island of Sumatra in Indonesia, which is only 163 km away from Great Nicobar, the Southern most Island of the Archipelago. The killer waves swooped all the fauna, flora, people, dwellings and establishments all along the coastline or its way. The earthquake occurred along the plate boundary marked subduction zone between Indian and Burmese plate. As a result of the movement of these tectonic plates, the Andaman and Nicobar Islands have experienced uplift and subsidence at different places (Jain *et al.*, 2005). It is quite evident that among Andaman and Middle Andaman areas were uplifted whereas South of South Andaman to Nicobar Islands were submerged from one to three meters.

The killer waves inflicted immense damage to everything that came on its invasion path by way of flooding. The calamity struck every fisher household in one way or the other. Apart

Table 2. Month-wise hooking rate obtained in tuna long line survey in Andaman & Nicobar waters by the vessels *Yellow fin* and *Blue Marlin* : 1989-2002

Month	Hooks operated	Hooks rate								
		Agg.	YFT	BET	SKJ	SAI	SWO	MAR	SHK	OTH
January	36070	2.600	1.322	0.003	0.014	0.061	0.103	0.014	0.970	0.114
February	48255	2.309	0.736	0.002	0.031	0.035	0.091	0.008	1.274	0.131
March	83525	1.905	0.595	0.007	0.010	0.037	0.075	0.000	0.876	0.304
April	55600	1.656	0.608	0.004	0.027	0.101	0.068	0.014	0.626	0.209
May	70745	1.356	0.649	0.001	0.040	0.048	0.085	0.013	0.431	0.089
June	65417	1.602	0.807	0.002	0.038	0.057	0.066	0.008	0.553	0.072
July	55795	1.833	0.778	0.000	0.043	0.073	0.124	0.004	0.699	0.113
August	74755	1.481	0.643	0.000	0.020	0.049	0.094	0.007	0.578	0.090
September	47390	0.937	0.236	0.004	0.006	0.032	0.089	0.019	0.409	0.141
October	55530	1.821	0.267	0.005	0.020	0.119	0.090	0.016	1.136	0.167
November	73115	2.212	0.261	0.001	0.012	0.085	0.182	0.004	1.457	0.209
December	60215	2.297	0.747	0.000	0.051	0.060	0.149	0.023	1.036	0.229
Total	726412	1.852	0.615	0.002	0.026	0.042	0.102	0.010	0.833	0.222

YFT: Yellow fin tuna, BET: Big eye tuna, SKJ; Skip jack tuna, MAR: Marlin, SAI: Sail fish, SWO: Sword fish, SHK: Shark

from the fishers and fish farmers, thousands of people depending directly or indirectly on the activities have been hard hit. The impact of the killer waves was more evident in the coastal areas within 0.5 kms from shoreline and to a lesser extent between 0.2-2 km. A change of shore topography resulting in submersion of Islands is reported. The maximum damage was done in the Southern most group of Islands. As per the Government report, about 10,000 houses were fully damaged and more than 3,500 people lost their lives. Most jetties in the region were severely hit. The total estimated loss to the fishery sector was 27 crores (Digal, 2006). The worst affected are the coastal population especially the Nicobar district including Little Andaman. Several fishers became homeless due to high tidal waves, which washed off their huts. Many lost their fishing inputs such as fishing crafts, fishing gears, engines, iceboxes etc. incapacitating them for fishing. However, the detailed survey report immediately after Tsunami presented by the Department of Fisheries regarding the loss incurred by the fishers are as follows.

- A. Totally damaged fishing vessels :
 - a. Local made dinghies without engine-735
 - b. Local made dinghies with engine-400
- B. Partially damaged fishing vessels
 - a. Local made dinghies-582
 - b. Engine fitted boats-389
 - c. Mechanized boats-03
- C. Loss of fishing gear
 - a) Gill nets-669
 - b) Cast nets-164
 - c) Hook& line-433
 - d) Long line-79
 - e) Shore seine-04
 - f) Anchor nets-1,349
- D. Loss of equipment
 - a) 117 Nos. of fish vendors lost their equipments
- E. Loss of life
 - a) 69 fisher lost their life during Tsunami.

Issues of concern

The following were the issues of concerns at that point of time

- ★ Loss of life/ missing of fishers
- ★ Loss of property of fishers
- ★ Rehabilitation of fishers
- ★ Inundation of low lying coastal areas by sea water
- ★ Providing storage facility and required amount of ice to fishers as the cold storage and ice plants were severely affected due to Tsunami.

Post Tsunami scenario

Post Tsunami studies was conducted by Department of Ocean Development revealed that there is reduction of marine fish catches and damages to coral reef and fauna in Central and Middle Andamans. The major issues of concern in the post tsunami scenario are loss of life/missing fishers, loss of property of the fishers including fishing crafts, gears and other accessories, rehabilitation of fishers and restoration of fishing activities, inundation of low lying areas by sea water and providing facilities and required ice to fishers.

To meet the immediate loss and initial expenditure, an assistance of Rs.15.01/- Crores was approved for the fishery sector, which includes Rs.2.53/- Crores for construction of a cold storage. On the lines of package for the fishery sector on mainland it was agreed that the cost of country boats, the lowest category may be fully reimbursed including the high cost of transportation of the boats from the mainland where these are fabricated. Cheques of Rs.10, 000/- each was distributed for repair and replacement of fishing boats. For rehabilitation of fishers, Rs.21.05/- Crores under the RGRP package for Tsunami affected fishers was earmarked by Govt. of India, and assistance was extended to fishers for repairing and replacement of boats, gears etc. to restore normal fishing. A roadmap was also prepared by ICAR covering the multidisciplinary and environment friendly promotion of fisheries in the island. Fish landing centers, cold storages

and ice plants were planned to be constructed for supporting the fishing industry to come in a big way.

Many NGO's such as CASA, ACTION AID, OXFAM, CARITAS, IGSSS, VHAI, CARE INDIA, HCC etc. extended assistance to the fishers. Altogether 527 boats have been distributed to the fishers during these years after Tsunami. The fishing units such as crafts and gears have increased to mechanised boats (5 Nos.), motorised (1,279) and non motorised boats (1,524 Nos.) in 2006. In 2006, 4,287 Nos. of gill nets, 13 Nos. of shore seines, 8 Nos of Anchor nets 2,350 Nos. of cast nets and 15,750 Nos. of hooks and lines are being operated in Andaman and Nicobar Islands. When the fishing units have increased during 2005 and 2006 *i.e.* after Tsunami, similarly the production of fish has also gone up from 8,635 tons (2005) to 24,096 tons in 2006.

While analyzing species wise landing it is seen that landing of few species has increased drastically where as few species has shown declining trend. The Elasmobranch landing has increased to 2,227 tons than that of before Tsunami *i.e.* 395 tons in 2003 and 250 tons in 2004. Silver belly landing has also increased to 2,376 tons than that of 1,129 tons in 2004. Crab landing has increased to 565 tons, where as there is a declining trend in the landing of perches from 9,065 tons to 4,366 tons in 2006.

In the Demersal resources, Anchovies landing has increased from 1,556 ton in 2004 to 2,308 tons in 2006. Mackerel landing increased to 2000 tons in 2006 from 1,363 tons in 2004. Landing of neritic tuna has increased from 630 tons in 2004 to 2068 tons in 2006. whereas the carangid landing has drastically gone down to 1070 tons in 2006 from 3038 tons in 2004 and 4725 tons in 2003.

The data of oceanic tuna shown in Table 3 seems to be not realistic as in the month of January 2006 the vessel MFV Blue Marlin, itself landed a quantity of 3,000 Kg of tuna which is the second highest landing after January 2005. From FSI survey results it is evident that after Tsunami there is an increase in Yellow fin tuna

hooking rate both in Andaman and Nicobar waters *i.e.* 0.19 per cent in Nicobar and 0.14 per cent in Andaman waters compared to 0.17 per cent in Nicobar and 0.27 per cent in Andaman waters before Tsunami.

CONCLUSION

The tsunami had caused an increase in turbidity of sea water which reduced transparency. Less light penetration resulted in less productivity in the inter-tidal Zone. The force of Tsunami waves also resulted in uprooting of corals in many areas, habitat loss for many associated organisms and disturbance in breeding cycle, which resulted in less catch of edible shell fish and fin fishes. The waves, which brought fine sediments to the surface, remain suspended for some time. This increased the turbidity and also affected the respiration, and general physiology of many fin fishes, leading to asphyxiation and death. This has also affected the larval fish population leading to mass mortality. Thus the finfish recruits declined at a rapid rate. It is suggested to conduct studies on the nutrient influx in the coastal areas of Tsunami affected region.

Though Tsunami has declined the catch rate immediately, there is a great variation of fish composition due to change in habitat which will take time to stabilize. To conclude Tsunami followed by earthquake has directly affected the livelihood of about 10,000 households with total population of about 50,000. There is damage to the personal assets of the fishers such as boats, gears and houses due to which the fish catch has drastically declined vis-a-vis catch in corresponding months of the previous years. However due to repair and replacement of damaged boats it is steadily improving and the catch in December 2005 is about 92 per cent of the catch in December 2004. ICAR's Road Map for fisheries covers modernization of fishery activities which includes capture and culture of fisheries in the sea fishery resource, value addition, marketing and export, Employment awareness and up gradation of fishery infrastructure. A prospective plan with a budget outlay of Rs. 410 crores has been

Table 3. The species wise landing before and after Tsunami (in tons)

	Species	2003	2004	2005	2006
Pelagic	Elasmobranchs	395	250	71	2227
	Silverbellies	662	1129	217	2376
	Perches	9065	9303	3019	4366
	Pomfrets	181	319	196	309
	Catfish	126	454	32	254
	Threadfins	30	12	07	18
	Clupeids	63	40	30	-
	Penaeid shrimps	661	273	108	550
	Crabs	460	386	163	565
	Deep sea lobster	27	35	37	-
	Others	2978	1285	695	1158
Demersal	Anchovies	976	1556	450	2308
	Sardines	3696	2906	539	2078
	Hilsa	180	292	74	117
	Chirocentridae	47	-	-	5
	Mackerel	1128	1363	314	2000
	Other carangids	4725	3038	1154	1070
	Ribbon fish	62	64	44	2
	Half beaks & Full beaks	70	87	16	125
	Barracuda	1277	870	376	514
	Mulletts	1196	1147	290	810
	Seer fish	1842	915	374	1150
	Neritic tuna	419	630	133	2068
	Others	-	384	189	15
Oceanic	Yellow fin tuna	61	07	20	2
	Skipjack tuna	55	06	17	1
	Big eye tuna	01	-	01	-
	Bill fishes	253	169	69	1
	Sharks	-	-	-	7

submitted to Govt. of India by the A & N Administration which is to be implemented within 3 years which covers creation of 14 fish landing centers, 2 major fishing harbours, creation of infrastructures like boat building and repairs. Feasibility and Environment Impact Assessment plan intends to harvest over 50 per cent of the estimated fishing potential in a period of 5 years. This also covers to develop

deep sea and oceanic fisheries by promoting joint ventures and private investing and separate resources survey for the resources like reef fishes, Groupers, Snappers, rabbit fish, lobsters, shrimps, bivalves, sharks, sea cucumbers and seaweeds.

The increasing trend of fish landing is a good sign for fishing industry and the result after

Tsunami indicates that there is a severe damage of fish habitats in the Southern group of islands, so the inhabited fish has shifted their spawning ground and habitat to the Northern group of islands of the Island groups where the damage due to Tsunami is less. However keeping in view, the sustainable fishery in the days to come, a few recommendations are also made in this paper.

- ★ Restoration and protection of inter-tidal region will secure future food resources such as coastal fish population.
- ★ Regular mapping of coastal systems and identify areas for protection and sustainable management.

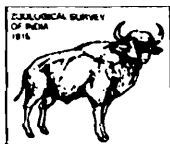
- ★ Regular monitoring to assess the changes and recovery in fish population.
- ★ Species wise resource estimation in the coastal areas.
- ★ Stringent conservation measures should be taken up to protect the damaged habitats from further disturbances.

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A PRELIMINARY SURVEY ON THE SUBTERRANEAN PISCINE DIVERSITY IN THRISSUR DISTRICT, KERALA, INDIA

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INTRODUCTION

The subterranean environment comprises the network of interconnected subsoil spaces, with variable sizes, filled with air or water. Subterranean aquifers and streams are sometimes found open to the epigeal realm through springs. Fishes are among the most conspicuous subterranean organisms throughout the world. More than 85 subterranean fish species belonging to 18 families and nine orders have been recorded world wide (Trajano, 2003).

A detailed survey is presently not practical to explore the faunal diversity and status of the less studied subterranean aquatic habitats, mainly due to the inaccessibility to such a cryptic habitat. In the Indian context all fishes presently described as subterranean was collected from deep wells that may have contained subterranean fauna accidentally trapped through springs. Ever since the discovery of *Horaglanis krishnai* (Menon) much interest has been taken by many workers to these 'well dwellers'. In 2000 Subash Babu and Nayar (2004) reported another species of *Horaglanis* from Trichur District of Kerala state. Besides catfishes, three species of the Synbranchiform Genus *Monopterus* were also reported as 'cavernicoles' from wells in Kerala

state namely *M. eapeni* Talwar (1991), *M. roseni* Bailey and Gans (1998) and *M. digressus* Gopi (2002).

In June 2007 Animal Behaviour and Wetland Research laboratory, an extension of the Research and Post Graduate Department of Zoology, Christ college Irinjalakuda, Kerala had reported an hitherto unreported genus and species of Siluriform catfish from a newly dug domestic well in Thrissur district, Kerala (The New Sunday Express, June 17, 2007; Malayala Manorama Thrissur Edn, June 16, 2007). The fish which in fact was first collected on May 22nd 2007 was identified as an unreported genus in subsequent studies. Three specimens of the unidentified fish were collected from the well which has 5.5 meter depth. In the following days when the well has been deepened to 6 meter, 16 live fishes were also collected that came in to the well through the water from subterranean spring. These fishes showed complete absence of dorsal fin, presence of four pairs of barbels and an anal fin which is completely confluent with the caudal fin. Following the collection of this obviously new Genus of fishes from a cryptic habitat, surveys had been conducted that recorded two undescribed species of Siluriform fishes, and few specimens of a Synbranchiform fish namely *Monopterus digressus* (Gopi, 2002). The present

paper deals with the results of a fish survey done along valley segments and associated springs in Thrissur district. It also tries to enumerate some of the traits peculiar to these fishes that may be considered as adaptation to their original habitat situations.

MATERIALS AND METHODS

Areas which are suspected of good ground recharge of water from natural springs were identified by analyzing satellite imageries available online (www.wikimapia.org). Knowledge on geomorphology also helped us to find out suitable places for sample collection and also to locate the most suitable well for study. Field visits were done fortnightly on a regular basis during the year 2007-2008. In addition to the voluntary surveys made from part of the researchers, field visit and sample collection were also done whenever we get informed about the presence of some fishes in well water used for domestic purposes, by the people in and around the study area. Whenever possible the fishes were collected alive and transported to the laboratory where they can be kept alive in good condition. Dead fishes were preserved in 7% formalin solution. Undescribed materials were deposited in the lab facility for thorough studies or deposited in the Zoological Survey of India, Calicut and Chennai. Morphometric and meristic data are procured as described by Jayaram (1999). Identification is based primarily on Jayaram (1999, 2006) and Talwar and Jhingran (1991). In case of Un-reported fishes we have also referred Burgess (1989). Help from expert fish taxonomists were also solicited in this regard (See Results and Acknowledgements). Morphological features such as fin ray counts of live animals were taken from photographs made at high shutter speeds in a zoom-macro facilitated digital camera. A transmitted light stereo microscope was used for detailed study of fin structures. Analysis of adaptive characteristics were done by examining specific characters such as pigmentation, position of eyes, fullness of stomach, type of food materials upon which the fish survives in Laboratory etc. Feeding habits and foraging behaviour was

studied by direct observation on fishes and by providing them with food materials in controlled environments.

RESULTS

The locations from where subterranean fishes collected are provided in the satellite image (Fig. 1). Red mark represents the collection site of new genus of catfish, and the yellow marks indicate the collection sites of *Monopterus digressus*.

Brief description of the species collected from subterranean stream outlets

Kryptoglanis shajii

(Siluriformes : Incertae sedis))

(Figs. 2 & 3)

Nineteen live specimens of a catfish of a new genus were collected. The absence of dorsal fin, presence of relatively small subcutaneous eyes, long based anal fin which is confluent with the caudal fin, superior mouth and four pairs of barbels are the distinguishing characteristics of this genus. Largest of these fish had a total length of 62.9 mm. This prospective new genus can be distinguished from all other genera of Siluridae by the presence of 4 (vs. 3) pairs of barbels, in addition to the combination of the following characters: anal fin with a long base, confluent with the caudal fin; caudal fin rays 4-7; subcutaneous eyes; a superior mouth with a distinctly projecting lower jaw; pectoral fins fan-like, lacking any hardened elements; and the absence of a dorsal fin. Preserved specimens of this fish were deposited in the Zoological Survey of India, Southern Regional Station, Chennai; Zoological Survey of India Calicut and Zoology Museum Christ College Irinjalakuda, Kerala. Live specimens are now kept in the animal care facility of Animal Behaviour and Wetland Research Laboratory Christ College Irinjalakuda, Kerala. Specimens were also examined by fish taxonomists of NBFGR Cochin Unit, CMFRI Cochin, ZSI Calicut and ZSI Chennai. Description of this new genus was published in April, 2011.

***Monopterus digressus* (Gopi, 2002)**
(Figs. 4 & 5)

Five specimens of a Synbranchid eel were collected from three different wells all located at the slopes of hilly terrain in the South eastern part of the Thrissur District, each spanning a distance of three kilometers. These wells are found to be protected by high side walls which prevent any surface inflow or out flow to and from the well. The worm like eels are blood red colour when collected, during cleaning of the well. The fishes may have reached the well through water coming from subsoil springs, while draining the well using a pump. They were identified as *Monopterus digressus* by Gopi, K. C of Zoological Survey of India Western Ghats Field Research Station Calicut. Largest specimen collected has 186 mm TL. Their body was slim, naked, sub cylindrical, elongate and cord or thread-like. Tail extremity well compressed and tapering with rudimentary dorsal and anal fin folds confluent at the caudal tip.

Foraging behaviour

Feeding in the new genus of fish was observed to be associated with tactile perception. They took the food material while swimming below the surface of water column. While swimming, barbels help them to detect the food items. In addition to tactile stimulation from barbels it is assumed that they use chemosensory ability to locate the food, because, whenever extracts from the food materials were added to water, resting fishes soon came out from their hides and exhibited foraging movements. In laboratory, these fishes were fed by different types of feeds. *Artemia* nauplii, fish larvae produced by induced breeding of *Puntius parrah*, *P. sarana* and *Anabas testudineus* were used for providing live food. But earth worm minces was found to be suitable for sustainable feeding because, the availability of fish larvae is limited. In addition to the live feed, minces of beef and fish flesh were also consumed by the fishes. It is found that they feed voraciously after a 24 hour break in regular feeding.

Monopterus digressus feeds on *artemia* nauplii, and finely minced tail ends of small sized earth worms. If a choice is given they showed preference to *artemia* nauplii.

Notes on Troglomorphic traits

Absence of pigmentation

In the new genus of Siluriform fish, body was reddish brown at the anterior part and the posterior part was translucent, when newly collected. But this colouration is not attributed to the skin of fishes which is responsible for spectacular colouration in epigeal fishes. The reddish brown colouration is in part due to the translucent nature of skin through which reflects the colour of muscles and internal organs. This kind of red colouration was also reported in many species of subterranean fishes including *Horaglanis*. It is observed that the fishes became darker a few hours after collection. Figure shows the live colouration of one of the species soon after collection (Fig. 1).

In *Monopterus digressus* the entire body was red in colour except for a yellowish tinge at the caudal region (Fig. 4). Two-three days after collection, live fishes became darker bodied.

Photophobic behaviour

In the new genus of catfish, eyes are subcutaneous and the eye diameter is only 10 per cent in head length. Whenever the room is slightly illuminated for observing the activity of the fish, it was found that they soon disappear into the crevices of laterite provided in the aquarium. However they will soon surface when food items (minced earth worm/ *artemia* nauplii/ larvae of cyprinid fishes) were introduced in to the water. It was found that these catfishes depend on tactile senses to catch the prey. The fish takes the food only when it touches the food with barbels while moving around the place where food materials were introduced. Even in close proximity, fishes lose their prey, if their barbels did not touch the food material. *Monopterus digressus* has no externally visible eyes.

Distinctive Cephalic Sensory Pores

In the new genus of catfish, head and anterior part of the body bears an array of sensory pores in addition to the lateral line system. Pattern of distribution of sensory pores on the head of one of the new species is shown in the figure (Fig. 2). These sensory pores are well distinguishable in live fishes and have a greater proportionate diameter in the total surface area of head than which is seen in other catfish species collected from epigeal waters of the same locality. *Monopterus digressus* also possess well distinguishable cephalic sensory pores. A detailed description is provided by Gopi, 2002.

Absence of spines/fins

In both of the studied genera of subterranean fish, reduction or complete absence of fin structures and associated hardened elements (spines) were observed. These traits may prove to be adaptive in their natural habitat. In the new genus of catfish complete absence of dorsal fin is remarkable. Pectoral fin spines which are usually present in most of the Siluriform fishes are replaced by a soft un-branched element, in the new genus.

In *Monopterus digressus* miniature (2-3 mm) caudal fin represents the retrogression in locomotory structures. Skin devoid of any scales and absence of any structures that may offer resistance during movement through narrow crevices and subsoil spaces can also be considered to be adaptive to the subterranean environment.

Cutaneous Respiration

Evidences are available to prove both genera of subterranean fishes can withstand low oxygen levels in water. Fishes of the new genus are quite capable of spending long time in scanty amounts of water that is only enough to moisten their skin. Microscopic examination of their delicate body parts such as anal fin showed that they are highly vascularised. There are no accessory respiratory air sacs in their body. But *Monopterus digressus* has supra-branchial air chambers and the fish was

observed to be spending a long time on surfaces which are just above the water level and were able to take short trips through moist surfaces. They were also found keeping their heads elevated from the water surface (Fig. 5) and periodically opening their mouth.

DISCUSSION

Even though the survey conducted was not exhaustive and most of the collections made, were in fact from information provided from people who reside in selected study areas, the study indicates the presence of a less understood subterranean habitat in peninsular India. The primary work on subterranean ichthyofauna of this area is on *Horaglanis krishnai* from wells in Kottayam district of Kerala. *Monopterus eapeni* was also reported from Kottayam district. Another probably subterranean species *Monopterus roseni* (also a blind fish) was reported from Periyam village in Northern Kerala (N 10°38' E 76°22'), 102 Km North West of Kottayam (Baily and Gans, 1998). The Blind catfish *Horaglanis alikunhi* (SubahBabu and Nair, 2004) was reported from Parappukkara village in Thrissur district central Kerala. All these reports indicate the presence of an understudied habitat associated with the biodiversity hot spot of Western Ghats. Further it was also found that all the studied areas are under the pressure of active urbanization, with streams resulting from subterranean springs being permanently filled-off and a number of artificial wells are increasing at a faster pace with up to 8 wells per hectare which can form traps for these fish species.

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Plate 1

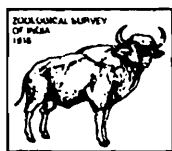


Fig. 1

Plate 2



Figs. 2-5. A preliminary survey on the subterranean piscine diversity...



NUTRITION STATUS OF SOME TRASH FISHES

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INTRODUCTION

The trash fishes vary from country to country and the availability is varied depends on both season and location. In India the estimated quantity of by catch discarded by the east coast trawlers alone are 1,00,000 - 1,30,000 tones during the year 1998 and about 10-12 per cent of the discards were used for retail market, which were found to be of a slightly high value, the rest were normally sold for feed use (Edward *et al.*, 2004). These waste fishes are being utilized to prepare fishmeal and as ideal raw material for the preparation of cattle feed (Chaya *et al.*, 1998) and other by products. The demand for trash fish increases on a number of fronts in the aquaculture sector. The main problem in aquaculture are the provision for supplementary feed for fulfillment of nutritional requirement, and for solving this problem trash fish plays a very important role. Moreover aquaculture farms tend to demand higher quality trash fish, which could be used instead for direct human consumption, all over the world. In India usually the trash fishes are discarded along the east coast trawlers since; there is not much knowledge about the nutritional status of the trash fishes. To know the nutritional values of the trash fishes, biochemical studies are very important. So studies on biochemical composition of trash fishes are very much the need of the hour, to

stop the wastage and utilize these trash fishes. So in the present study, biochemical composition (Protein, carbohydrate and moisture) including fatty acids were studied from some of the major trash fishes such as *S. commersoni*, *T. mystax* and *L. dussumieri* (*Stelophorous commerson*, *Thrya mystax* and *Leiognathus dussumieri*).

MATERIALS AND METHODS

The trash fishes were collected from the Parangipettai landing centre and the species were identified with the help of "FAO" (Food and Agriculture Organization) species identification sheets. After confirmation, the specimens were washed thoroughly with seawater then again washed with running tap water. The moisture content of fish tissue was estimated gravimetrically. The weighed fresh muscle tissue was dried in a hot air oven at 60° C for 24 h and reweighed. The difference in weight was taken as the moisture content of the tissue. The protein and carbohydrate content were estimated by adopting the standard method of Raymont *et al.*, (1964) and Dubois *et al.*, (1956) respectively. To know the moisture content, 1g of fresh tissue was oven dried at a constant temperature of 105°C for 24 hrs (AOAC, 1990). The loss of weight was taken as moisture content. For fatty acid analysis the samples were homogenized with chloroform:

methanol (2:1/v/v) mixture and they were extracted using the method of Bligh and Dyer (1959). After fat extraction they were esterified with 1 per cent H_2SO_4 and fatty acid methyl esters were prepared by following the procedure of AOAC (1995). The identification and quantification of fatty acid was done using a gas chromatography (Hewlett Packard, 5890).

RESULTS

In the present study, protein, carbohydrate, moisture and fatty acids in various trash fish (*S. commersoni*, *T. mystax* and *L. dussumieri*) are given in Fig. 1.

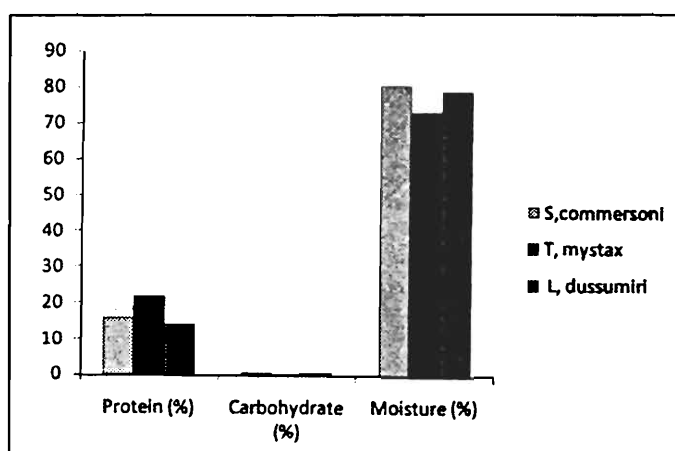


Fig. 1. Biochemical composition of various trash fishes

The protein level was found to be more 21.79 percent in the species *T. mystax*. The carbohydrate level was higher 0.48 percent in *L. dussumieri* than that of other species, which

have been evaluated in the present study. Among the three species the moisture level was found higher in *S. commersoni*.

The saturated fatty acid of the three species *S. commersoni*, *T. mystax* and *L. dussumieri* are given in Table 1. The results shows that the total composition of saturated fatty acids was maximum as 45.37 percent in *L. dussumieri* followed by *T. mystax* (41.86%) and minimum was found *S. commersoni* (39.04%) respectively.

The monounsaturated fatty acids of the three species as *S. commersoni*, *T. mystax* and *L. dussumieri*, are given in Table 2. The result shows that the total composition of monounsaturated fatty acids were found to be higher in *L. dussumieri* as 10.63 per cent followed by *T. mystax* (9.51%) and *S. commersoni* (6.24%) the least compared to other species. Myristoleic acid was absent in *L. dussumieri*.

The polyunsaturated fatty acids also showed higher values (21.98%) in *L. dussumieri* and minimum values (2.48%) in *T. mystax*. Among 6 polyunsaturated fatty acid studied in the present study Elaidic acid was maximum (12.12%) in *L. dussumieri* and icosapentaenoic acid (0.25%) was minimum in *S. commersoni* (Table 3).

DISCUSSION

In the present paper the nutritional composition was studied in three different

Table 1. Saturated fatty acid composition in various trash fishes

Sl. No.	Fatty Acids	Position of the C-atoms	<i>S. commersoni</i> %	<i>T. mystax</i> %	<i>L. dussumieri</i> %
1	Undecylenic acid	C 11 : 0	...	0.95	1.11
2	Lauric acid	C 12 : 0	0.74	...	1.06
3	Tridecanoic acid	C 13 : 0	...	0.23	...
4	Myristic acid	C 14 : 0	2.15	9.81	10.22
5	Pentadecanoic acid	C 15 : 0	1.82	1.27	1.15
6	Palmitic acid	C 16 : 0	33.22	27.65	29.42
7	Heptadeanoic acid	C 17 : 0	1.11	1.21	2.09
8	Heneicosanoic acid	C 21 : 0	...	0.42	0.32
9	Behenic acid	C 22 : 0	...	0.32	...
	Total		39.04	41.86	45.37

Table 2. Monounsaturated fatty acid composition in various trash fishes

Sl. No.	Fatty Acids	Position of the C-atoms	<i>S. commersoni</i> %	<i>T. mystax</i> %	<i>L. dussumieri</i> %
1	Myristoleic acid	C 14 : 1	2.1	0.43	...
2	Palmitoleic acid	C 16 : 1	3.28	7.98	9.82
3	Eicosenoic acid	C 20 : 1	0.33	0.33	0.29
4	Nervonic acid	C 20 : In-9	0.49	0.77	0.52
	Total		6.24	9.51	10.63

Table 3. Polyunsaturated fatty acid composition in various trash fishes

Sl. No.	Fatty Acids	Position of the C-atoms	<i>S. commersoni</i> %	<i>T. mystax</i> %	<i>L. dussumieri</i> %
1	Elaidic acid	C 18:1	2.13	...	12.12
2	Linolelaidic acid	C 18:2	3.68		1.28
3	Linoleum acid	C 18:9	...	1.31	...
4	Linolenic acid	C 18:12,15		0.34	...
5	Arachidonic acid	C 20:4	8.58	0.93	8.58
6	Icosapentaenoic acid	C 24:1	0.25	0.26	
	Total		14.64	2.84	21.98

species of trash fishing such as *S. commersoni*, *T. mystax* and *L. dussumieri* collected from Parangipettai coastal water. To study the nutritional composition of any fish, at first their water content should be evaluated. A number of reports regarding the proximate composition of many trash fish is already available in Indian coastal water (Jayalaxmi 1987, Devadasan & Venkataraman 1978, Chaya *et al.*, 1998, Kavitha, 1998 and Kumar, 2006). The moisture constituents of *S. commersoni*, *T. mystax* and *L. dussumieri* were estimated as 80.40, 73.29 and 78.94 percent respectively. This result was almost similar to that of the earlier reports in various fishes (Manoharan, 1988; Kamal *et al.*, 1996 and Das *et al.*, 2004). The level of water content is more during the post monsoon seasons (Thomy, 2006), this is because of loss of energy for reproduction and migration, which will be compensated by drinking more water which leads to more water in the body tissue. The second major constituent of fish meal is protein and it is generally present in the range of 16 to 18 percent (Nair and Mathew, 2000). In the present study from the three major

freshfishes the protein range was 22 percent (Fig. 1). Our data on the chemical composition of *S. commersoni*, *T. mystax* and *L. dussumieri* were good in agreement with the literature of many other species of pelagic fishes by Shree Parvati (1994) from the Parangipettai coastal water. Thomy (2006) reported 30 to 36 per cent in *Auxis rochei* which is higher than the present result (15.72, 21.79 and 14.00%) but in *Hilsa illisa* the protein level was 16.18 per cent (Kamal *et al.*, 1996) which almost similar to the present results. In general the amount of protein in these fishes varies from reproductive stages of live and it also depends upon the habits (Thirunavukarasu, 2005). The protein content of fish varies widely depending on factors such as natural feeding habits, availability of feed, season spawning and migration (Nair and Mathew, 2000). Carbohydrate percentage of *S. commersoni*, *T. mystax*, *L. dussumieri* were 0.41, 0.40 and 0.48 and almost similar to previous reports (0.41 percent to 0.48 percent) on trash fish and various commercial fishes (Thomy, 2006). The carbohydrate level varies from species to species mainly due to the availability

of food, and feeding habitat of the species and seasonal distribution. On the other hand the carbohydrate percentage in trash fishes is very less in food fishes or commercially important fishes (Saraswathi, 1999; Nair and Methew, 2000). The marine animals are richest source of PUFA and HUFAs. Thus it appears that fish exhibit considerable differences in these chemical compositions among species and they also vary significantly in response to tropic conditions. It includes oil containing high percentage of PUFA, which are useful for suppressing the plasma cholesterol level. Fish and other marine life are a rich sources of a special class of polyunsaturated fatty acids known as omega-3 or n-3 fatty acids. The fatty acids of the trash fishes like *S. commersoni*, *T. mystax* and *L. dussumieri* has not been previously analyzed in Parangipettai coastal waters. The total amount of fatty acids from these three species were about 59.92, 54.21 and 77.98 (Table 1, 2 and 3) respectively. Among these three species *L. dussumieri* contained more fatty acids than the other species. Within the fatty acid profile the SFA (Saturated fatty acid) percentage was more which constitute about 40 percent (Table 2). These results are in agreement with the results of previous authors in other marine fishes (Das *et al.*, 2001 and

Thomy, 2006). The fatty acid is very much necessary for the cultivable organisms (Kumarchandan, 2006) some fatty acids are not synthesized in the body but it is very much important. So, in our present investigation shows the important nutritive value of the trash fishes. These trash fishes can be act as a great ingredient and production of other biochemical compounds. The level of protein was found in a considerable amount in *S. commersoni*, *T. mystax* and *L. dussumieri*, which will be useful to prepare the fishmeal. The protein level is almost similar to that of commercial species and it is also recommended as edible if the species is of marketable size. But the case of fatty acids the percentage of the saturated fatty acids and it is more lead them as low taste and not preferred by the people. So this might be the reason for their market value getting down.

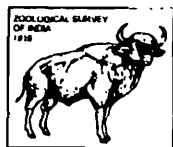
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IMPACT OF AQUATIC MACROPHYTES AND RIVER CONNECTIVITY ON FISH BIODIVERSITY OF FLOODPLAIN WETLANDS OF DHUBRI DISTRICT OF ASSAM, INDIA

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INTRODUCTION

The state of Assam is blessed with numerous floodplain wetlands covering an area of approximately 1 lakh ha. Most of these wetlands are ox-bow shaped in nature, created by meandering behaviour of tributaries of Brahmaputra River in north Assam and Barak River in south Assam. These wetlands (locally called as *beels* in north Assam) constitute about 72.5 per cent of the lentic area of the State. They nurture a wide variety of fish species which attracted many researchers and policy makers (Goswami and Goswami, 2006; Acharjee, 1997; Goswami, 1985; Kar, 1984; Lahon, 1983). Eighty species of fishes have been reported from the beels of Assam (Rahman *et al.*, 2008). Large Asian rivers like Brahmaputra and its associated floodplain wetlands are more diverse than those in other continents like Africa or Latin America (Welcomme, 2000).

The wide variety of fish species in beels of Assam is strongly supported by riverine connection of these wetlands. Establishment of connection of beel with the parent river (at least seasonally) brings freshness to the aquatic environment by removing organic carbon deposition which produces reduced toxic gases

like NH_3 , H_2S etc as well as it removes organic acids (Manna and Aftabuddin, 2007a). Many riverine fish species enter the beel through the connecting channel especially when floodwater recedes from the beel. Beels with riverine connection is more diverse than the beels which have lost their river connectivity.

Shallow nature of beels helps in prolific growth of aquatic macrophytes in them. All four types of aquatic macrophytes *viz.* free-floating, rooted-floating, submerged and emergent varieties are available in beels of Assam. Many researchers have reported a wide species diversity of aquatic macrophytes in beels (Sarma and Kalita, 2008, Kar and Barbhuiya, 2001; Acharjee *et al.*, 1997; Dey and Kar, 1989; Goswami, 1987). These macrophytes influence the aquatic environment as well as fish fauna differently. Floating macrophytes like water hyacinth have many detrimental effects like lowering of dissolved oxygen, increase of free CO_2 , lowering of water transparency, which is not favourable for fish growth except some air-breathing fishes (Rai and Datta Munshi, 1979; Manna and Aftabuddin, 2007b). Submerged macrophytes, on the other hand, help in epiphytic growth on them which is fed by many fish species associated with them.

Submerged macrophytes also support different types of fauna like mollusks, insect etc. which are also eaten by some fishes. Detritus produced from macrophytes help in proliferation of detritivorous fishes. Thus, two major factors that determine fish biodiversity of a beel are river connectivity and macrophyte type. Present communication is an attempt to understand the relation between macrophyte types with fish species diversity in a beel based on data collected from 61 beels located in Dhubri district of Assam. Analysis of data also reveals the influence of river connectivity on fish species diversity in beels.

MATERIALS AND METHODS

Surveys have been made to individual beels of Dhubri district and data on different aspects related to fisheries were collected from beels using a scheduled questionnaire. Data on area (percent) under different category of macrophyte types and fish catch pattern under different category of fish species (percent) have been collected and analysed. Data on area covered by aquatic macrophyte infestation in a beel was collected under four broad heads - clear area, floating macrophyte covered area, submerged macrophyte covered area and area covered by emergent and rooted-floating variety. Similarly, total fish catch from a beel was categorized under four heads - major and minor carps, carnivores, air-breathing fishes and small economic fishes (SEF). The group of SEF comprised of species like *Amblypharyngodon mola*, *Badis badis*, *Chanda* sp., *Chela* sp., *Colisa* sp., *Danio aequipinnatus*, *Glossogobius giuris*, *Gudusia chapra*, *Mastacembelus armatus*, *Macrognathus* sp., *Mystus* sp., *Nandus nandus*, *Puntius* sp., *Xenentodon cancila*. Similarly, information on river connectivity status of beels were collected and analysed for the present study.

RESULTS AND DISCUSSION

Dhubri district located in western part of Assam covers an area of 2,838 km². About 156 floodplain wetlands (beels) are located in the district covering an area of approximately 7000

ha. Under the present study, a total number of 61 beels of the district located in 14 development blocks of Dhubri district have been visited which covers an area of about 2057.8 ha (Table 1). Dhir beel (577 ha) is the largest beel of the district visited.

For the present study, data on fish catch composition were collected under four broad heads viz. major and minor carps (*Catla catla*, *Labeo* spp., *Cirrhinus* spp. including exotics like silver, grass, common and bighead carps), carnivores (*Wallago attu*, *Chitala chitala* and *Notopterus notopterus*), air-breathing fishes (*Clarias batrachus*, *Heteropneustes fossilis*, *Anabus testudineus* and *Channa* spp.) and small economic fishes (SEF) containing all other fishes. SEF is mainly consisted of macrophyte associated fish species like *Amblypharyngodon mola*, *Botia dario*, *Chanda* sp., *Colisa* spp., *Danio aequipinnatus*, *Glossogobius giuris*, *Gudusia chapra*, *Macrognathus* spp., *Mystus* spp., *Nandus nandus*, *Puntius* sp., *Salmostoma bacaila*, *Tetrodon cutcutia* and *Xenentodon cancila*. As maximum numbers of fish species are grouped in the category of SEF, the percent contribution of these fishes in total catch from a beel can be considered as index of fish biodiversity of a beel. *Gudusia chapra* (locally called *Koroti*) constitutes a significant share of fishery in many beels like in Dhir beel (~30 per cent of the total catch), Harinchora beel (~8 per cent), Kaliadanga beel (10 per cent). Harvest from Chakchaka beel, Dumardah beel etc have a significant share of *Macrognathus* spp. Similarly, many beels have their unique species composition with significant share of a particular native fish species like Tariachara beel (*Mystus* spp.), Nandini-1 (*H. fossilis*), Nandini and Soulmari beel (*A. testudineus*).

Aquatic macrophytes form an integral part of most of the beels of Assam. Floating macrophytes like water hyacinth do not support many fish species due to low oxygen level below the floating mats. Water hyacinth becomes a menace in many wetlands of Assam where it forms a floating mat covering most parts of those beels. Other semi-aquatic plant species also use water hyacinth mat for their

Table 2. List of floodplain wetlands (beel) surveyed in Dhubri, Assam with present area, macrophyte infestation and fish catch composition

Sl. No.	Water body name (Beel)	Present area (ha)	Area (%) covered by macrophyte				Fish groups (%)			
			Floating macro-phyte covered	Sub-merged macro-phyte covered	Emergent / rooted floating macro-phyte covered	Clear area	Major & minor carp	Carni-vores	Air breathing	Small economic fishes
1.	Dhir	577	0	39.9	0.2	60	20	15	10	55
2.	Moragaurang	50	5	30	0	65	5	5	20	70
3.	Dakra	46	26.1	23.9	0	50	30	5	25	40
4.	Kamarkhata	46.6	60.1	21.5	14.2	4.3	25	5	20	50
5.	Betbari	20	10	40	10	40	20	5	25	35
6.	Reni	8	6.3	77.5	12.5	3.8	5	0	10	85
7.	Chakchaka	21	66.7	21.4	4.8	7.1	15	3	35	47
8.	Sonai Mukhir Dara	4	5	5	0	90	25	3	10	62
9.	Charuabakra	50	28	54	12	6	60	0	12	25
10.	Udmarichara	10	10	40	10	40	25	5	10	60
11.	Raghunathchara	34	11.8	58.8	0	29.4	70	5	15	10
12.	Hakama	12	33.3	50	8.3	8.3	50	3	20	27
13.	Bhelakopa	2.5	0	0	0	100	5	0	15	80
14.	Bhelakopa- I	1.5	26.7	0	13.3	60	15	0	25	60
15.	Talumalu	20	10	25	0	65	70	5	15	10
16.	Dadhua	30	6.7	53.3	6.7	33.3	6	2	17	75
17.	Purni	10	60	20	10	10	20	6	19	55
18.	Bherbheri	5	10	30	40	20	10	2	10	78
19.	Mora Tipkai/ Ambari	30	13.3	33.3	0	53.3	5	0	10	85
20.	Sulkani	13	15.4	61.5	7.7	15.4	5	2	12	81
21.	Chakchaka	13	7.7	61.5	7.7	23.1	6	7	17	70
22.	Borkandardanga	35	5.7	48.6	0	45.7	20	5	15	60
23.	Khudimari	26	23.1	30.8	0	46.2	80	10	5	3
24.	Laukhowa	10	30	20	10	40	25	3	27	45
25.	Tariachara	80	10	0	12.5	77.5	60	2	4	34
26.	Shubad kaji	4	25	12.5	37.5	25	15	2	23	60
27.	Vaishpuri	30	13.3	13.3	20	53.3	73	2	5	20
28.	Motirkuti	12	25	10	10	55	70	1	9	20
29.	Nandini-1	43	34.9	23.3	18.6	23.3	10	2	20	68
30.	Dhaka	116	22.4	25.9	24.1	27.6	20	3	30	47
31.	Khoira	9	88.9	5.6	0	5.6	10	10	20	60
32.	Chandakhola & hawra	15	0	46.7	0	53.3	45	5	2	48
33.	Barundanga	25	4	8	8	80	75	0	0	25
34.	Harinchora	31	1.9	10	0	88.1	50	2	10	38
35.	Manusmara	12	20	20	10	50	50	2	18	30

Table 2. Contd.

Sl. No.	Water body name (Beel)	Present area (ha)	Area (%) covered by macrophyte				Fish groups (%)			
			Floating macro-phyte covered	Sub-merged macro-phyte covered	Emergent / rooted floating macro-phyte covered	Clear area	Major & minor carp	Carni-vores	Air breathing	Small economic fishes
36.	Bhimdaha	5	36	10	10	44	20	2	33	45
37.	Nandini	12	25	11.7	30	33.3	33	2	25	40
38.	Kaliadanga	75	5.3	69.3	20	5.3	65	5	10	20
39.	Berbhangir chara	11	0	72.7	0	27.3	30	0	10	60
40.	Satbhendi	12	60	25	5	10	20	3	27	50
41.	Dumardah	12	35	33.3	11.7	20	10	0	10	80
42.	Bhelka	9	44.4	0	44.4	11.1	20	5	20	55
43.	Sonachara	20	30	0	0	70	75	5	10	10
44.	Jhashkaal	13.2	15.2	68.2	9.1	7.6	70	2	18	10
45.	Paborchara	6	16.7	0	16.7	66.7	80	4	5	11
46.	Brokurunda	6.7	44.8	17.9	6	31.3	60	2	18	20
47.	Simli	21	71.4	2.4	2.4	23.8	10	2	78	10
48.	Gualwani	19	10.5	5.3	5.3	79	50	2	25	23
49.	Dubachuba	40	10	15	0	75	78	2	10	10
50.	Dahar	20	0	20	0	80	25	5	20	50
51.	Jhogra	21	57.1	19.1	9.5	14.3	30	3	27	40
52.	Bhelakoba	38	7.9	79	2.6	10.5	20	4	26	50
53.	Soulmari	46	43.5	5.4	43.5	7.6	33	2	25	40
54.	Moishnadi	12	50	8.3	33.3	8.3	23	4	25	48
55.	Koitorinari	22	60	20	15	5	40	5	30	25
56.	Gachua	60.8	40.8	12.2	39.5	7.6	14	6	20	60
57.	Potna	26	0	46.2	15.4	38.5	10	5	5	80
58.	Gotla	33	9.1	72.7	0	18.2	15	3	27	55
59.	Sona	17.5	8.6	22.9	0	68.6	15	5	25	55
60.	Bosaimari	20	10	25	5	60	60	1	14	25
61.	Medo	28	35.7	35.7	14.3	14.3	5	5	30	60
	Total	2057.8	1443.3	1718.6	646.8	2291.9	2006	142	1113	2750
	Average	33.7	23.7	28.2	10.6	37.6	32.9	2.3	18.2	45.1

growth and make the floating mat stronger and more durable. Only a few air-breathing fishes are able to survive in a beel choked with floating macrophytes. It is also observed that choking of beels by water hyacinth wipes out most of the native fish fauna. During our survey it was noted that major area of some beels of Dhubri district are choked with floating

macrophytes. These include Kamarkhata beel (60.1 per cent), Chakchaka beel (66.7 per cent), Purni beel (60.0 per cent), Khoira beel (88.9 per cent), Satbhendi beel (60.0 per cent) Simli beel (71.4 per cent), Koitorinari beel (60.0 per cent). Altogether 23.7 per cent beel area of the surveyed wetlands is covered with floating macrophytes especially water hyacinth. When

area (percent) under floating macrophytes are correlated with air-breathing fish production (percent), a strong correlation was observed ($r = 0.56$, $p < 0.01$) signifying the fact that air-breathing fish can survive in floating macrophyte choked beels (Table 2). On the other hand, negative correlation is observed between area covered by floating macrophytes and SEF ($r = -0.12$) and also between floating macrophytes and carp fishes ($r = -0.17$). This indicates the fact that floating macrophytes are detrimental to the fish biodiversity of beels of Assam.

Different types of submerged macrophytes occur in beels of Assam. Nutrient rich shallow wetland with transparent water supports prolific growth of a wide range of submerged aquatic macrophytes (if floating macrophyte is not there). *Hydrilla verticillata*, *Potamogeton pectinatus*, *Vallisneria spiralis*, *Ceratophyllum demersum*, *Myriophyllum spicatum*, *Najas minor* are very common submerged macrophytes commonly observed in beels of Assam. About 28.2 per cent area of the total wetland area surveyed are covered with submerged macrophytes (Table 1). Even in some seasonally open beels, sudden turbid floodwater intrusion during monsoon cause large scale mortality of submerged macrophytes, which again start flourishing in beel as water level decreases and water become transparent during winter as observed in case of 46, Morakolong beel in Morigaon (Manna and Aftabuddin, 2007a). Silt load by floodwater intrusion during monsoon is unable to prevent macrophyte regeneration

from seed bank in bottom sediment of such beels. Submerged aquatic macrophytes provide a suitable substratum for epiphytic growth to be used as food by many small weed associated fishes. With ageing submerged macrophytes produce detritus to be used as food by detritivorous fishes and invertebrates. They are also observed to be a suitable habitat for different types of mollusks and insects. Many fishes use larvae as well as adult of those invertebrates as food. Dense infestation of submerged macrophytes also prevents predatory fishes to devour those small weed associated fishes. Thus submerged macrophytes support a large variety of small economic fishes (SEF). Positive correlation ($r = 0.22$) was observed between area (per cent) covered by submerged macrophytes and SEF. When area covered by rooted-floating macrophytes like water lily (*Nymphaea* spp.), lotus (*Nelumbo* spp.), makhana (*Euryale ferox*) etc and emergent variety like reed grass etc. are added with the area covered by submerged macrophytes, the positive correlation value increases ($r = 0.28$, $p < 0.05$) signifying the fact that rooted-floating variety does not have detrimental effect like their floating counterpart.

Some parts of the beel especially deeper regions (like meander scroll depression in oxbow Lake) do not favour much submerged macrophyte growth and remain clear. A significant area of the beels in Dhubri district is reported without macrophytes. Clear area (per cent) of the beels surveyed is positively

Table 2. Correlation between macrophyte type and available fish groups

Parameter	Vs	Parameter	Coefficient (r)
% Area covered with submerged, rooted-floating and emergent macrophytes	Vs	Small economic fishes (%)	0.2809***
% Area covered with only submerged macrophytes	Vs	Small economic fishes (%)	0.2159
% Area covered with floating macrophyte	Vs	Air-breathing fishes (%)	0.5620*
% Area covered with floating macrophyte	Vs	Carp fishes (%)	-0.1645
% Area covered with floating macrophyte	Vs	Small economic fishes (%)	-0.1129
% Area without macrophyte	Vs	Carp fishes (%)	0.3024**

*Significant at 1% level; **Significant at 2% level, ***Significant at 5% level

correlated with carp production from beels ($r = 0.30$, $p < 0.02$). Probably, plankton concentration is higher in clear zone of a beels as there is no nutrient limitation created by dense macrophyte infestation. This helps in growth and production of planktivorous carp fishes in beels.

Seasonal flushing of floodplain wetlands with floodwater from parent river during monsoon through connecting channel creates a natural hydrologic disturbance, which removes excess organic matter, inhibits competitive exclusion of macrophyte species, and thus maintains macrophyte diversity (Wilcox, 1995). Macrophyte diversity also promotes fish biodiversity of beels as most of the species of SEF group is associated with macrophytes. Out of 61 beels surveyed under the present study, 8 beels have lost their riverine connection, while 13 are open throughout the year and rest are seasonally open. In closed beel, SEF occupy a share of 27.5 per cent out of total fish production. Perennially open and seasonally open beels have a much higher share of SEF with av. 55.4 and 45.25 per cent respectively. This signifies the beneficial nature of river connectivity in sustaining fish biodiversity of floodplain wetlands.

CONCLUSION

From the present study, it can be concluded that floating macrophytes like water hyacinth should be discouraged to conserve fish biodiversity of floodplain wetland of Assam. Submerged macrophyte variety promotes fish biodiversity of beels of Assam which must be there for fish biodiversity conservation. Rooted-floating and emergent varieties of aquaic macrophytes do not have negative impact on fish biodiversity like their floating counterpart. River connectivity also supports fish biodiversity and beels should maintain the connectivity at least seasonally to sustain the fish biodiversity of wetlands of Assam. Removal of floating macrophytes and restoration of riverine connection are advised as necessary management measures for fish biodiversity conservation of the wetland of Assam.

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HABITAT ASSOCIATION AND FORAGING PATTERNS OF TWO SMALL CYPRINID FISH SPECIES; *CHELA* *DADIBURJORI* MENON AND *HORADANDIA* *ATUKORALI* DERANIYAGALA

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INTRODUCTION

Cyprinid fishes form an important component of the wetland ecosystems of tropical freshwater habitats. Being the most important food material for piscivorous fishes, they have a pivotal role in the food web of these wetland ecosystems. Enormous primary production in tropical freshwater wetlands is primarily consumed by zooplanktons which in turn form the major source of food for the planktophagous organisms like the aggregates of small cyprinid fishes present in these habitats. These secondary consumers are equally important as the primary consumers in the food web. The existence of economically important food fishes like *Wallago attu*, *Ompok malabaricus* and *Channa striatus* in freshwater wetlands depends on the availability of gregarious cyprinid fishes. The small cyprinid fishes of the Subfamily Rasborinae, Cultrinae, and Cyprininae are usually found in large numbers in the freshwater wetland ecosystems of Kerala. Their importance as forage fishes was revealed by gut content analysis of the carnivorous fishes (Unpublished data). A detailed study on the habitat preference and

foraging patterns of two smaller (less than 40 mm TL at maturity) Cyprinid fishes, *Chela dadiburjori* (Menon) and *Horadandia atukorali* (Deraniyagala), was studied to understand their ecological role in those ecosystems which carry these fishes in great numbers.

MATERIALS AND METHODS

In clear waters of shallow streams and irrigation channels that traverse paddy and coconut cultivating areas in and around a freshwater wetland ecosystems of Thrissur district, *Chela dadiburjori* and *Horadandia atukorali* were located by their characteristic small and peculiar body shape (Figure 1 and 2), reflecting colouration, undulating swimming pattern and, above all by experience. The behaviour of fish in the water and their association to different zones of the stream habitat were observed directly. After observations were completed the fishes were collected from their habitat to study gut content or food preference. Fishes were collected alive using a scoop net having small mesh size (1 mm) or by sieving water along the bank-vegetations of small streams and irrigation



Fig. 1 : *Chela dadiburjori*



Fig. 2 : *Horadondia atukorali*

channels. Identification follows Silas, (1958) and Talwar and Jhingran, (1991). Gut content analyses was done to find out different types of food materials they consume. In laboratory they were grown in aquaria 50x 25x 25cm size (lbh) and water filled up to 15 cm. Different types of food items (*Artemia* nauplii, zooplankton concentrate from their natural habitat, mosquito larvae, and powdered fish feed) were provided to test their food preference in laboratory. All experiments in laboratory were done during the months of September to December of 2007 and 2008.

RESULTS

All fish collections were done in and around the periphery of a tropical freshwater wetland ecosystem, the Muriyadu Wetland, part of Vembanadu Lake a Ramsar site. *C. dadiburjori* and *H. atukorali* together were also present in all seasons in a wetland and associated irrigation canal system in Alur village (N 10°19', E 76°17'). Different size groups of both species were present during post monsoon and summer season.

This wetland is an isolated valley segment where the core area is found to be inundated for most part of the year. An irrigation canal originating from the upper reaches of

Chalakydy River is the major source of water during post monsoon season. This wetland which is found fragmented by land filling for coconut, plantain and tapioca cultivation, drains into the valley reaches of Chalakydy River. *C. dadiburjori* and *H. atukorali* were also collected from southern part of the Muriyadu wetland, from Thazhekkadu (N10°19', E 76°16'), Avittathur (N10°19', E 76°14') and Nadavaramba (N 10°19', E 76°13'). *C. dadiburjori* were collected from Avittathur and Nadavaramba only during August to November from shallow fresh water ponds associated with paddy fields. *C. dadiburjori* was collected during August to January from Thazhekkadu.

H. atukorali were collected year round from many locations associated with the Muriyadu wetland. They were found in great numbers during September to January in Muriyadu (N 10°21' E 76°15'), Konthipulam (N 10°23' E 76°14'), Porathissery (N 10°22' E 76°12') and Chemmanda (N 10°23' E 76°11').

C. dadiburjori was found swimming against the current in small streams. Larger individuals occupy the middle part of the course while smaller ones swim in groups along the margins of streams. Catches of larger individuals also contain same sized individuals of *Danio aequipinnatus* (McClelland), *Parluciosoma daniconius* (Hamilton-Buchanan) or sometimes *Esomus danricus* (Hamilton-Buchanan). Smaller individuals were collected along with *Puntius vittatus* (Day), *P. ticto* (Hamilton-Buchanan) and *Aplocheilus lineatus* Valenciennes. *Horadandia atukorali* swims among the shaded regions of both stream habitats and lentic waters, in shoals. These shoals are usually composed of similar sized individuals, and were found associated with submerged vegetations in shallow freshwater pools associated with the paddy and coconut cultivating low lands, and Kol wetlands in the southern part of Thrissur district.

Food and Feeding

Gut content analysis of *C. dadiburjori* reveals a diet mostly composed of zooplanktons.

Among zooplankton they consume, rotifers are the most represented. Copepods, ostracods and cladocerans are present in gut contents in all seasons. In addition to this, body parts of small terrestrial insects and mosquito larvae were found in their diet. Considerable amount of phytoplanktonic material was also found in the gut contents of this fish. The diet of *H. atukorali* was also similar to *C. dadiburjori* except that phytoplankton content is comparatively less in gut of this species. In laboratory, preference of these two species to different food materials were tested and it is observed that even in the presence of plankton concentrate collected from their natural habitat, they prefer *artemia* nauplii. They can be maintained on a mixed diet in which artificial feeds (powdered fish-feed pellets) surpass all the live prey items that can be used to feed these fishes regularly.

DISCUSSION

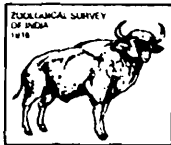
From the present study it is clear that *Chela dadiburjori* and *Horadandia atukorali* performs an

important role in the food web of the wetland ecosystem which forms their habitat. *H. atukorali* is one of the most abundant prey species upon which the juveniles of piscivorous fishes of the study area forages (Anisha, 2008). Morphological peculiarities of these fishes correlate with their foraging preferences. The shape of the mouth and the deep body are adaptations associated with a trend towards specialized surface or aerial feeding habits (Talwar and Jhingran, 1991; Hugueny and Pouilly, 1999).

In the present study *C. dadiburjori* was collected only from stream and lentic habitats that are connected to the Chalakudy River. But *H. atukorali* was found distributed in the valley reaches of both Chalakudy and Karuvannur Rivers. Thus the present study is also a report on the range extension and, geographical locations where these fishes are distributed (Gopi *et al.*, 2004), besides being a guide to their ecological role which is generally underestimated.

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STRUCTURE AND SPECIES COMPOSITION OF BIRD COMMUNITY IN GREAT NICOBAR BIOSPHERE RESERVE, ANDAMAN AND NICOBAR ISLANDS

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INTRODUCTION

The community studies have been largely expressed in terms of species richness, abundance, density and diversity. All these components have been used as indicators of habitat quality, because an increase in the value of the components is generally thought to reflect larger amounts of the necessary resources to sustain larger population within a given area. The quantitative information on bird species abundance in different habitats is necessary for solving many fascinating ecological issues. Through monitoring, it might be possible to identify long term population trends by determining the magnitude of annual population fluctuations. In addition, monitoring could detect a population's response to short term perturbations, whether they are natural or human caused.

Information on abundance, distribution, ecology and management of bird community in Great Nicobar Biosphere Reserve (GNBR) are meagre. The aim of this study is to address the topic of site-focused monitoring in detail, to meet the needs of a variety of users, from amateur to professional. Monitoring in the conventional sense of detecting change in

population parameters over both short term and long term periods, can help identify bird communities or species undergoing important population change, can contribute to the setting of habitat objectives, and serves as a tool for evaluating conservation and management actions. The structure and composition of bird communities are known to vary in different vegetation types (Wiens, 1989). The pioneering attempt has been made by MacArthur and MacArthur (1961) to assess the relationship between bird diversity and vegetation structure.

Many studies have been reported in other countries (Anderson, 1970; Beedy, 1981 and Manuwal, 1983), but in India, Beechler *et al.* (1987), Johnsingh *et al.* (1987), Daniels (1989), Katti (1989), Rai (1991), Johnsingh and Josha (1994), Jayson and Mathew (2000 and 2002) and Robin and Davidar (2002) has major contribution in this field. Scientific studies on the birds of Andaman and Nicobar Islands commenced with listing the avifauna by Blyth (1845, 1846, 1863 and 1866) followed Beavan (1867), Hume (1873, 1874a, 1874 a, 1876). Later, Bombay Natural History Society, conducted many avifaunal survey in the Andaman and Nicobar Islands (Abdulali, 1964, 1965, 1967,

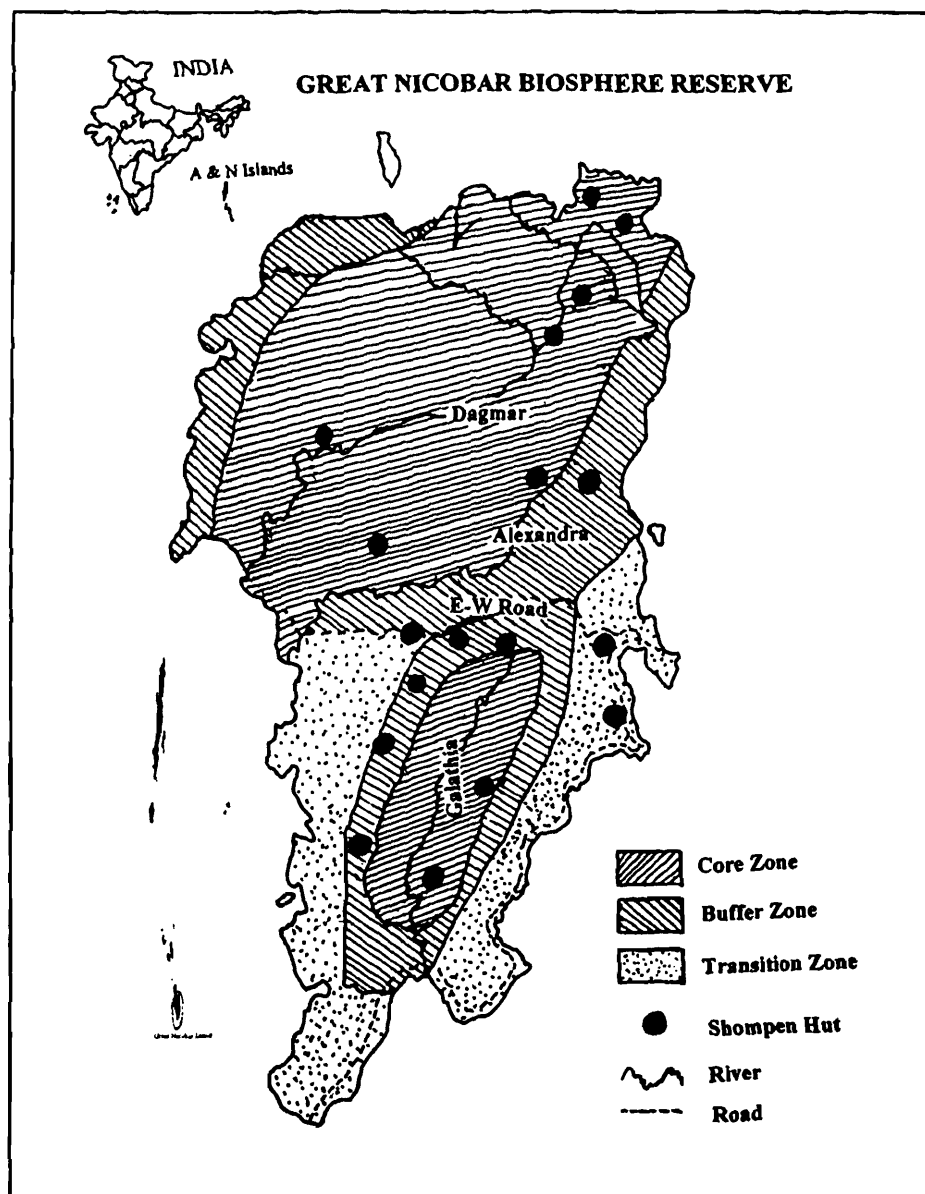


Fig. 1. Great Nicobar Biosphere Reserve

1979, and 1981). Zoological Survey of India also carried out several surveys (Das, 1971; Mukherjee and Dasgupta, 1975; Dasgupta, 1976; Saha and Dasgupta, 1980; Mukherjee, 1981; Chandra and Rajan, 1996).

Recently various researchers have been studied the population of ecology of particular species e.g. Nicobar Magapode (Sankaran, 1995), Andaman Teal (Vijayan, 1996), Edible-Nest Swiftlets (Sankaran, 2001), Narcondam Hornbill (Yahya and Zarri, 2003). Review of literature reveals that only few studies have been carried out on avifauna of the Great Nicobar Biosphere Reserve (Chandra and Kumar 1994; Sankaran, 1995). Based on the

above fact, the present study was made to describe the bird community structure of Great Nicobar Biosphere Reserve.

STUDY AREA

The Great Nicobar Biosphere Reserve (GNBR) is the southern most Island of Andaman and Nicobar archipelago. It lies between 6°45' and 7°15' N latitudes and 93°38' and 93°55' E longitudes in the Bay of Bengal (Fig. 1). The GNBR includes Campbell Bay and Galathea National Parks. It spreads over an area of 885 km². This reserve is known for its unique biodiversity and houses rich genetic germplasm resources. The Great Nicobar Biosphere Reserve

represents the tropical rain forest in Andaman and Nicobar Islands of bio geographic region. The major forest area in this Biosphere Reserve is still in its virgin state and rich in species composition. The GPNBR has rich heritage of faunal diversity and this area also inhabits the most endangered species *viz.*, Megapode (*Megapodius frycinet*) and Edible-nest swiftlet (*Collocalia fuciphaga*). Other important species include White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Nicobar Serpent-Eagle (*Spilornis minimus*), Nicobar Pigeon (*Caloenas nicobarica*) and Nicobar Parakeet (*Psittacula caniceps*).

METHODS

The study was conducted during month of August 2008 and January 2009. Bird species were estimated by Line transect method (Burnham *et al.*, 1980). Birds were identified based on physical features with the help of field guides and reference books (Ali and Ripley, 1983; Grimmett *et al.*, 1998). Richness Indices like R1 and R2, Hill's number N1 and N2, Diversity Indices like Shannon-Weiner (H') and Simpson's (l), Evenness measures like E1 and E2 were calculated using the computer program SPDIVERS.BAS (Ludwig and Reynolds, 1988). Density of birds was calculated using the programme DISTANCE 5.1. Similarity Index between the intensive study areas was calculated using Jaccard Index (Magurran, 1988).

RESULTS AND DISCUSSION

Species composition of avifauna

During the present study, a total of 57 species of birds belong the 11 Orders and 24 Families were recorded from Great Nicobar Biosphere Reserve. Out of these 48 (84 per cent) were residents and 9 (16 per cent) migrant (Table 1).

Highest number of birds was recorded in Aquatic feeders (24) followed by Insectivores (13), Granivores (8), Nectar-frugivores (5), Carnivores (3), Frugivores (4) (Table 2)

Species of birds recorded in different location during the period of study is given in

Table 3. Out of the fifty seven species, Hill Myna, Nicobar Racket-tailed Drongo, Crimson Sunbird, and Nicobar Red-checked Parakeet were recorded in all the sites. Species like Nicobar White-headed Starling, Pacific Reef-Egret, Osprey, Wood Sandpiper, Broad-billed Sandpiper, White-bellied Swiftlet, Purple Heron, Grey Heron, Malayan Night-Heron, Eurasian Curlew, Common Greenshank, Ruddy Turnstone, Little Stint, Grey Wagtail, and Tickell's Blue Flycatcher were recorded only in one location.

Similarity index between different locations

An alternative approach to measure the similarity of different sites is using similarity indices, using the proportional similarity measures and Jaccard similarity Index was calculated. Similarity indices between the intensive study areas were computed using qualitative data. Similarity between B. Quarry and Gingen Basti (0.39), Amphibian road and B. Quarry (0.32), Amphibian Road and Lakshman Beach (0.35), Gingen Basti and Gandhi Nagar (0.33), East West Road and Lakshman Beach (0.35) were showed high similarity (Table 4).

Abundance of birds : Out of 57 species of birds, Hill Myna was highest in dominance followed by Nicobar Red-checked Parakeet, Crimson Sunbird, Nicobar Wood Pigeon and Common Edible-nest Swiftlet (Table 6).

Diversity Indices and density of birds : Most widely used diversity indices like Shannon-Weiner Index, Simpson's Index and Hill's numbers were estimated for the birds of Great Nicobar Biosphere Reserve. Richness Index (R1 and R2) showed the richness of birds. Shannon Index (H') showed high values of diversity, similarly Hill's number also showed high values (Table 6). The Nicobar Wood Pigeon was in highest density (702.46 km²) followed by Nicobar Red-checked Parakeet (651.21 km²) and Common Edible-nest Swiftlet (561.64 km²). Similarly, Shannon index of diversity was highest in Nicobar Rocket-tailed Drongo (3.94) followed by Nicobar Red-checked Parakeet (3.78) (Table 7).

Table 1. Species of birds recorded from the Great Nicobar Biosphere Reserve

Sl. No.	Common Name	Scientific Name	Status*
	Ciconiiformes		
	Ardeidae		
1.	Little Egret	<i>Egretta garzetta</i> (Linnaeus)	R
2.	Pacific Reef-Egret	<i>Egretta sacra</i> (Gmelin)	RM
3.	Great-billed Heron	<i>Ardea sumatrana</i> Raffles	R
4.	Purple Heron	<i>Ardea purpurea</i> Linnaeus	RM
5.	Grey Heron	<i>Ardea cinerea</i> Linnaeus	RM
6.	Median Egret	<i>Mesophoyx intermedia</i> (Wagler)	RM
7.	Indian Pond-Heron	<i>Ardeola grayii</i> (Sykes)	R
8.	Malayan Night-Heron	<i>Gorsachius melanolophus</i> (Raffles)	RM
9.	Yellow Bittern	<i>Ixobrychus sinensis</i> (Gmelin)	RM
	Falconiformes		
	Accipitridae		
10.	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i> (Gmelin)	R
11.	Great Nicobar Crested Serpent Eagle	<i>Spilornis klossi</i> Richmond	R
	Pandionidae		
12.	Osprey	<i>Pandion haliaetus</i> (Linnaeus)	RM
	Gruiformes		
	Rallidae		
13.	White-breasted Waterhen	<i>Amaurornis phoenicurus leucocephalus</i> Abdulali	R
14.	Common Moorhen	<i>Gallinula chloropus</i> (Linnaeus)	RM
	Charadriiformes		
	Charadriidae		
15.	Pacific Golden-Plover	<i>Pluvialis fulva</i> (Gmelin)	M
16.	Little Ringed Plover	<i>Charadrius dubius</i> Scopoli	RM
17.	Lesser Sand Plover	<i>Charadrius mongolus</i> Pallas	RM
18.	Kentish Plover	<i>Charadrius alexandrinus</i> Linnaeus	RM
	Scolopacidae		
19.	Eurasian Curlew	<i>Numenius arauata</i> (Linnaeus)	M
20.	Common Greenshank	<i>Tringa nebularia</i> (Gunner)	M
21.	Wood Sandpiper	<i>Tringa glareola</i> Linnaeus	M
22.	Common Sandpiper	<i>Actitis hypoleucos</i> Linnaeus	M
23.	Ruddy Turnstone	<i>Arenaria interpres</i> (Linnaeus)	M
24.	Little Stint	<i>Calidris minuta</i> (Leisler)	M
25.	Broad-billed Sandpiper	<i>Limicola falcinellus</i> (Pontoppidan)	M
	Colimbiformes		
	Columbidae		
26.	Blue Rock Pigeon	<i>Columba livia</i> Gmelin	R
27.	Nicobar Wood-Pigeon	<i>Columba palumboides nicobaria</i> (Abdualali)	R

Table 1. Contd.

Sl. No.	Common Name	Scientific Name	Status*
28.	Andaman Cuckoo-Dove	<i>Macropygia rufipennis andamanica</i> Abdulali	R
29.	Nicobar Emerald Dove	<i>Chalcophaps indica augusta</i> Bonaparte	R
30.	Nicobar Pigeon	<i>Caloenas nicobarica</i> (Linnaeus)	R
31.	Pompadour Green-Pigeon	<i>Treron pompadora chloroptera</i> Blyth	R
32.	Nicobar Green Imperial-Pigeon	<i>Ducula aenea nicobarica</i> (Linnaeus)	R
33.	Pied Imperial-Pigeon	<i>Ducula bicolor</i> (Scopoli)	R
	Psittaciformes		
	Psittacidae		
34.	Nicobar Parakeet	<i>Psittacula caniceps</i> (Blyth)	R
35.	Nicobar Redcheeked Parakeet	<i>Psittacula longicauda nicobarica</i> (Gould)	R
	Cuculiformes		
	Cuculidae		
36.	Asian Koel	<i>Eudynamys scolopacea</i> (Linnaeus)	R
37.	Drongo Cuckoo	<i>Surniculus lugubris</i> (Horsfield)	R
	Apodiformes		
	Apodidae		
38.	White-bellied Swiftlet	<i>Collocalia esculenta</i> (Linnaeus)	R
39.	Common Edible-nest Swiftlet	<i>Collocalia fuciphaga</i> Thunberg	R
	Coraciformes		
	Alcedinidae		
40.	Nicobar White-collared Kingfisher	<i>Halcyon chloris occipitalis</i> (Blyth)	R
	Meropidae		
41.	Blue-tailed Bee-eater	<i>Merops philippinus</i> Linnaeus	RM
	Piciformes		
	Picidae		
42.	Great Black Woodpecker	<i>Dryocopus javensis</i> (Horsfield)	R
	Passeriformes		
	Motacillidae		
43.	Grey Wagtail	<i>Motacilla cinerea</i> Tunstall	M
	Pycnonotidae		
44.	Red-whiskered Bulbul	<i>Pycnonotus jocosus</i> (Linnaeus)	R
	Muscicapinae		
45.	Tickell's Blue Flycatcher	<i>Cyornis tickelliae</i> Blyth	R
	Monarchinae		
46.	Nicobar Black-naped Monarch Flycatcher	<i>Monarcha azurea nicobarica</i> (Bianchi)	R
	Dicaeidae		
47.	Plain Flowerpecker	<i>Dicaeum concolor</i> Jerdon	R

Table 1. Contd.

Sl. No.	Common Name	Scientific Name	Status*
	Nectariniidae		
48.	Nicobar Olive-backed Sunbird	<i>Nectarinia jugularis klossi</i> Linnaeus	R
49.	Crimson Sunbird	<i>Aethopyga siparaja</i> (Raffles)	R
	Zosteropidae		
50.	Oriental White-eye	<i>Zosterops palpebrosus</i> (Temminck)	R
	Sturnidae		
51.	Asian Glossy Starling	<i>Aplonis panayensis albiris</i> Abdulali	R
52.	Nicobar White-headed Starling	<i>Sturnus erythropygius erythropygius</i> (Blyth)	R
53.	Common Myna	<i>Acridotheres tristis</i> (Linnaeus)	R
54.	Hill-Myna	<i>Gracula religiosa halibretha</i> Abudulaali	R
	Oriolidae		
55.	Eurasian Golden Oriole	<i>Oriolus oriolus</i> (Linnaeus)	RM
56.	Nicobar Black-naped Oriole	<i>Oriolus chinensis macrourus</i> Blyth	RM
	Dicruridae		
57.	Nicobar Racket-tailed Drongo	<i>Dicrurus paradiseus nicobariensis</i> Baker	R

Table 2. Order and status of birds recorded from GNBR

Sl. No.	Order	Status			Feeding Guilds						
		R	M	Total	A	I	G	N/F	C	F	O
1.	Ciconiiformes	9	-	9	9	-	-	-	-	-	-
2.	Falconiformes	3	-	3	-	-	-	-	3	-	-
3.	Gruiformes	2	-	2	2	-	-	-	-	-	-
4.	Charadriiformes	3	8	11	11	-	-	-	-	-	-
5.	Colimbiformes	8	-	8	-	-	8	-	-	-	-
6.	Psittaciformes	2	-	2	-	-	-	-	-	2	-
7.	Cuculiformes	2	-	2	-	2	-	-	-	-	-
8.	Apodiformes	2	-	2	-	2	-	-	-	-	-
9.	Coraciiformes	2	-	2	2	-	-	-	-	-	-
10.	Piciformes	1	-	1	-	1	-	-	-	-	-
11.	Passeriformes	14	1	15	-	8	-	-	-	-	-
	Total	48	9	57	24	13	8	5	3	4	0

R = Resident, M = Migrant, A = Aquatic Feeders, I = Insectivores, C = Carnivores, G = Granivores, F = Frugivores, N/F = Nectar-frugivores, O = Omnivores

Table 3. Distribution of bird species in the GNBR

Sl. No.	Common Name	1	2	3	4	5	6	7	8	9
1.	Little Egret				√					√
2.	Pacific Reef-Egret						√			
3.	Great-billed Heron		√	√	√			√	√	
4.	Purple Heron						√			
5.	Grey Heron						√			
6.	Median Egret				√		√			
7.	Indian Pond-Heron	√					√			
8.	Malayan Night-Heron						√			
9.	Yellow Bittern				√		√	√		
10.	White-bellied Sea-Eagle	√		√			√			√
11.	Great Nicobar Crested Serpent Eagle		√	√					√	
12.	Osprey		√							
13.	White-breasted Waterhen	√					√			
14.	Common Moorhen						√			
15.	Pacific Golden-Plover		√				√			
16.	Little Ringed Plover		√							
17.	Lesser Sand Plover		√		√		√			
18.	Kentish Plover						√			
19.	Eurasian Curlew						√			
20.	Common Greenshank						√			
21.	Wood Sandpiper		√							
22.	Common Sandpiper		√				√			
23.	Ruddy Turnstone						√			
24.	Little Stint						√			
25.	Broad-billed Sandpiper				√					
26.	Blue Rock Pigeon	√						√	√	
27.	Nicobar Wood-Pigeon	√						√	√	√
28.	Andaman Cuckoo-Dove					√	√			
29.	Nicobar Emerald Dove	√				√				
30.	Nicobar Pigeon	√				√	√	√		√
31.	Pompadour Green-Pigeon					√		√		√
32.	Nicobar Green Imperial-Pigeon					√	√			
33.	Pied Imperial-Pigeon	√	√					√		
34.	Nicobar Parakeet					√	√		√	
35.	Nicobar Red-cheeked Parakeet	√	√	√	√	√	√	√	√	√
36.	Asian Koel	√	√	√		√				

Table 3. *Contd.*

Sl. No.	Common Name	1	2	3	4	5	6	7	8	9
37.	Drongo Cuckoo				√	√				
38.	White-bellied Swiftlet						√			
39.	Common Edible-nest Swiftlet					√	√	√	√	
40.	Nicobar White-collared Kingfisher	√	√			√			√	
41.	Blue-tailed Bee-eater						√			
42.	Great Black Woodpecker								√	
43.	Grey Wagtail						√			
44.	Red-whiskered Bulbul						√			
45.	Tickell's Blue Flycatcher					√				
46.	Nicobar Black-naped Monarch Flycatcher	√	√	√		√				
47.	Plain Flowerpecker	√				√	√	√		
48.	Nicobar Olive-backed Sunbird	√	√							
49.	Crimson Sunbird	√	√	√	√	√	√	√	√	√
50.	Oriental White-eye					√				
51.	Asian Glossy Starling					√	√	√		
52.	Nicobar White-headed Starling						√			
53.	Common Myna						√			
54.	Hill-Myna	√	√	√	√	√	√	√	√	√
55.	Eurasian Golden Oriole					√	√		√	
56.	Nicobar Black-naped Oriole					√			√	
57.	Nicobar Racket-tailed Drongo	√	√	√	√	√	√	√	√	√

1-Amphibian Road, 2-B Quarry, 3-Gingem Basti, 4-Gandhi Nagar, 5-East West Road , 6-Indira Point, 7-Lakshman Beach, 8-Mahar Nala, 9-Navidara

Table 4. Jaccard similarity index for various locations

	1	2	3	4	5	6	7	8	9
1	0	0.32	0.37	0.17	0.31	0.16	0.35	0.2	0.3
2		0	0.39	0.23	0.19	0.16	0.15	0.16	0.14
3			0	0.33	0.29	0.1	0.35	0.29	0.31
4				0	0.33	0.12	0.32	0.33	0.27
5					0	0.28	0.35	0.31	0.21
6						0	0.2	0.09	0.13
7							0	0.35	0.16
8								0	0.17
9									0

1-Amphibian Road, 2-B Quarry, 3-Gingem Basti, 4-Gandhi Nagar, 5-East West Road , 6-Indira Point, 7- Lakshman Beach, 8-Mahar Nala, 9-Navidara

Table 5. Abundance and dominance of birds of GNBR

Common Name	Abundance	Dominance Index
Hill Myna	250	11.95
Nicobar Red-checked Parakeet	233	11.14
Crimson Sunbird	177	8.46
Nicobar Wood Pigeon	151	7.22
Common Edible-nest Swiftlet	124	5.93
Blue Rock Pigeon	92	4.4
Nicobar Rocket-tailed Drongo	78	3.73
Nicobar Parakeet	75	3.59
Asian Glossy Starling	68	3.25
Lesser Sand Plover	55	2.63
Oriental White-eye	50	2.39
Nicobar White-Collared Kingfisher	46	2.2
Pompodar Pigeon	44	2.1
Pied Imperial Pigeon	42	2.01
Nicobar White-headed Starling	41	1.96
Wood Sandpiper	40	1.91
Little Ringed Plover	38	1.82
White-bellied Sea eagle	36	1.72
Black-naped Oriole	34	1.63
Dusky Grey Heron	44	2.1
Plain Flowerpecker	31	1.48
Common Sandpiper	30	1.43
Pond Heron	29	1.39
Yellow Bittern	26	1.24
White breasted waterhen	26	1.24
Little Egret	24	1.15
Nicobar Pigeon	17	0.81
Olive-backed Sunbird	16	0.76
Koel	13	0.62
Great Nicobar Crested Serpant Eagle	13	0.62
Common Myna	13	0.62
Pacific Golden-Plover	12	0.57
Eurasian Golden Oriole	19	0.91
Median Egret	9	0.43
Nicobar Black-naped monarch	9	0.43
Red-Checked Parakeet	8	0.38
Broad-billed Sandpiper	8	0.38
Ruddy Turnstone	7	0.33
Emerald Dove	7	0.33

Table 5. *Contd.*

Common Name	Abundance	Dominance Index
Tickell's Blue Flycatcher	6	0.29
Blue-tailed Bee-eater	6	0.29
Red-whiskered Bulbul	4	0.19
Kentish Plover	4	0.19
Drongo cuckoo	4	0.19
Common Moorhen	4	0.19
White-bellied Swiftlet	3	0.14
Pacific Reef Egret	3	0.14
Malayan Night Heron	3	0.14
Little Stint	3	0.14
Purple Heron	2	0.1
Osprey	2	0.1
Grey Wagtail	2	0.1
Green Imperial Pigeon	2	0.1
Curlew	2	0.1
Common Greenshank	2	0.1
Pompodar Green Pigeon	2	0.1
Andaman Cuckoo dove	2	0.1
Great Black woodpecker	1	0.05

Table 6. Diversity indices of birds in GNBR

Richness Indices		Diversity Indices		Hill's numbers		Evenness Indices	
R1	R2	Simpson's Index	Shannon Index	N1	N2	E1	E2
7.95	1.34	0.05	3.37	29.15	19.33	0.82	0.47

Table 7. Diversity indices and density of selected bird species in GNBR

Species name	Density/km ²	Simpson Index	Shannon Index
Nicobar Rocket-tailed Drongo	223.59	0.02	3.78
Nicobar Wood Pigeon	702.46	0.06	3.07
Asian Glossy Starling	477.24	0.27	1.51
Black-naped Oriole	138.16	0.05	2.68
Blue Rock Pigeon	504.6	0.14	2.26
Nicobar White-collared Kingfisher	226.88	0.35	1.60
Crested Serpent Eagle	257.24	0.08	1.88
Crimson Sunbird	412.13	0.02	3.94
Common Edible-nest Swiftlet	561.64	0.12	2.31
Eurasian Golden Oriole	400.57	0.1	2.07

Table 7. Contd.

Species name	Density/km ²	Simpson Index	Shannon Index
Hill myna	449.90	0.02	3.94
Koel	52.753	0.02	2.35
Nicobar Red-cheeked Parakeet	651.21	0.04	3.48
Nicobar parakeet	240.65	0.15	2.24
Pied Imperial Pigeon	320.83	0.04	2.96
Nicobar White-headed Starling	522.94	0.27	1.51
White-bellied Sea eagle	154.22	0.02	3.20

Table 8. Comparison of density of birds in different area

Country/area	No. of Species	Density/km ²	Vegetation	Source
Silent Valley National Park	99	1,122	Tropical Evergreen	Jayson & Mathew, 2000
Mukkali	96	780	Moist Deciduous Forest	Jayson & Mathew, 2000
Mannanvan Shola	76		Shola	Nameer, 2001
Panama		1820	Tropical Evergreen	Karr, 1971
Guinea	263	1520		Thiollay, 1986
Gabon	364	3690	Rain Forest	Brosset, 1990
New Guinea		3,450	Lowland Rain Forest	Bell, 1983
Amazon	245	1910		Terborgh <i>et al.</i> 1990
Great Nicobar Biosphere Reserve	57	2020	Evergreen	Present Study

During the period of study 2092 individuals were sighted. Species like Hill Myna, Nicobar Red-checked Parakeet, Crimson Sunbird, Nicobar Wood Pigeon, Nicobar Rocket-tailed Drongo were most common in this area. The present study showed the high species diversity (H') was 3.37, which is comparable with other areas (Table 8) (Johnsingh *et al.*, 1987; Daniels, 1989; Johnsingh and Josha, 1994; Gokula, 1998; Jayson and Mathew, 2000 and 2002). The bird species richness and diversity may be influenced by the patchiness (Wiens and Rottenberry, 1981). The available of micro habitat in the study area may be persuading the species diversity of Great Nicobar Biosphere Reserve. Diversity indices are extensively used in environmental monitoring and testing and in

conservation. As the objective of the world conservation strategy is to maximize diversity habitats, these indices are extensively used to monitor and evaluate habitats. According to a study conducted by Usher (1986) among the criteria used for evaluation of conservation schemes, diversity is the most frequently adopted criteria. Diversity indices correlated with the stability of the ecosystem and will be high in biologically controlled ecosystem and low in disturbed ecosystem.

The results of the density and diversity in the Great Nicobar Biosphere Reserve are comparable to a number of similar studies on the composition and abundance of tropical forest birds, which are presently available. Karr (1971) estimated a population density of 1820

pairs of birds/km² in Panama's tropical forests. Thiollay (1986) reported a density of 760 pairs/km² for a total of 263 species in French Guiana. A long-term study conducted by Brosset (1990) in Gabon on 364 species of birds produced a density of 3,690 individuals/km². A study by Bell (1983) on birds of lowland rainforest in New Guinea produced a density of 3450 pairs/km². A study by Terborgh *et al.* (1990) on 245 species of Amazonian forest bird community had shown a density of 1910 individuals/km². The forest and adjacent area provides good habitat for rich avifaunal diversity in the Great Nicobar Biosphere Reserve. The species richness in an area is dependent on the availability of

food resources, climate of the area, evolutionary history and predation pressure. The presence of high species density and globally significant species showed the conservation of Tropical forest of Great Nicobar Biosphere Reserve.

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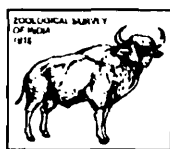
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STATUS OF VULTURES IN KOLLI HILLS, TAMIL NADU, INDIA

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INTRODUCTION

The Indian subcontinent harbours nine species of vultures i.e. Oriental White-backed Vulture *Gyps bengalensis*, Slender billed Vulture *Gyps tenuirostris*, Long billed Vulture *Gyps indicus*, Egyptian Vulture *Neophron percnopterus*, Red Headed Vulture *Sarcogyps calvus*, Indian Griffon Vulture *Gyps fulvus*, Himalayan Griffon *Gyps himalayensis*, Cinereous Vulture *Aegypius monachus* and Bearded Vulture or Lammergeier *Gypaetus barbatus* and all are known to be residents (Ali and Ripley 1983). A small population of Cinereous Vulture *Aegypius monachus* only breeds in India while majority of the population is migratory. Among the nine species, the Oriental White-backed Vulture (OWBV) has historically been the commonest species in India.

In recent times, populations of the three *Gyps* vultures i.e. White-backed Vulture, Slender billed Vulture and Long billed Vulture have declined drastically to below sustainable limits throughout their distributional range. Because of the evidence of widespread and rapid population decline (Prakash, 1999; Prakash *et al.*, 2003; Virani, 2006), three *Gyps* vultures were listed by IUCN, the World Conservation Union, in 2000 as 'Critically Endangered'

It has been established that the residues of Diclofenac, a non-steroidal anti-inflammatory drug (NSAID) and a popular painkiller drug, caused decline in population of vultures in Pakistan. Later, simulation modeling results also confirmed the Diclofenac poisoning to be the sole cause of the observed vulture declines (Green *et al.*, 2004). In order to ban the Diclofenac and find an alternative an African white-backed vulture *Gyps africanus* was used as a surrogate species for Asian *Gyps* vultures for laboratory tests (Cuthbert, 2006). Finally an alternative drug, Meloxicam, was found to be safe (Swarup, 2006; Swan *et al.*, 2006). The Government of India ordered the drug controllers to phase out Diclofenac for veterinary use through Drugs and cosmetic act on 11th May 2006 and finally a ban was imposed in August 2006. Several initiations have also been taken by the government to restore the population through vulture breeding centre and conservation/rescue centre.

In this scenario, a complete documentation of the status and distribution of vulture irrespective of the protection status of their distributional sites are of an immense need and thus a special attempt was made to understand the population structure of vulture in Kolli Hills, Tamil Nadu, India.

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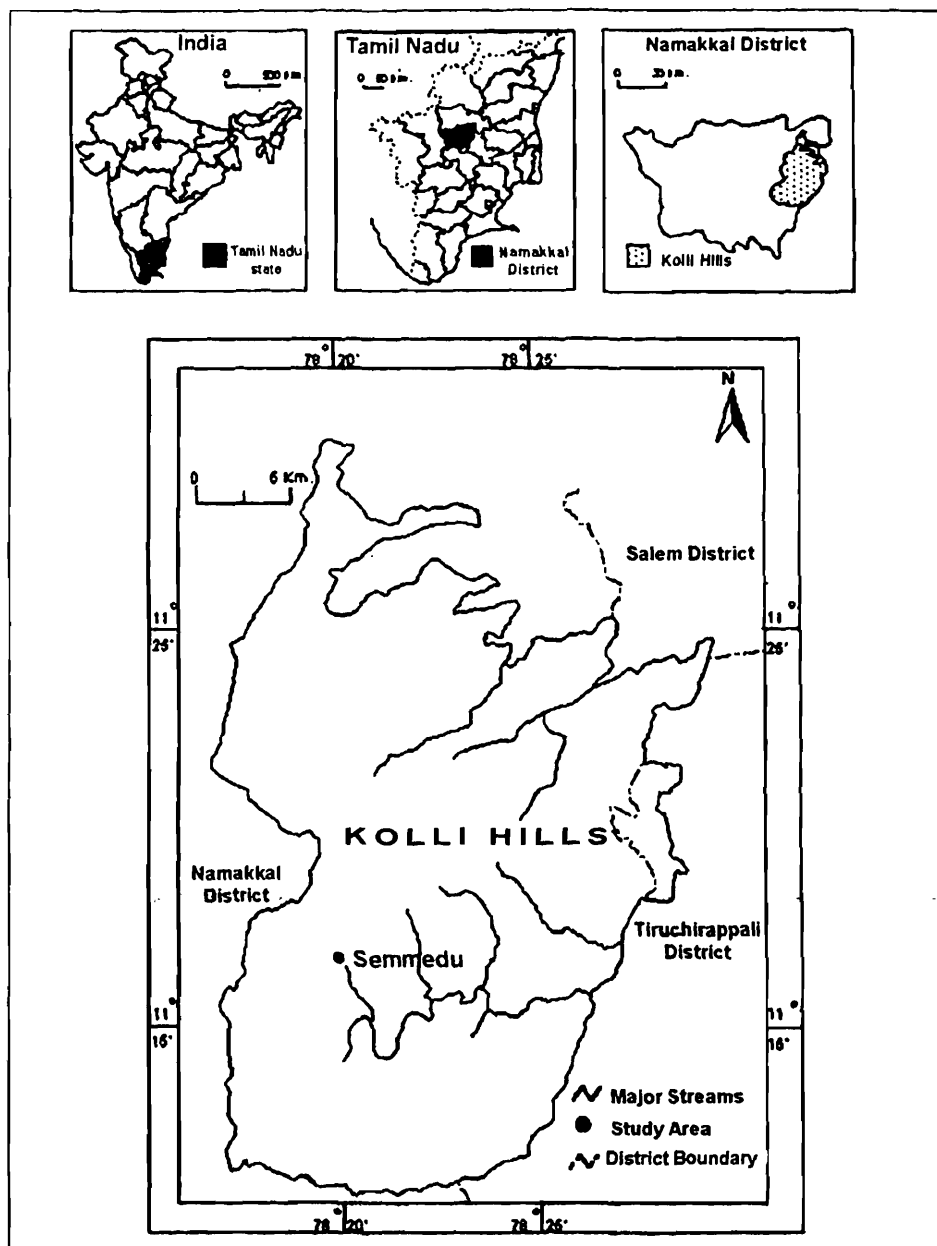


Fig. 1. Location of the study area

STUDY AREA

Kolli Hills lies geographically between $11^{\circ}11'$ to $11^{\circ}30'$ N and $78^{\circ}16'$ to $78^{\circ}29'$ E and covers an area of about 485 km^2 (Fig. 1). Average rainfall ranges from 786.9 mm to 910 mm in the plains while it varies from 1188.8 mm to 1333.3 mm in the Hills (Jawahar Raj, 2001). On the plateau portion, temperature fluctuates from 10°C to 30°C , but in the foothills and the adjoining plains it varies from 20°C to 40°C . The total human population of Kolli Hills is about 37,516 with a thick population in the central parts and thin population in the northern, north western and northeastern parts

of Kolli Hills. A homogeneous community (About 97 per cent of the total population), the *Malayalis*, have been largely managing the landscape of Kolli Hills. Majority of them are directly involved in agricultural activities. Among the crops cultivated, the *Cassava* dominates some parts while Millet dominates other areas. The encroachment of forests by the local people, bauxite mining activity, land use pattern, disturbance of water regimes and clogging of stream channels, are the existing threats to the fauna and flora. However, the aggressive hunting-gathering nature of the local inhabitants may not be overlooked in this issue.

Forest types of Kolli Hills vary from dry thorn forest to wet shola forest depending on the rainfall (Fig. 2). Shola forest occurs between the altitude 900 and 1370 meters above mean sea level and receives ample rainfall during the north-east monsoon. *Memecylon edule*, *Persea marmacrantha*, *Memecylon umbellatum*, *Clausena dentate* and *Cinnamomum macrocarpum* are the dominant species along with *Ficus virens* and *Redia floribunda*. The tropical dry evergreen

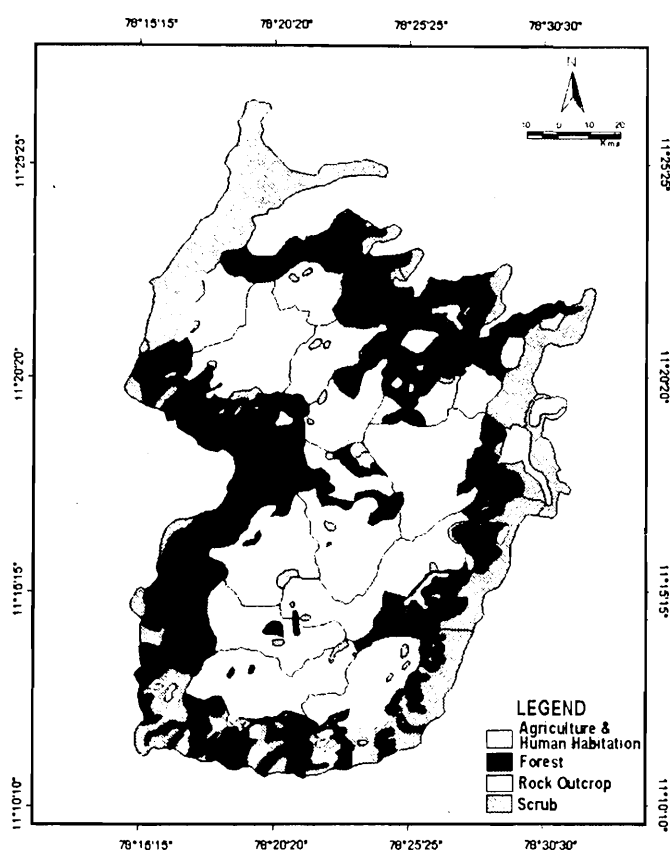


Fig. 2. Forest cover of Kolli Hills

forest occurs between 900 and 1200 meters above msl and only on the western aspect. *Ammora canarana*, *Canarium strictum*, *Syzygium cumini*, and *Filicium decipiens* are the dominating species. Semi-evergreen Forest occurs between 400 and 1200 meters above mean sea level and present in all aspects. *Persea macrantha*, *Epiprinus mallotiformis*, *Terminalia paniculata*, *Terminalia chebula*, and *Terminalia bellarica* are dominating this forest type. It occurs in depressions and upper slopes and plateau portions of the Karavallikombai and Ariyurshola Reserve Forest. Southern Dry mixed deciduous forest occurs between 400 and 110 meters above msl. The dominant species are *Wrightia tinctoria*,

Bridelia retusa, *Phyllanthus emblica*, *Terminalia chebula* and *Tectona grandis*. Southern Thorn Forest occurs between 220 (foothills) and 1100 meters above msl. The dominant species is *Moringa concanensis*. Southern Euphorbia Scrub occurs between 200 and 1100 meters above msl. The following are the predominant species: *Euphorbia antiquorum*, *Cassia auriculata* and *Randia malabarica*. Besides natural forests, plantations of eucalyptus, bamboo, tamarind and silver oak are also seen in Kolli Hills. The Kolli Hills has been poorly studied and thus prehistoric information on many of the faunal species are completely lacking.

METHODS

Determining densities is rarely practical for raptors, only techniques related to distribution and relative abundance were focused for the present study as suggested by Fuller and Mosher (1981). The Kolli Hills was surveyed by foot and vehicle using the existing roads/trails. Daily surveys were organized to take the maximum advantage of optimal hours (0900-1300). In total, 18 trails were established for the present study (Fig. 3).

Interviews were conducted with local peoples within the study area, to assess qualitatively their perceptions of vultures. A questionnaire prepared and used for this purpose. In total, 150 individuals were interviewed and their opinions were recorded.

RESULTS AND DISCUSSION

Surveys were carried out from May 2005 to May 2007 at various locations throughout Kolli Hills. Approximately 168 km were traversed twice in a year (October-December 2005, April-June 2006, October-December 2006, and April-June 2007) and about 248 daylight hours was spent. Earlier literature (Ali and Ripley, 1993) shows that Kolli Hills could possibly support four species of vultures viz. Egyptian Vulture, White-rumped Vulture, Long-billed Vulture and Red-headed Vulture. However, no individual of any species of vultures was sighted in Kolli Hills throughout the study

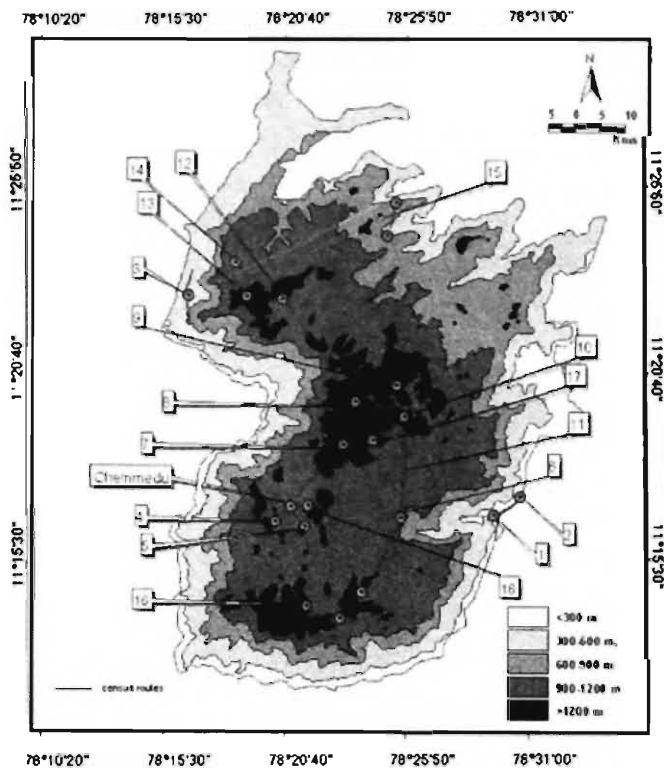


Fig. 3. Details of the census routes

Census routes : 1. Puliyanjolai Riverine, 2. Puliyanjolai Left and right, 3. Belukurichi Left and right, 4. Chemmedu to Vasalur, 5. Chemmedu to Ellaikkiraipatti, 6. Chemmedu to Arappali Ishwar Temple, 7. Chemmedu to Sholaikkadu, 8. Sholaikkadu to Kulivalavu, 9. Kulivalavu to Alathurnadu, 10. Kulivalavu to Nattukuli, 11. Nathukuli to Arapalli Ishwar Kovil, 12. Kulivalavu to Sengarai, 13. Sengarai to Makkani kaadu, 14. Sengarai to Ottakadai, 15. Peria Kombai to Valkuli, 16. Arapalli Ishwar Kovil to Vandalapadi, 17. Ariyur Sholaikkadu to Periyasamy Kovil, 18. Chemmedu to Mission settlement.

period. Interview we had with local tribal and non-tribal people in Kolli Hills also confirmed the presence Egyptian Vulture and Gyps species in Kolli Hills but were unable to say anything about Red-headed vulture. However, they further revealed that no individuals of species of vultures were seen for the past three years (Fig. 4). Some people reported that they sighted vultures (matches with White-rumped Vulture) even in large numbers (10 to 15) just three years back. Interviews further revealed that no vulture was found neck drooped or lying dead on the nest/ground/trees as observed and reported in various parts of India due to Diclofenac by Prakash (1999).

Four factors may be postulated for the total disappearance of vultures in Kolli Hills : 1. Loss

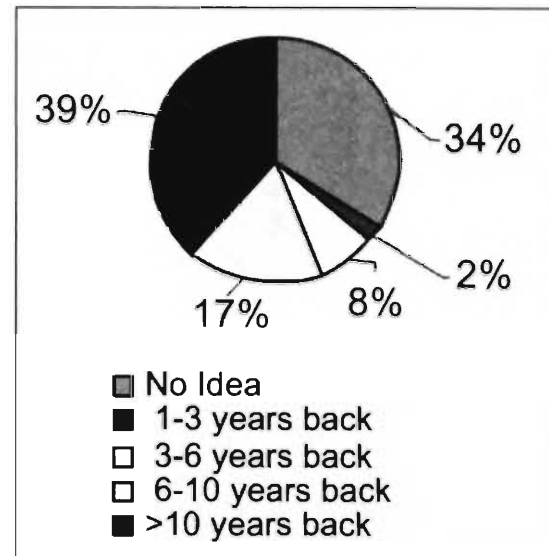


Fig. 4. Public opinion about the last Sightings of vultures in Kolli Hills

of forest cover, 2. lack of food availability, 3. effect of Diclofenac, and 4. hunting pressure. The loss of forest cover affects the availability nest and roost sites of vulture and thereby reducing the vulture population. However, Kolli hills still have some potential nest and roost sites to support a reasonable population of vultures despite the fact that >50 per cent of forest cover of kolli Hills has been lost over a period of about 60 years (Fig. 5; Source: Jawahar Raj, 2001). Apart from domestic animals no larger wild animals are left in wild in Kolli Hills. Moreover, due to increasing demand for flesh, sick or old cattle are sent mostly to slaughter house before they die. Hence, sighting dead cattle itself has become increasingly infrequent on the road or inside the forest. Hence, finding a carcass with enough biomass

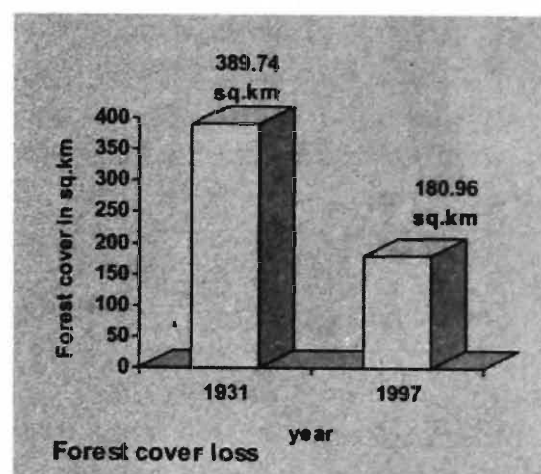


Fig. 5. Forest cover loss observed in Kolli Hills (Source : Jawahar raj 2001)

to support vulture now a days would certainly be impossible in Kolli Hills. No evidence was left to support the impact of Diclofenac except the total disappearance of vultures. The year of the last sighting of vultures in Kolli Hills coincides with the year when many parts of India faced the decline of vultures. The usage of Diclofenac for cattle in Kolli Hills was confirmed and still in majority of the medicals the diclofenac has been supplied to the farmers even after the ban (Fig. 6). Hence, it is also a likely factor. Moreover, the last factor, Local tribes, being fierce hunters, diminished



Fig. 6. Diclofenac tablets purchased even after the ban

considerable wild prey population very long back. The interview also revealed that many people in their past killed not only carnivores but also vultures by poisoning the dead animals with pesticides. Similarly, many admitted that they shot many individuals of raptors including vultures in their past. During the interview, a local inhabitant informed that there were only eight licensed gun holders in 1959 (while he obtained the license) and now it exceeds 500 in addition to unlicensed gun holders in Kolli Hills (Fig. 7).



Fig. 7. A local people showing the bullet cases

Hence, any one of the or combination of factors such as lack of food resources, loss of forest cover, hunting habits of the local people and the usage of Diclofenac could have possibly driven the vultures towards local extinction. However, it should also be noted that during the study period three individuals of White-backed vultures were sighted in Pachamalai Hills, lies geographically between the north latitudes $11^{\circ}08'-11^{\circ}29'$ and $78^{\circ}30'-78^{\circ}50'$ east longitudes, covering an area of about 700 km^2 near Kolli Hills. As studies on the distribution of vultures in Pachamalai Hills are also lacking, confirmation of movement of vultures from Kolli to Pachamalai Hills seems to be difficult. Hence, identification of status and distribution of vultures in Pachamalai Hills is an urgent need for the conservation of existing vultures before local extinction.

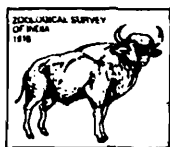
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DIVERSITY AND SPECIES ABUNDANCE OF BIRD COMMUNITIES IN DIFFERENT HABITATS IN THE SOUTHERN WESTERN GHATS

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INTRODUCTION

The community studies have been largely expressed in terms of species richness, abundance, density and diversity. All these components have been used as an indicator of habitat quality, because of an increase in the value of the components in generally thought to reflect larger amounts of the necessary resources to sustain larger population within a given area. The quantitative information on bird species abundance in different habitats is necessary for solving many fascinating ecological issues. The Kerala State is rich in bird fauna and a total of about 493 species have been recorded from the State (Jayson and Sivaperuman, 2005 and 2006). Many studies have been reported in other countries on bird community studies (Anderson, 1970; Beedy, 1981 and Manuwal, 1983), but in India, Beechler *et al.* (1987), Johnsingh *et al.* (1987), Daniels (1989), Katti (1989), Rai (1991), Johnsingh and Josha (1994), Jayson and Mathew (2000 and 2002) and Robin and Davidar (2002) has major contribution in this field of bird community. Based on the above information, the study was aim to assess and document the bird

community structure in different habitat in various protected areas in the Southern Western Ghats.

STUDY AREA

The study was conducted in different habitats in four protected areas in the southern Western Ghats, part of Kerala (Fig. 1).

Nelliampathy Reserved Forest

The Nelliampathy hills lies between 10°20' and 10°48' N and between 76°30' and 76°55' E and is in the western slopes of the Western Ghats (Fig. 2). The total area of the Nelliampathy hills is 220 km² and the area under plantations like cardamom, coffee and tea is about 30 km². The topography is of highly undulating terrain with numerous ridges and valleys. The altitude of Nelliampathy hills varies from 40 to 1530 MSL. The climate is fairly cool in the higher elevations as the temperature drops down to 12°C in the December. Nelliampathy hills receiving southwest and the northeast monsoon and it vary from 1270 mm to 3306 mm. The plantation practices in the Nelliampathy hills started in the 1860s where

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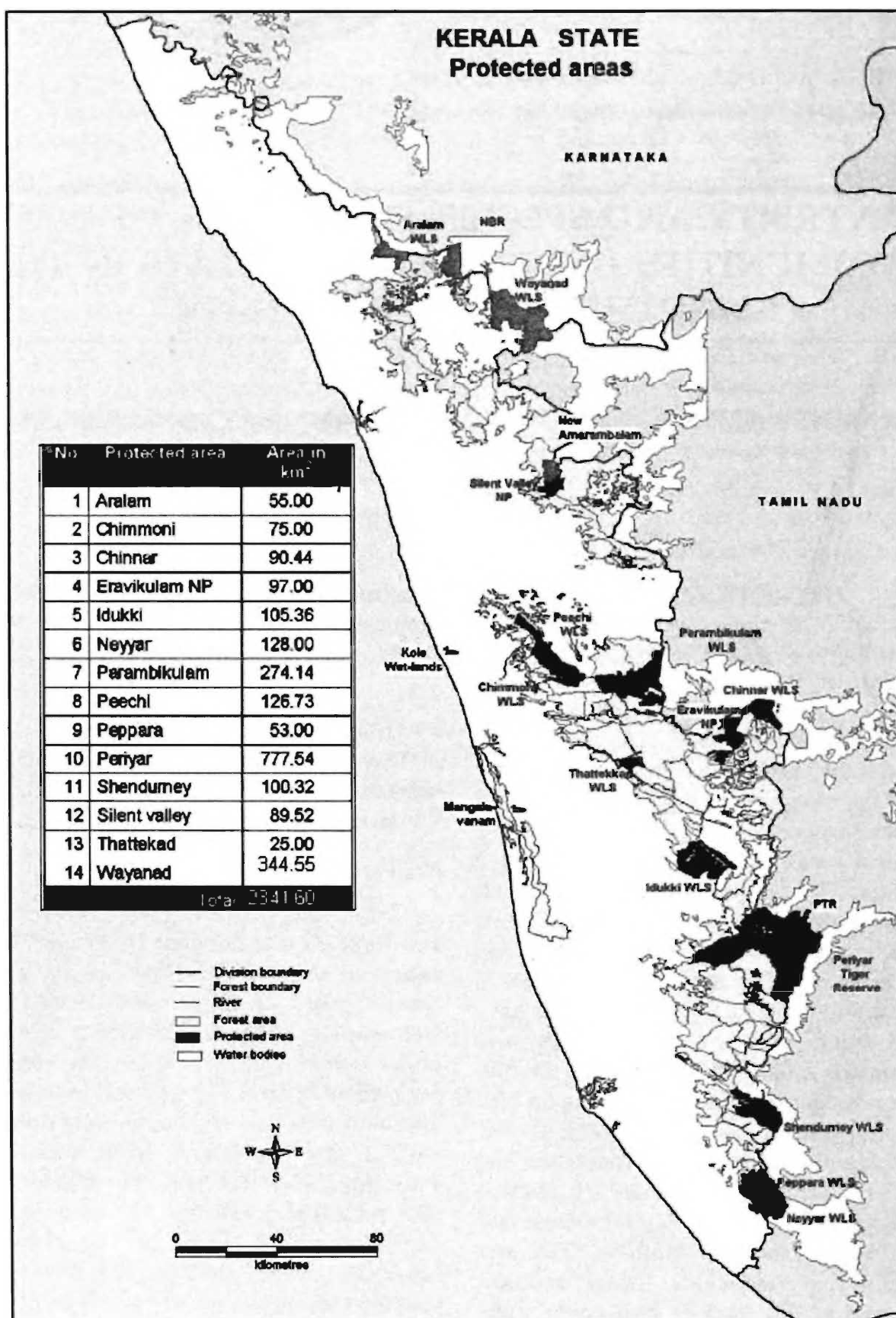


Fig. 1. Kerala map showing the intensive study area

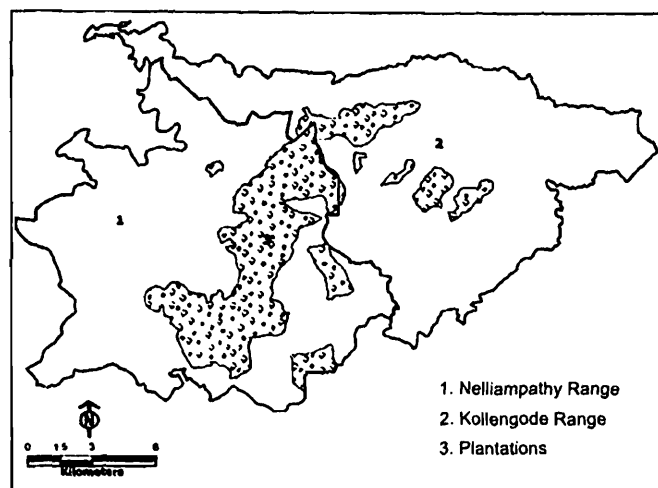


Fig. 2. Map of Nelliampathy Reserve Forest

the intensive transformation was done in the early 20th century. After all these perturbations and habitat changes, Nelliampathys still has some remnant pristine forests, which harbours the rich diversity of life in the Western Ghats.

Parambikulam Wildlife Sanctuary

Parambikulam Wildlife Sanctuary is situated in Palakkad district, Kerala state, India (between 76°35' and 76°50' E and between 10°20' and 10°26' N) (Fig. 3). The Sanctuary is part of the contiguous larger area of forest comprising Anamalai's, Nelliampathis, Sholayar, High ranges and Palani hills. Easa (1989), Uniyal and Easa (1990) have given a detailed description of the Sanctuary.

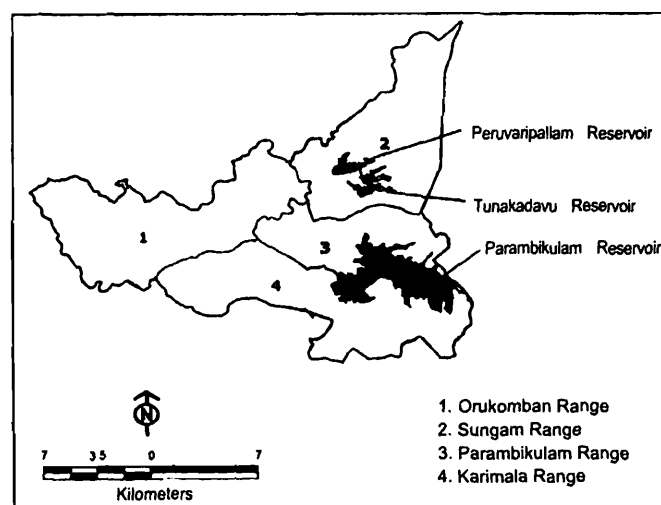


Fig. 3. Map of Parambikulam Wildlife Sanctuary

Peechi-Vazhani Wildlife Sanctuary

The Peechi-Vazhani Wildlife Sanctuary situated in Thrissur District, Kerala was formed

by combining some portions of Peechi, Pattikkad and Machad ranges of Thrissur Forest Division. The total area of the sanctuary is 125 km² (Fig. 4). Peechi and Vazhani dams are situated within the sanctuary with water spread area of 12.95 sq. km and 1.843 km² respectively. The sanctuary is contiguous with the forest areas of Nelliampathy and Palappilly Reserves, and has a common boundary with the Chimmony wildlife sanctuary on the south. It is situated between 10°28' and 10°38' north and between 76°18' and 76°28' east longitude. The continuity of the Peechi Forest Range with the Vazhani side is lost due to the Thrissur-Palakkad National Highway.

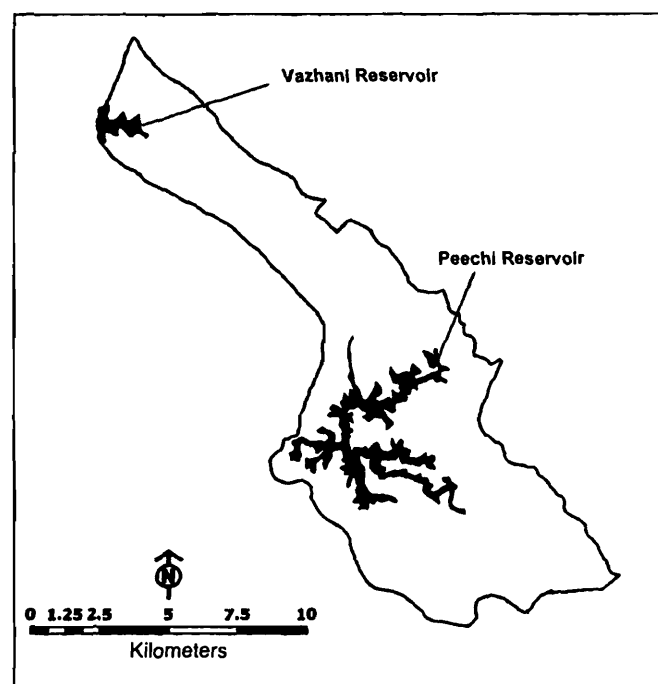


Fig. 4. Map of Peechi-Vazhani Wildlife Sanctuary

The habitat in the Peechi-Vazhani sanctuary is dominated by the moist deciduous forests and semi evergreen forests, which are confined to the upper regions. There are about 500 ha of teak and teak-soft wood plantations (*i.e.* teak mixed with *Bombax*) in the sanctuary adjacent to Peechi reservoir and Kuthiran areas. The sanctuary area harbours a good variety of mammals including tiger, elephant, gaur, sambar deer and bear.

Vazhachal Reserved Forest

The riparian forests of the Chalakudy River have revealed the existence of a thick riparian

vegetation of more than 10 metres width for a distance of 10.5 km downstream from Peringalkuth, covering an area of 58.5 ha. Out of this, 26.4 ha lie within the Vazachal area, including three large islands densely covered by riparian forests (Fig. 5). The riparian forests of the area have been found to be characterised by the presence of typical riparian species of plants, in addition to evergreen and semi-evergreen species.

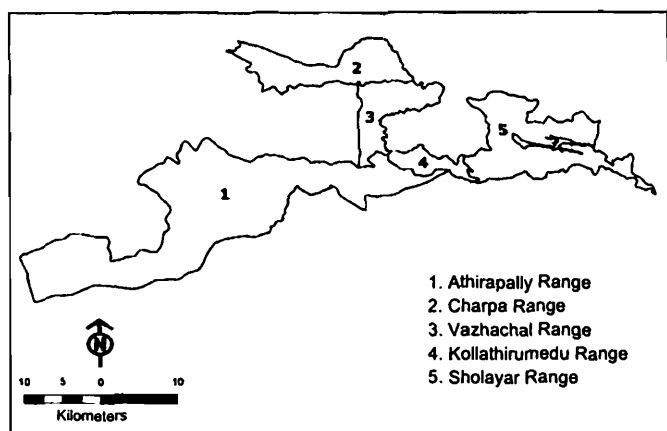


Fig. 5. Map of Vazhachal Reserve Forest

Athirappalli and Vazhachal, the two scenic and popular waterfalls on the edge of the Sholayar forest ranges are just 5 km apart. The Athirappalli Falls joins the Chalakkudy River after plummeting down a drop of 80 feet. Vazhachal is part of the Chalakkudy River. Both the waterfalls, their cool, misty waters cascading down in the backdrop of thick green forest and rocky terrain, are a scintillating experience to visitors.

Forests in the Chalakkudy River Basin occupy a pivotal position in the natural vegetation cover of Western Ghats. Forests of this basin form a major chunk of the wildlife habitat extending from Peechi to Indira Gandhi Wildlife Sanctuary (in Tamil Nadu) through the Anamalais and therefore sustain large, viable populations of wildlife. The Parambikulam Wildlife Sanctuary which is the proposed second 'Tiger Reserve' in the State forms the central part of the above mentioned wildlife biological unit. Parambikulam Wildlife Sanctuary also forms the heart of the forest area along the upper reaches of the Chalakkudy

Basin. To the North and North East of this sanctuary lies the Nelliampathy Hills, to the East and South-East is the Indira Gandhi Wildlife Sanctuary, in the West the continuity of forests is maintained through natural forests of Vazhachal and Chalakkudy forests divisions. Because of all these reasons this broadest reach of forests in the entire Western Ghats needs special protection and scientific management.

MATERIALS AND METHODS

The study was conducted from December 2005 through March 2006. Bird species was estimated by Point Count Method (Burnham *et al.*, 1980). Birds were identified based on physical features with the help of field guides and reference books (Ali and Ripley, 1983; Grimmett *et al.*, 1998).

Species richness and abundance of birds

Total number of bird species and number of individuals seen in each protected areas and different habitats were calculated using the census data and field observations.

Diversity indices

Diversity indices were calculated using the programme SPDIVERS.BAS developed by Ludwig and Reynolds (1988).

Dominance Index

The dominance of the each bird species in different habitat was calculated using the dominance index.

$$\text{Dominance Index} = n_i \times \frac{100}{N}$$

where n_i = Number of individuals

N = Total number of all the species seen during the study period

Density of birds

Density was estimated using the point count method (Burnham *et al.*, 1980). The density of birds was computed by the software "DISTANCE 5.0"

RESULTS

Occurrence of species

A total of 154 taxa of birds were recorded during the period, these belong to 36 families and 16 orders. Of the recorded species 124 were residents and 30 migrants. Out of 16 species of endemic species in the Western Ghats, nine species were recorded from the four areas namely White-bellied Blue Flycatcher, Nilgiri Wood Pigeon, Blue-winged Parakeet, Malabar Grey Hornbill, Small Sunbird, White-bellied Treepie, Grey-headed Bulbul, Nilgiri Flycatcher and Indian Rufous Babbler. Of the recorded species 30 species were migrant, 24 species were resident with migrant, six were transcontinental migrant.

Species richness and abundance of birds in different protected areas

Species richness and abundance of birds varied in the intensive study areas. Highest number of species richness and abundance was

recorded in Nelliampathy Reserve forest and lowest in Parambikulam Wildlife Sanctuary (Fig. 6).

Diversity indices birds in different protected areas

Most widely used diversity indices like Shannon-Weiner Index, Simpson's Index and Hill's numbers were estimated. Richness Index (R1 and R2) showed the richness of birds. Shannon Index (H') showed high values of diversity, similarly Hill's number also showed high values (Table 1).

Species richness and abundance of birds in different habitats

Species richness of birds was highest in the Teak Plantations of Parambikulam Wildlife Sanctuary and Peechi-Vazhani Wildlife Sanctuary. Abundance of birds was highest in Teak Plantations in Peechi-Vazhani Wildlife Sanctuary and lowest in Evergreen forests of Nelliampathy Reserve forest (Fig. 7).

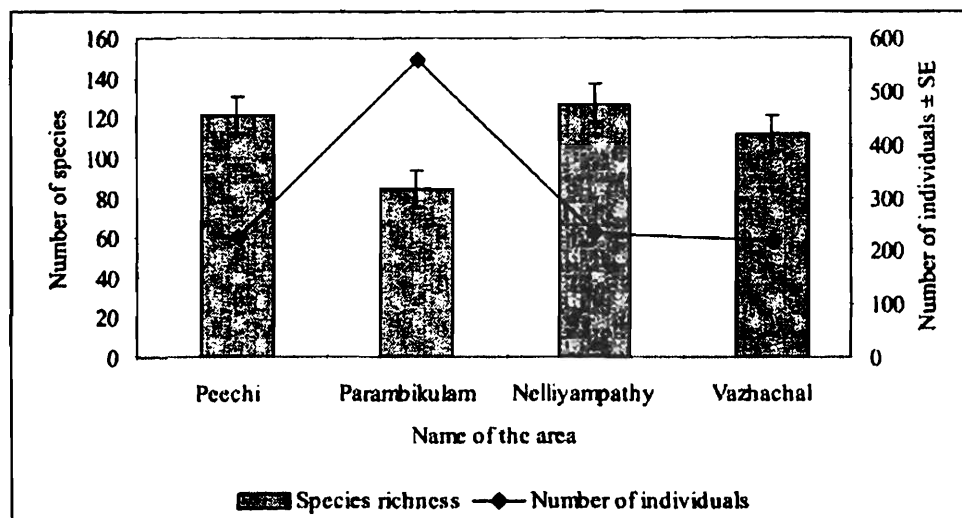


Fig. 6. Species richness and abundance of birds in different protected areas

Table 1. Diversity indices for different protected areas

Diversity indices	Peechi	Parambikulam	Nelliampathy	Vazhachal
Simpson	0.05	0.06	0.04	0.04
Shannon	3.30	3.23	3.33	3.31
R1	8.12	8.00	6.97	7.79
R2	2.99	2.54	2.55	2.91
N1	27.22	25.30	27.92	27.43
N2	21.07	15.95	25.26	22.84

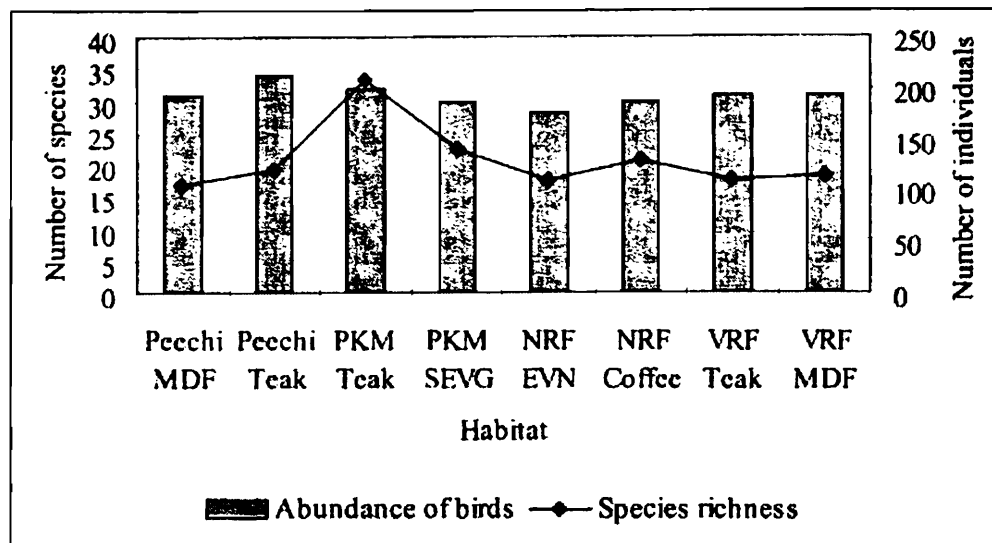


Fig. 7. Species richness and abundance of birds in different habitat in different protected areas

Diversity indices birds in different habitat

Species diversity index (H') was highest in Teak Plantations at Peechi-Vazhani Wildlife Sanctuary (3.22) and lowest at Teak Plantations at Parambikulam Wildlife Sanctuary (2.89). Simpson Index was highest at Teak Plantation at Parambikulam Wildlife Sanctuary (0.08), followed by Semi Evergreen forest at Parambikulam Wildlife Sanctuary (0.06) (Table 2).

Density

Density of birds in each habitat in different protected area is presented in Table 3. Minimum density was found in the Teak Plantation at Parambikulam Wildlife Sanctuary (3014.9 individuals/km²) and maximum in Coffee plantations at Nelliampathy Reserve Forest (4542.8 individuals/km²).

DISCUSSION

During this study, high species richness, abundance, diversity and density have been recorded from different habitats. Neelakantan *et al.* (1993) described 475 species, belonging to 64 Families, under 18 Orders from Kerala. Higher number of species (154) belonging to 36 Families, under 16 Orders reported during the short period of study. The high avian species richness recorded is due to the presence of diverse vegetation and microhabitats. Of the recorded species 124 were residents and 30 migrants. Out of 16 species are endemic species in the Western Ghats, nine species were recorded from the four areas namely White-bellied Blue Flycatcher, Nilgiri Wood Pigeon, Blue-winged Parakeet, Malabar Grey Hornbill, Small Sunbird, White-bellied Treepie, Grey-

Table 2. Diversity indices for different habitat

Diversity indices	Peechi		Parambikulam		Nelliampathy		Vazhachal	
	Moist deciduous forest	Teak	Teak	Semi Evergreen	Evergreen	Coffee	Teak	Moist deciduous forest
Simpson	0.06	0.04	0.08	0.06	0.06	0.05	0.06	0.05
Shannon	2.99	3.22	2.89	2.98	2.97	3.10	3.04	3.07
R1	6.45	6.88	5.80	5.86	5.74	5.97	6.38	6.33
R2	3.03	3.09	2.10	2.53	2.67	2.64	2.96	2.90
N1	19.92	24.96	17.96	19.63	19.43	22.22	20.95	21.46
N2	17.17	23.09	11.89	16.11	16.95	20.10	17.64	19.11

Table 3. Density of birds in different habitat in various protected areas

Name of the area	Habitat	Density (km ²)	SE	CV	95% confidence interval	
					LCL	UCL
Nelliampathy	Coffee Plantations	4542.8	1606.3	35.36	2144.9	9621.2
	Evergreen Forest	3014.9	850.44	28.21	1703.9	5334.6
Parambikulam	Semi Evergreen Forest	4013.7	967.20	24.10	2429.0	6632.3
	Teak Plantations	2469.3	953.86	38.63	1116.4	5461.7
Peechi	Moist deciduous Forest	3475.4	1071.2	30.82	1825.9	6615.1
	Teak Plantations	3656.8	1520.4	41.58	1513.4	8835.7
Vazhachal	Moist deciduous Forest	2753.8	845.61	30.71	1449.6	5231.3
	Teak Plantations	4284.2	991.80	23.15	2659.3	6901.9

SE = Standard Error; CV = Coefficient Variation; LCL = Lower Confidence Level; UCL = Upper Confidence Level

headed Bulbul, Nilgiri Flycatcher and Indian Rufous Babbler.

During the period of study 217 individuals in Vazhachal, 224 in Peechi, 234 in Nelliampathy and 560 in Parambikulam were sighted. The present study showed high species diversity (H') was 3.23 at Parambikulam, 3.30 at Peechi, 3.31 at Vazhachal and 3.33 at Nelliampathy, which is comparable with other studies in the Western Ghats (Johnsingh *et al.*, 1987; Daniels, 1989; Johnsingh and Josha, 1994; Gokula, 1998; Jayson and Mathew, 2000 and 2002).

In the present study 4,542 individuals/km² were recorded in Coffee Plantation and 3,014 in Evergreen forests at Nelliampathy Reserve Forest, 4,013 individuals/km² in Semi Evergreen forests and 2,469 in Teak plantations at Parambikulam Wildlife Sanctuary, 3,475 individuals/km² in Moist deciduous forests and 3,656 in Teak plantations at Peechi-Vazhani Wildlife Sanctuary, 2,753 individuals/km² in Moist deciduous forests and 4,284 in Teak plantations at Vazhachal Reserve Forests. The above values are comparable to a number of similar studies on the composition and abundance of tropical forest birds, which are presently available. Karr (1971) estimated a

population density of 1820 pairs of birds/km² in Panama's tropical forests. Thiollay (1986) reported a density of 760 pairs/km² for a total of 263 species in French Guiana. A long-term study conducted by Brosset (1990) in Gabon on 364 species of birds produced a density of 3,690 individuals/km². A study by Bell (1983) on birds of lowland rainforest in New Guinea produced a density of 3450 pairs/km². A study by Terborgh *et al.* (1990) on 245 species of Amazonian forest bird community had shown a density of 1910 individuals/km². The presence of high species density and globally significant species showed the conservation of Tropical forest of Parambikulam Wildlife Sanctuary, Peechi-Vazhani Wildlife Sanctuary and Vazhachal reserve forests.

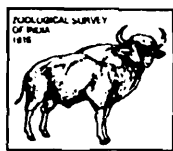
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ROLE OF COMMON PASSERIFORMES BIRD SPECIES IN VARIOUS FOREST ECOSYSTEM OF SOUTHERN WESTERN GHATS

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INTRODUCTION

India's richness in avian diversity is well recognized. 13% of the world's bird species are present in India and classified under 20 orders with 77 families with the total 1200 bird species. Of them only 900 are resident species and the rest are migratory (Diamond *et al.*, 1987; Jayson and Mathew, 2000; Singh, 2008). Each bird species has its preferences and requirements in terms of food, roosting, and nesting (Ali, 1977, Ricklefs, 2003). The more diverse the vegetation the greater the variety of birdlife. There is a direct relationship between vegetation diversity and bird diversity (Ericson *et al.*, 2003; Singh 2008). Southern Western Ghats being a 'hot spot' possesses multispecies and multiaged trees covering a recorded forest area of 2433 km² (Gaston and Spicer, 1998; Annamalai, 2004). The Avian is represented in all elevations from foot hill to the top, including the hill slopes habituated with various tropical forest types (Ali and Ripley, 1983). Passeriformes are the largest avian order containing more than half of all avian species (Scott, 2006). In general they are known as perching birds or song birds. These birds involve in pollination during the flowering phase of the forest cover. They are also attracted to the fruits with mature seeds

ready for dehiscence (Mac Donnell *et al.*, 1983; Raju, 2007). Birds by virtue of their greater mobility are more effective seed disseminators (Ridley, 1930). Role of birds in the restoration of tropical forests are vital because they carry seeds both externally and internally to far away places (Green, 1993; Whittaker and Jones, 1994). Knowledge about the common frugivores and their interaction in forest types could be very useful to plan effective and efficient regeneration schemes. The passerine birds belonging to the families Corvidae, Muscicapidae, Sturnidae, Pycnonotidae, Ciotiolidae, Silvidae and Nectaridae are the important modules in any forest ecosystem, playing a major role in pollination, seed dispersal and pest control.

In the tropical forest 52-70% trees possess, fleshy fruits adapted for animal consumption (Howe, 1984). Effective and efficient forest management with a regeneration scheme of planting trees can sustain biodiversity. Information about the plant interaction more with bird species in each forest ecosystem are important and will be useful for the forest managers while planning reforestation programmes (Balasubramanian *et al.*, 1998). Therefore, an attempt has been made to identify

the common and highly interactive bird species and to document the plant species which attract more animal visitors. This study has also provided more information about the impact of Passeriformes species in the southern Western Ghats forest ecosystem.

MATERIALS AND METHODS

The activities of the bird species were studied in the predominant forest types of southern Western Ghats namely Tropical thorn forest, Dry deciduous forest, Moist deciduous forest, Dry and Semi evergreen forest and Evergreen forest (Annamalai, 2004). Vegetation sampling was done by quadrat method in each forest type. In one hectare sample plot the predominant three bird attractive plant species with flowers, fruits and both with flowers and fruits were selected as focal plant species for the observation of bird activities. In each forest type the bird species which frequently and abundantly visited the focal plant species are considered as the common bird species. The bird visits and the purpose of their visits were observed in the morning hours between 6.30 and 8.30 when the bird feeding activities were higher.

The observations were made 5 times in each

forest quadrat with the focal plant species covering a period of one year, from January 2008 to January 2009. The data provided the details of role of the Passeriformes bird species in southern Western Ghats.

RESULTS

The selection of the study site, 5 major forest types was made based on the forest area coverage (Fig. 1) in Tamil Nadu.

In each forest type the bird's activity with the focal plant species were recorded. The passerines dominated the plant-bird interaction activities. Table 1 situates the focal plants with flowers, with fruits and both with flowers and fruits for bird-plant interaction. Table 2 listed out the observed birds and their distribution at various elevations. The passerine fauna is represented in all elevations of the studies five major tropical forest types. Based on their activity the birds are classified as frugivorous, nectivorous, insectivorous and granivorous. Fig. 2. shows the percentage of the available birds based on their foraging activities. Fig. 3a explains the comparisons of the passerine interaction in each forest type. Fig. 3b Indicate the percentage of passerine bird interaction with the focal plants are similar. Fig. 4 a-c

Table 1. Focal Plant species which attract high bird visitors activity

Sl. No.	Forest Type	Animal Preference		
		Flowering Plant Species	Fruiting Plant Species	Flowering & Fruiting Plant Species
1	Thorn Forest	<i>Acacia planifrons</i>	<i>Ficus benghalensis</i>	<i>Carissa carandas</i>
		<i>Albizia lebbeck</i>	<i>Morinda tinctoria</i>	<i>Hugonia mystax</i>
2	Dry Deciduous Forest	<i>Ochna obtusa</i> *	<i>Fluggea leucopyrus</i> *	<i>Pavetta indica</i> *
		<i>Orthosiphon thymiflorus</i> *	<i>Polyalthia suberosa</i>	<i>Lannea coromendalica</i>
3	Moist Deciduous Forest	<i>Cassia fistula</i>	<i>Gmelina arborea</i>	<i>Eugenia calacadensis</i>
		<i>Alstonia scholaris</i>	<i>Cipadessa baccifera</i> *	<i>Sygyium cumini</i>
4	Dry and Semi Evergreen Fores	<i>Eriodendrum pentadrum</i>	<i>Ficus asperrima</i>	<i>Cullenia exarillata</i>
		<i>Clerodendrum viscosum</i> *	<i>Solanum verbascifolium</i> *	<i>Jasminum auriculatum</i> *
5	Evergreen Forest	<i>Bombax malabaricum</i>	<i>Rauwolfia densiflora</i> *	<i>Cinnamomum macrocarpum</i>
		<i>Erythrina indica</i>	<i>Maesa perrottetiana</i> *	<i>Sygyzium mundagam</i>

* Indicate the shrub species. Other focal plants are trees

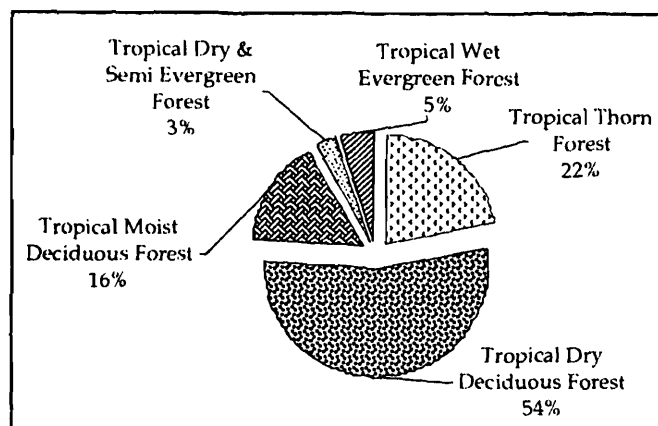


Fig. 1. Five major forest types selected to study the role of common Passeriforme bird species

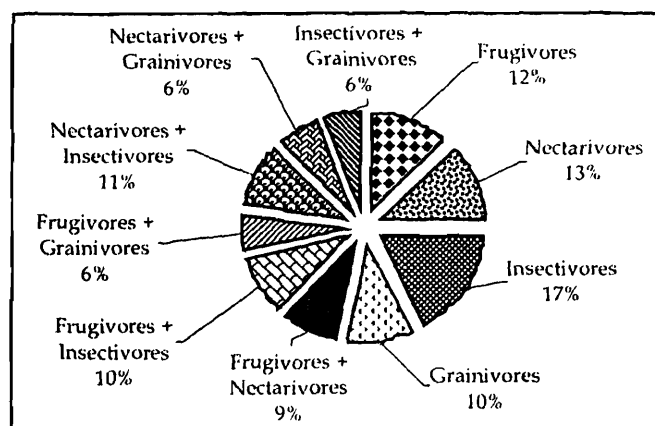


Fig. 2. Available common Passeriforme bird species in the forests of southern Western Ghats based on their foraging activity

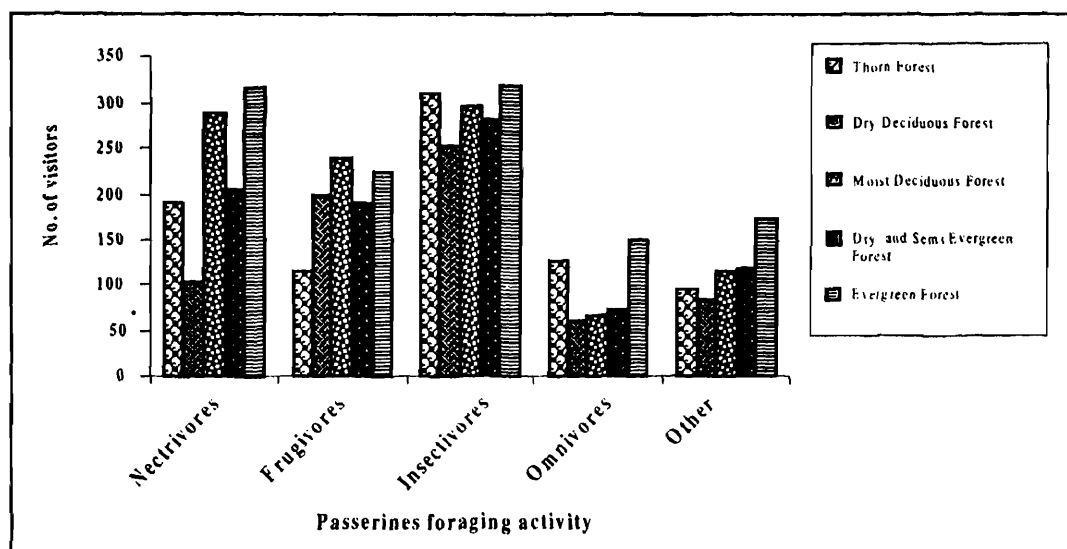


Fig. 3a. Graph representing the actual number of Passerine bird visitors observed during extended watch

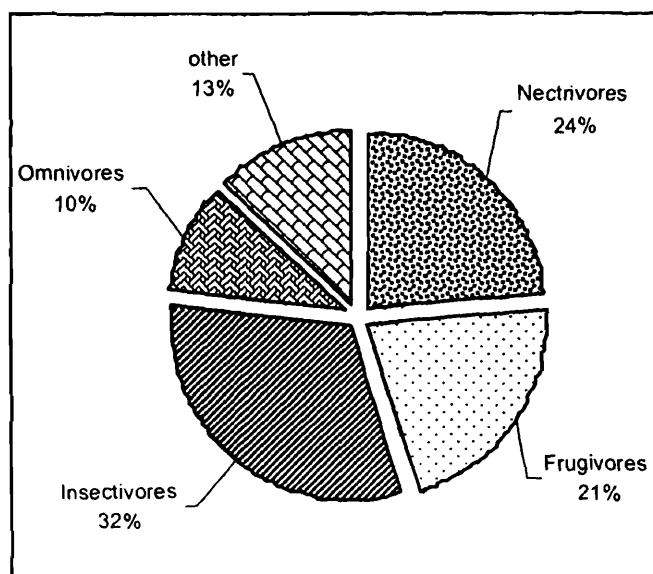


Fig. 3b. Percentage of Bird Interaction in Each Forest type

shows the frequency of the common, intermittent, occasional passerine bird visitors and their purpose of visit to the focal plant species. The left out members are rare members sited once in a while in the forest area.

DISCUSSION

The interaction between the forest birds and forest flora are one of very close interdependences (Brown, 1984). Natural forests with their multi-tiered vegetation have always been the ideal home for a large variety of avian assemblage (Ali and Ripley, 1983). Southern Western Ghats forest sustains several living communities in which each entity is linked to one another either directly or indirectly (Balasubramanian, 1996). Family members of

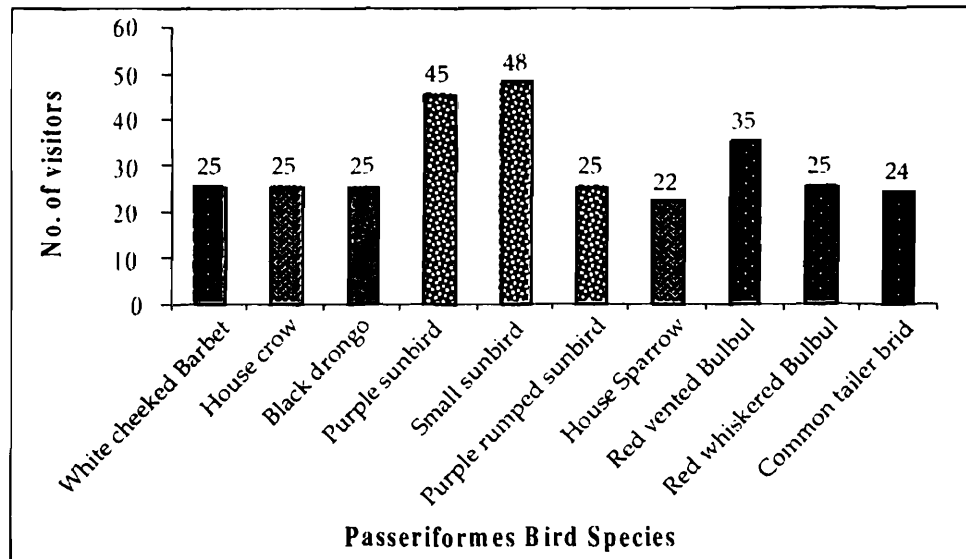


Fig. 4a. Common and frequent passerine visitor to the focal plant

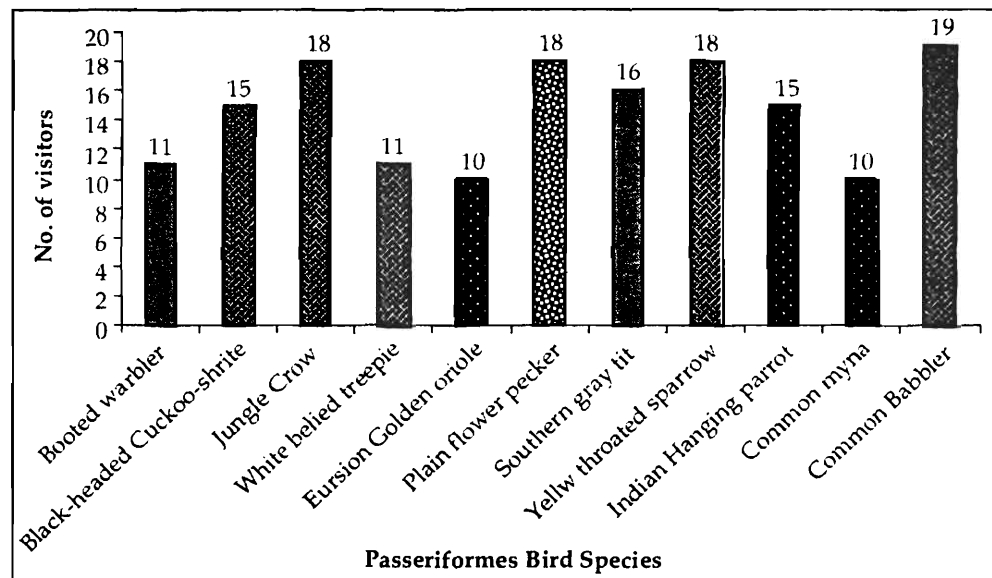


Fig. 4b. Intermittent passerine visitor to the focal plant

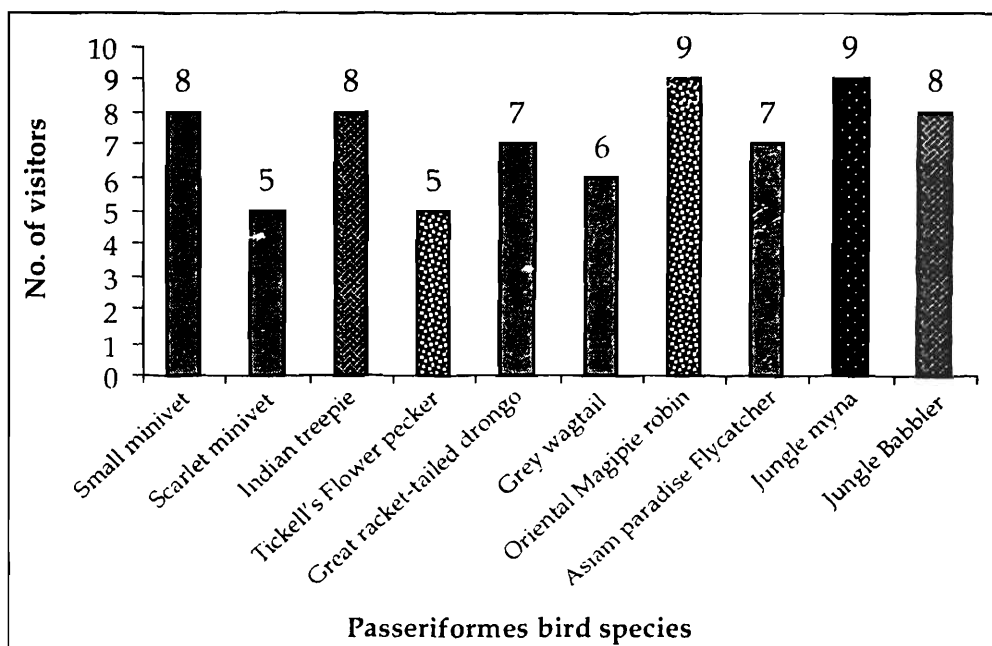


Fig. 4c. Occasional passerine visitor to the focal plant

passeriform avian assemblage play the most important roles in the forest ecosystem such as pollination, seed dispersal and insect predation (Balasubramanian, 1996).

The study has identified 36 species of birds belongs to the Order Passeriformes which commonly interact with various forests available in the southern Western Ghats. These birds are classified based on their interactions with the common plant species in each forest type which also attract many other animal visitors in addition to Passeriforme visitors. The nectivorous members of the order Passeriformes are the exclusive and effective cross pollinators with 13% of the bird visitors to the focal plants are passerine nectivores possessing special adaptations in their structure and the mechanism of their tongue and bill modification for extracting honey from flower tubes (Tara, 2000). These birds have a poor sense of smell. In general they show preference to the red, yellow and orange colour flowers (Kannan, 1998). While foraging these birds try to feed nectar by inserting the forehead. Some birds up to the throat level in to the flower tubes and thus they have contact with the anthers (Tara, 2000). These involvements in plant species provide cross pollination and thus they help to increase the genetic diversity of plant species (Howe and Henry, 1977). Such remarkable plant members benefited through Passeriforme nectivore activities are *Acacia planifrons*, *Albizia lebbek*, *Alstonia scholaris*, *Bombax malabaricum*, *Cassia fistula*, *Clerodendrum viscosum*, *Eriodendrum pentatum*, *Erythrina indica*, *Hugonia mystax*, *Ochna obtusata* and *Orthosiphon thymiflorus*.

Quite a few nectivores act as pollinators as well as insectivores, frugivores and granivores. In each forest type the plants with highly organized flowers rich in nectar with high carbohydrate nutrients attract the nectar foraging birds of the Passeriforme representations (Foster *et al.*, 1983). During the present observation apart from 13% of the exclusive nectivores, 26% of other Passeriforme birds also visit such flowers for their nutriment. The nectivores have poor sense of smell.

In the dissemination of seed and the distribution of plant life, birds play a predominant role (Singh, 2008). During the extended the feeding observations on the focal plant species 12% of the identified common passerine birds are frugivores. However, during casual observation several more passerines up to 25% in addition to frugivore feed on fruits. Thus, the total number of fruit eating Passeriforme record in the study area was 37%. This results conforms the number of passerine birds are principle foraging avian fauna. Techniques of handling fruits by these frugivorous birds vary. The birds sat on branch either pecked or plucked fruit and then either swallowed wholly or crushed the fruit before swallowing. Fruits sometimes carried in the bill probably to feed the nestlings to faraway distance from the parent tree (Majumdar and Bramachari, 1987). Red-vented and Red-whiskered bulbuls, Myna, Crow, Barbet, Oriole are the common members who swallow small fruits (Balasubramanian *et al.*, 1998). The major plants which experiences this benefit of are *Cinnamomum macrocarbum*, *Eugenia calacandensis*, *Ficus asperifolia*, *F. benghalensis*, *Ixora leucantha*, *Lannea coramandalica*, *Polyalthia spp*, *Maesa perrottetiana*, *Morinda tintoria*, *Rauwolfia densiflora*, *Syzygium cumini*, *S. mundagam*.

Seeds passed through the digestive tract of bird passes out unharmed along with faeces. Earlier studies proved the seeds acquire the benefit of quick germination rate and retrieve seed dormancy (Mishra *et al.*, 1987; Midya and Brahmachary, 1991; Yan, 1993; Traveset and Wilson, 1997). After swallowing the passeriformes visitors like bulbul and barbets never stay more than 10 minutes on the foraging tree. Balasubramanian *et al.*, (1998) also observed distance traveled by these birds after leaving the fruit tree is 22 to 50m and other passerine like myna and crow disappear from view. The present study also confirmed these observations. Borgers (1993) and Kannan (1994) also recorded such advantage of faraway dispersal in several valuable trees in southern Western Ghats.

Bird dispersal in *Ficus* spp. was studied and elaborated by several authors (Lambert, 1989;

Table 2. Common Interactive Passerine Birds and their Distribution in the Study Area

Sl. No.	Species Name	Family name	Frugivores (F)	Nectivores (N)	Insectivores (I)	Grainivores (G)	Elevation		No. of bird observed
							Below 1500 ft	Above 1500 ft	
1	<i>Pericrocotus cinnamomeus</i> (Small minivet)	Campephagidae	–	–	I	–	√	–	8
2	<i>Pericrocotus flammeus</i> (Scarlet Minivet)	Campephagidae	–	–	I	–	–	√	5
3	<i>Megalaima viridis</i> (White cheeked Barbet)	Capitonidae	–	N	–	–	√	√	25
4	<i>Hippolais caligata</i> (Booted warbler)	Cisticolidae	–	–	I	–	√	–	11
5	<i>Coracina melanoptera</i> (Black-headed Cuckoo-shrike)	Corvidae	–	–	I	–	√	√	15
6	<i>Corvus macrorhynchos</i> (Jungle Crow)	Corvidae	F	N	I	G	√	√	18
7	<i>Corvus splendens</i> (House crow)	Corvidae	F	N	I	G	√	–	25
8	<i>Dendrocitta leucogastra</i> (White bellied treepie)	Corvidae	F	N	I	G	√	√	11
9	<i>Dendrocitta vagabunda</i> (Indian treepie)	Corvidae	F	N	I	G	√	–	8
10	<i>Oriolus oriolus</i> (Eursion Golden oriole)	Corvidae	F	–	I	–	√	√	10
11	<i>Dicaeum erythrorhynchos</i> (Tickell's Flowerpecker)	Dicaeidae	F	N	I	–	√	–	5
12	<i>Dicrurus macrocercus</i> (Black drongo)	Dicrciridae	–	–	I	–	√	√	25
13	<i>Dicrurus paradiseus</i> (Greater racket-tailed drongo)	Dicrciridae	–	N	I	G	√	√	7
14	<i>Lonchura kelaarti</i> (Black throated munia)	Estrildinae	–	–	–	G	–	√	–

Table 2. Contd.

Sl. No.	Species Name	Family name	Frugivores (F)	Nectivores (N)	Insectivores (I)	Grainivores (G)	Elevation		No. of bird observed
							Below 1500 ft	Above 1500 ft	
15	<i>Lonchura punctulata</i> (Spotted munia)	Estrildinae	—	—	—	G	—	√	—
16	<i>Lonchura striata</i> (White-rumped munia)	Estrildinae	—	—	—	G	—	√	—
17	<i>Motacilla cinerea</i> (Grey wagtail)	Motacillidae	—	—	I	—	—	√	6
18	<i>Cosychus saularis</i> (Oriental Magpie robin)	Muscicapidae	—	N	I	—	—	√	6
19	<i>Terpsiphone paradisi</i> (Asianparadise Flycatcher)	Muscicapinae	—	—	I	—	√	√	7
20	<i>Dicaeum concolor</i> (Plain flower pecker)	Nectarinidae	F	N	I	—	√	√	18
21	<i>Nectarinia asiatica</i> (Purple sunbird)	Nectarinidae	—	N	I	—	√	√	45
22	<i>Nectarinia minima</i> (Small sunbird)	Nectarinidae	—	N	—	—	√	√	48
23	<i>Nectarinia zeylonica</i> (Purple rumped sunbird)	Nectarinidae	—	N	I	—	√	√	25
24	<i>Parus major</i> (Southern gray tit)	Paridae	F	—	I	—	√	√	16
25	<i>Passer domesticus</i> (House sparrow)	Passeridae	F	N	I	G	√	—	22
26	<i>Petronia xanthocollis</i> (Yellow throated sparrow)	Passeridae	F	N	I	G	√	—	18
27	<i>Ploceus philippinus</i> (Baya weaver)	Passeridae	—	—	—	G	√	—	—
28	<i>Pitta brachyura</i> (Indian pitta)	Pittidae	—	—	—	G	√	—	—

Table 2. Contd.

Sl. No.	Species Name	Family name	Frugivores (F)	Nectivores (N)	Insectivores (I)	Grainivores (G)	Elevation		No. of bird observed
							Below 1500 ft	Above 1500 ft	
29	<i>Loriculus vernalis</i> (Indian Hanging-parrot)	Psittacidae	F	N	—	—	√	—	15
30	<i>Pycnonotus cafer</i> (Red vented Bulbul)	Pycnonotidae	F	N	I	—	√	—	35
31	<i>Pycnonotus jocosus</i> (Red-whiskered Bulbul)	Pycnonotidae	F	N	I	—	√	√	25
32	<i>Acridotheres fuscus</i> (Jungle myna)	Sturnidae	F	N	—	G	√	√	9
33	<i>Acridotheres tristis</i> (Common myna)	Sturnidae	F	—	—	—	√	—	10
34	<i>Orthotomus sutorius</i> (Common tailer bird)	Sylviidae	F	N	I	—	√	—	24
35	<i>Turdoides caudatus</i> (Common Babbler)	Timalinae	F	N	I	G	√	—	19
36	<i>Turdoides straiatus</i> (Jungle Babbler)	Timalinae	F	N	I	—	√	√	8

Lambert and Marshall, 1991). Similar study on *Azadiracta indica* was done by Vijayan, 1975; Mishra *et al.*, 1987; Balasubramanian, 1996. *Premna tomentosa* is referred as keystone taxa in the Anaimalai hills enjoy the frequent vegetation by bulbul and barbets in the tropical forest (Kannan, 1994; Balasubramanian, 1996).

According to Snow (1981) the Rubiaceae members with succulent fruits provide huge foraging ground to the passeriforme frugivores. Other remarkable members that utilized the seed dispersal activity of passerine birds are *Santalum album*, *Cassine glauca* and *Ehretia ovalifolia* (Ridley, 1930; Snow, 1981; Johnson, 1982).

Apart from abiotic factors such as climatic conditions and soil nutrients a plant also needs to be free from disease and attack by predators (Majumdar and Bramachari, 1987). Insect pests attack can occur at every stage in the life cycle of a plant. These hazards can either severely impede its growth or results in its mortality (Cairns and John, 1988). From the seed stage until maturity, the plant has to continuously battle with these dangers for its survival. Insects such as termites, beetles, wood-borers, lepidopterous caterpillars and ants cause untold damage to the growing plants. In the present study 17% Passeriforme visitors are the effective insectivores. In addition other members like omnivores and the nectivores to the extent of 17% feed on insects. These species by consuming large numbers of insects enable the survival and healthy growth of natural vegetation. Howe *et al.* (1977), Howe (1982, 1984), Majumbar and Bramachari (1987) has extensively studied about the biological control of insects by birds in tropical forest.

Among the Passeriforme birds nectivores and frugivores namely the sun birds, bulbuls are the common and frequent visitors in all forest types. The babblers, flower peckers, crow and sparrows are the median visitors. The wagtails, drongos and flycatchers are the occasional bird visitors.

The present study suggests if the preferred plant species of the passerines are planted in the fragmented and degraded forest area that will enhance the natural forest restoration. In addition increase in the nectarivore activities of passerine birds will provide an essential ecosystem service that result in the out-crossing to increase their genetic diversity. Avian seed dispersal is important for the plants' fitness and also enhances the survival of seeds and seedlings further away from inter-species competition. Passeriforme birds interaction can modify the vegetation structure to sustain biodiversity.

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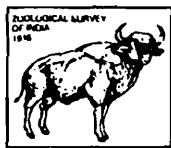
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RESOURCE PARTITIONING IN NESTING AMONG WATERBIRDS AT VEDANTHANGAL BIRD SANCTUARY

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INTRODUCTION

Selection of nest-site that meets nesting requirements of a bird is critical to its evolutionary fitness as it determines the gene flow. It often takes place on several levels in birds, however, in colonial birds it is based upon two major levels *i.e.* social (attraction to a place) and physiognomic factors (structural stability, foliage density, vegetation height, orientation to the sun and perch site availability) (Birkhead and Harries, 1985). Hence, colonial birds compete among themselves for the levels to be chosen in nest-site selection and it is presumably stronger within a species (Burger, 1981). As nest sites of many colonial species appear similar, interspecific competition for available resources is well pronounced. To avoid such competition, birds show differential division of nest site resources among species (Ralph and Ralph, 1958; Lowe-McConnell, 1967; Dusi, 1968). Knowledge of resource partitioning among birds in an area would give a better understanding of the resource availability and the management of waterbirds. The present study tries to identify such resource

partitioning among waterbirds in nesting in Vedanthangal waterbird sanctuary.

MATERIAL AND METHODS

Study area

Vedanthangal Waterbird Sanctuary (VBS) is situated in Vedanthangal, a small village located (12°32' N and 79°52' E) in the North-Western part of the Madhuranthagam taluk in Chengalpeta district of Tamil Nadu (Fig. 1). The lake has been the prime source for water for 250 acres of agricultural land. On the Western and Southern sides of the lake there is a long bund which impounds water while Northern and Eastern sides of the lake are sloppy and extend into the agricultural fields. Every year the lake is filled during North-East monsoon (October-December) and it is almost dry during summer (April-June). Input of water in to the tank is through four small canals. Maximum depth of the lake is 5 m near the bund. The countryside surrounding Vedanthangal lake is flat, comprising primarily of rocky plains. There are frequent low-ridged denuded small hillocks. Common herbaceous plants of the lake include *Chrozophora rottleri*, *Cleome chelidonii*

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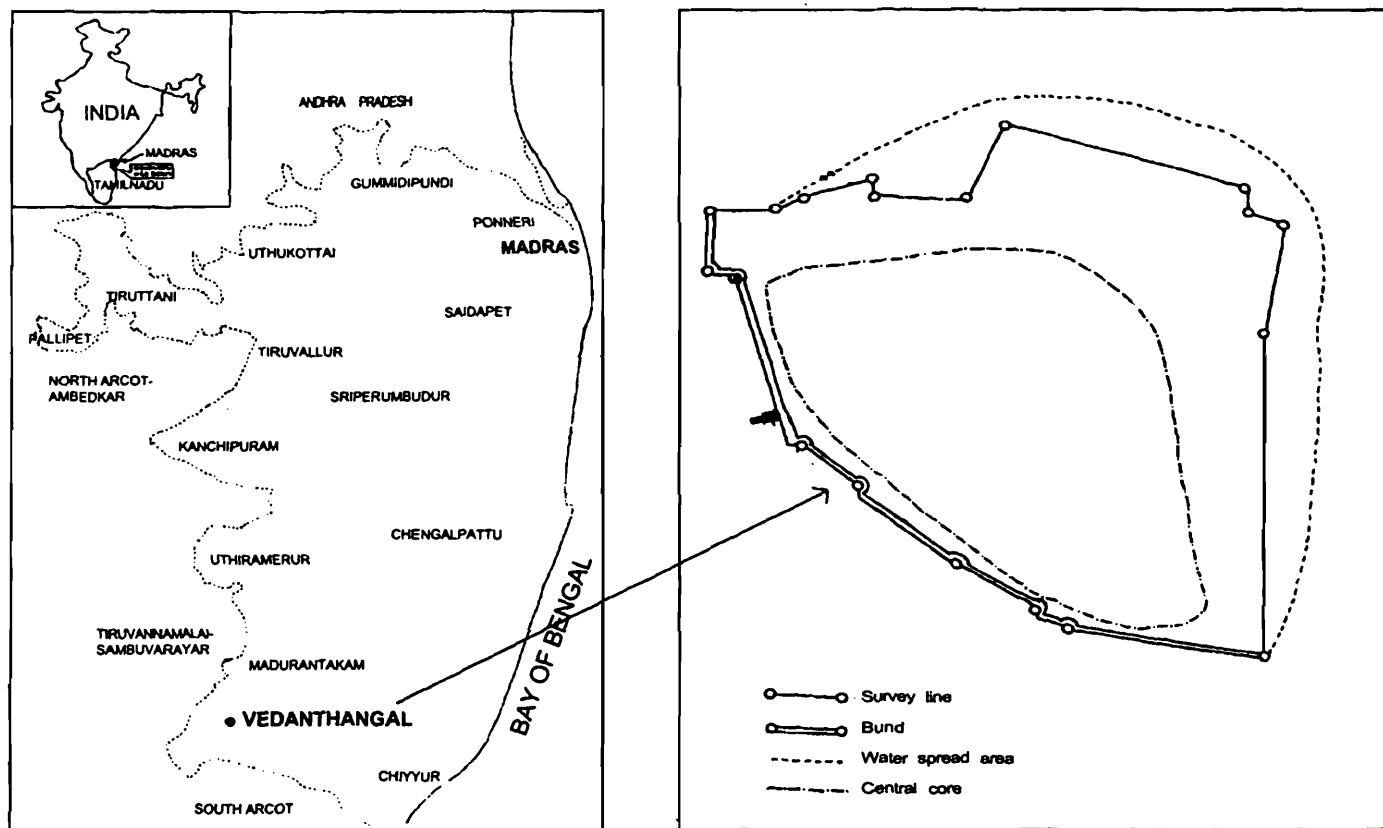


Fig. 1. Map of Vedanthangal Waterbird Sanctuary

and *Phyla nodiflora*. *Acacia nilotica* and *Alangium salvifolium* are the common trees along the bunds. This region receives an average rainfall of 1000mm per annum mostly from the North-East monsoon. The temperature varies from 25°C to 40°C.

A boat was used to cover the entire lake to search for nests. Once nest is located, name of the bird species nested and name of the tree species used for nesting were noted and water level at nest-tree trunk was marked with paint. Other variables namely, total number of nests on the tree, nest height from the water level and ground level, gbh of the tree species, canopy width, bole length (the length starting from ground to where the branch started) and distance to the nearest water spread area were collected after successful fledging. Maximum care was taken not to disturb nesting activities of birds.

Analyses

Pearson correlation co-efficient was performed between the total number of nests in a tree and other parameters. The first three

correlated parameters were again entered in to multiple stepwise regressions. The total number of nests was taken as independent factor and the remaining parameter as a dependent factor. Principal Component Analysis (PCA) was performed on the nesting data to determine the important factor(s) responsible for the nest site selection of waterbirds. All analyses were performed using SPSS 6.1 software. Student 't' test was used to test significance between nesting and non nesting trees of waterbirds.

Niche breadth and niche overlap was calculated for eight waterbird species using the following formula.

Niche breadth

Niche breadth (B_i) of each species was measured by Levin's index (1967) which is the reciprocal of Simpson index.

$$B_i = 1/\sum P_{ij}$$

where B_i = Niche breadth of species j and P_{ij} = The proportion of occurrences of species found j in niche category i

Niche Overlap

The Niche overlap was estimated by Horn's (1966) formula

$$j_k = 2\sum p_{ij} p_{ik} / \sum p_{ij}^2 + \sum p_{ik}^2$$

where j_k = Overlap of species j and k ; p_{ij} = Proportion of occurrences of species j in niche category i and p_{ik} = Proportion of occurrences of species k in niche category i

RESULTS AND DISCUSSION

The analysis of data by Pearson correlation co-efficient, Multiple Stepwise regression and Principle component analysis delineated that tree height, canopy width and tree dbh as crucial factors that could influence waterbird nesting in Vedanthangal and details can be found elsewhere (Venkatraman, 2007).

Niche breadth based on tree height

The niche breadth calculated for the variable tree height among birds varied between 0.23 and 0.50 (Table 1). The lowest was noticed for Eurasian Spoonbill and highest for Oriental White Ibis. Except Grey Heron, all others had a niche breadth between 0.29 and 0.36. These values show that Eurasian Spoonbill is a habitat specialist and White Ibis is a generalist. Other species showed comparatively moderate niche breadth values (Table 1).

Niche breadth based on canopy width

The niche breadth calculated for canopy width among birds ranged from 0.21 to 0.67. Eurasian Spoonbill (0.21) and Asian Openbill Stork (0.29) had low values while White Ibis (0.67), Grey Heron (0.57) and Little Cormorant (0.57) had high niche breadth values (Table 1).

Niche breadth based on tree gbh

The niche breadth calculated for bird species for the selection of the variable tree dbh varied between 0.24 and 0.64. The lowest value was noticed for Black-crowned Night Heron and the highest value for Little Cormorant 0.64. Except Little Cormorant, Little Egret and Cattle Egret, remaining species such as Grey Heron, Asian Openbill Stork and White Ibis appear to be moderate specialists (Table 1).

The overall ranking of niche breadth values indicates that Black-crowned Night Heron and Asian Openbill Stork were generalist in utilizing all the available resources in different habitats effectively. They recorded a high average of 6.075 and 6.062 followed by Spoonbill (5.62) while Little Egret, Cattle Egret and Grey Heron showed more or less the same degree of specialization. As a whole, the Little Cormorant appeared to be the most specialized on all resource.

Table 1. Niche breadth of waterbird species in different resource axes

Bird species	Resource axes							Average rank
	THT	CYL	CYW	GBH	BH	NHG	NHW	
Little Cormorant	0.36	0.34	0.57	0.64	0.41	0.51	0.60	2.75
Little Egret	0.35	0.36	0.44	0.51	0.46	0.48	0.55	3.87
Cattle Egret	0.33	0.48	0.47	0.49	0.36	0.52	0.65	3.50
Grey Heron	0.27	0.36	0.57	0.41	0.66	0.51	0.48	3.50
Asian Open-bill Stork	0.29	0.00	0.29	0.36	0.51	0.00	0.00	6.62
Eurasian Spoonbill	0.23	0.35	0.21	0.27	0.52	0.08	0.12	5.62
Black-crowned Night Heron	0.33	0.31	0.32	0.24	0.31	0.06	0.11	6.75
White Ibis	0.50	0.50	0.67	0.38	0.46	0.28	0.58	2.85

THT-Tree height; CYL-Canopy length; CYW-Canopy width; DBH-Diameter at breast height; BH-Bole height; NHG-Nest height from the ground level; NHW-Nest height from the water level

Niche overlap of water birds

Niche overlap measured by Horn's (1966) index in the eight resource axes, varied from 0.00 to 0.99. Important parameters like tree height, dbh and canopy width were calculated. The highest overlap in the tree height axis with regard to Cattle Egret, Little Cormorant, and Grey Heron was 0.96 and the least in the case of Grey Heron and Night Heron and Black-crowned Night Heron 0.18 (Table). Eight out of 28 pairs showed overlap values more than 0.70 and 13 pairs had values less than 0.40. This indicates that most of the species probably use different heights for nesting (Table 2).

Regarding canopy width, high overlap was recorded in respect of Little Cormorant and Eurasian Spoonbill (0.36). Ten out of 28 pairs showed overlap values more than 0.70 and only one pair had value less than 0.40. This indicates that most of the bird species preferred similar canopy width for nesting (Table 3).

Overlap in tree dbh was high in Asian Openbill Stork and Eurasian Spoonbill (0.93). Low overlap values were recorded for Grey Heron and Night Heron (0.015). Twelve out of 28 pairs had an overlap of more than 0.70 and only 4 pairs showed values less than 0.40 (Table 4).

Table 2. Niche overlap in tree height resource axis

Bird species	Little Cormorant	Little Egret	Cattle Egret	Grey Heron	Asian Openbill Stork	Eurasian Spoonbill	Black-crowned Night Heron	White Ibis
Little Cormorant	-	0.9473	0.9655	0.9677	0.3278	0.3330	0.2068	0.6000
Little Egret		-	0.94915	0.9206	0.2580	0.2388	0.2033	0.5882
Cattle Egret			-	0.9687	0.2539	0.2352	0.2000	0.5000
Grey Heron				-	0.2388	0.2222	0.1875	0.4640
Asian Openbill Stork					-	0.9859	0.4126	0.8000
Eurasian Spoonbill						-	0.3235	0.7666
Black-crowned Night Heron							-	0.5000
White Ibis								-

Table 3. Niche overlap in canopy width resource axis

Bird species	Little Cormorant	Little Egret	Cattle Egret	Grey Heron	Asian Openbill Stork	Eurasian Spoonbill	Black-crowned Night Heron	White Ibis
Little Cormorant	-	0.7812	0.9321	0.7234	0.6025	0.3969	0.6650	0.5540
Little Egret		-	0.8807	0.8832	0.7018	0.5975	0.6237	0.5457
Cattle Egret			-	0.8259	0.6251	0.4640	0.6046	0.4736
Grey Heron				-	0.7404	0.7106	0.6753	0.6940
Asian Openbill Stork						0.9316	0.4665	0.6088
Eurasian Spoonbill							0.4136	0.6376
Black-crowned Night Heron							-	0.4099
White Ibis								-

Table 4. Niche overlap in tree dbh resource axis

Bird species	Little Cormorant	Little Egret	Cattle Egret	Grey Heron	Asian Openbill Stork	Eurasian Spoonbill	Black-crowned Night Heron	White Ibis
Little Cormorant		0.9066	0.8999	0.8686	0.5245	0.5101	0.3646	0.7637
Little Egret			0.9314	0.9423	0.6222	0.6766	0.2774	0.7526
Cattle Egret				0.8990	0.5834	0.5960	0.2848	0.7195
Grey Heron					0.4346	0.5028	0.1509	0.6423
Asian Openbill Stork						0.9501	0.6582	0.7447
Eurasian Spoonbill							0.4521	0.7558
Black-crowned Night Heron								0.4571
White Ibis								

Depending the range of adaptability and specialization, waterbirds could be placed in an ascending order as below: Black-crowned Night Heron > Asian Openbill Stork > Eurasian Spoonbill > Little Egret > Cattle Egret > Grey Heron > White ibis > Little Cormorant. This showed the existence of social hierarchy in waterbirds to certain extent (Miller, 1987; Morse, 1974). Normally large sized birds showed high niche breadth (Hutchinson, 1959; Morse, 1974; Vijayan, 1984). Contrary to this, Black-crowned Night heron, a medium sized bird when compared to other species, showed a high niche breadth values in the present study.

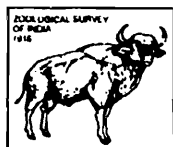
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DIVERSITY OF WETLANDS BIRDS IN THE THAR DESERT, INDIA

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INTRODUCTION

The Great Indian Desert or Thar Desert is biogeographically the easternmost edge of the Saharan-Arabian Desert zone, with an extent of 280,000 km² consisting 61 per cent of the total geographical area of the State. The hot desert in the north-western region of India is unique and the only habitat type over the Indian subcontinent. The Great Indian Desert is considered to be a unique desert because of its location at the crossing where Palaearctic, Oriental and Saharan elements of biodiversity both at species level and at the level of ecological communities are found. The number of species of plants and animals may be low but their xerophytic characteristics make some of them a special taxonomic significance. Animals and plants have developed to adapt to the difficult climate conditions with extreme temperature and lack of moisture.

The arid climate has marked variations in diurnal and seasonal range of temperature, exhibiting the most characteristic phenomenon of the warm-dry continental climate. During summer (March to June), the maximum temperature can go up to 48°C, and occasionally rises to 51°C. The night temperature drops down considerably and remains between 20° C to 29° C. January is observed as the coldest

month. During winter (December to February) minimum temperature may fall to -2°C in night. Occasional secondary Western disturbances which mostly cross western, northern and eastern Rajasthan during winter months, causing light rainfall and increased wind speed creates wind-chill effect.

The average rainfall of the state varies less than 10 cm to 160 cm in the Thar Desert. The main rivers of the State are Luni, Kantli, Gambhiri, Chambal, Banas, Banghargh and Matri. Of these Luni, Kantli and Dohan are run across the Thar Desert. Prasad *et al.* (2004) have been reported detailed district wise wetland in the Thar Desert (Table 1). Objectives of this paper aim to present the detailed diversity and distribution of wetland birds in the Thar Desert.

MATERIALS AND METHODS

The study was conducted during the period from May 2000 to January 2004. Bird species were assessed in different wetlands by total count and point count method (Burnham *et al.*, 1980; Hoves and Bakewell, 1989). Total of 26 wetlands were surveyed and species richness and species composition of birds in different wetlands were computed from the census data. Birds were identified based on physical features with the help of field guides and reference

Table 1. District wise distribution of wetlands in Thar Desert (Prasad *et al.*, 2004)

District	Geographical Area (km ²)	Wetland Extent (km ²)	Per cent of Geographical Area Under Wetlands
Ajmer	8481.00	160.80	1.90
Barmer	283870.00	210.24	0.74
Bikaner	27284.00	17.26	0.06
Dhaulpur	3033.00	52.64	1.74
Ganganagar (Including Hanumangarh)	20634.00	83.07	0.40
Jaisalmer	38428.00	212.20	0.55
Jalore	10640.00	385.52	3.62
Jodhpur	22783.00	119.73	0.53
Nagaur	17718.00	208.94	1.18
Pali	12387.00	189.93	1.53
Sikar	7732.00	9.86	.013
Sirohi	5136.00	45.24	0.88

books (Ali and Ripley, 1983; Grimmett *et al.*, 1998). The Common and scientific names are after Manakadan and Pittie (2001).

Species richness and abundance

Species richness and abundance of birds in the study area were calculated from the census data and field observations. Species richness indices were calculated using the formula given by Magurran (1988).

Species diversity indices

Shannon-Weiner (H'), Simpson's (λ), and Hill's diversity number N_1 and N_2 were calculated using the computer program SPDIVERS. BAS developed by Ludwig and Reynolds (1988).

RESULTS AND DISCUSSION

Total of one hundred and twenty species wetland and wetland dependant species of birds were recorded during the period of the study. Of these, Common coot (37.90) showed highest in abundance followed by Lesser Flamango (6.81), Black-winges Stilt (5.14) and Streak-throated Swallow (3.51). Species like

White-eyed Buzzard, Marsh Sandpiper, Indian White-backed Vulture, Comb Duck, Common Shelduck, Bronze-winged Jacana, Buff-breasted Sandpiper, Black-crowned Night Heron, Black Bittern, Chestnut Bittern, Eurasian Sparrowhawk, Great Spotted Eagle, Eastern Imperial Eagle, Gull-billed Tern and White-tailed lapwing were showed less than 0.01 per cent in abundance (Table 2).

The species richness and abundance of birds were varied in different orders. The species richness was highest in the order Charadriiformes and Anseriformes. The abundance was maximum in Gruiformes and minimum in Falconiformes (Table 3).

Among the wetlands the species richness was highest in IGNP canal area and abundance in Kailana Lake (Table 4).

Diversity Indices of birds : Most widely used wetland diversity indices like Shannon-Weiner Index, Simpson's Index and Hill's numbers were estimated for the Thar desert birds of Richness Index (R_1 and R_2) showed the richness of birds. Shannon Index (H') showed high values of diversity, similarly Hill's number also showed high values (Table 5).

Table 2. Abundance of wetland birds in the Thar Desert (+ = less than 0.01)

Sl. No	Name of the species	Estimated number of individuals	Dominance
1.	Common Coot	8709	37.90
2.	Lesser Flamingo	1565	6.81
3.	Black-winged Stilt	1180	5.14
4.	Streak-throated Swallow	806	3.51
5.	Bar-headed Goose	744	3.24
6.	Little Ringed Plover	539	2.35
7.	Little Cormorant	475	2.07
8.	Common Redshank	472	2.06
9.	Red-wattled Lapwing	461	2.01
10.	Little Stint	459	2.00
11.	Northern Shoveller	416	1.81
12.	Little Egret	406	1.77
13.	Asian Openbill-Stork	391	1.70
14.	Little Grebe	385	1.67
15.	Temminck's Stint	248	1.08
16.	Common Teal	248	1.08
17.	Common Poachard	242	1.05
18.	Pied Avocet	241	1.05
19.	Great Cormorant	236	1.03
20.	Northern Pintail	230	1.00
21.	River Tern	222	0.97
22.	Lesser Sand Plover	220	0.96
23.	Spotted Redshank	206	0.89
24.	Spot-billed Duck	172	0.75
25.	Ruff	167	0.73
26.	Cattle Egret	166	0.72
27.	Common Swallow	157	0.68
28.	Greater Flamingo	152	0.66
29.	Oriental White Ibis	151	0.66
30.	Large Egret	143	0.62
31.	Green Sandpiper	143	0.62
32.	Common Moorhen	140	0.61
33.	Wood Sandpiper	131	0.57
34.	Medium Egret	130	0.56
35.	Demoiselle Crane	117	0.51
36.	Tufted Duck	107	0.47
37.	Dalmatian Pelican	100	0.44
38.	Green Bee-eater	100	0.43
39.	Whiskered Tern	97	0.42
40.	Common Sandpiper	87	0.38

Table 2. *Contd.*

Sl. No	Name of the species	Estimated number of individuals	Dominance
41.	Eurasian Spoonbill	82	0.36
42.	Beach Stone Plover	76	0.33
43.	Yellow-wattled lapwing	75	0.33
44.	Indian Shag	67	0.29
45.	Painted Stork	67	0.29
46.	Brahminy Shelduck	64	0.28
47.	Kentish Plover	64	0.28
48.	Stone Curlew	63	0.27
49.	Indian Pond-Heron	61	0.27
50.	Red-rumped Swallow	56	0.25
51.	Lesser Whistling-Duck	53	0.23
52.	Gray Heron	52	0.23
53.	Eurasian Wigeon	52	0.22
54.	Black-tailed Godwit	47	0.21
55.	Purple Heron	44	0.19
56.	Great White Pelican	43	0.19
57.	Gadwall	42	0.18
58.	Large Pied Wagtail	40	0.17
59.	Sarus Crane	36	0.16
60.	Grey Wagtail	35	0.15
61.	Black-headed Gull	35	0.15
62.	Garganey	32	0.14
63.	Small Partincole	31	0.13
64.	White Wagtail	26	0.12
65.	Spot-billed Pelican	26	0.11
66.	Marbled Teal	24	0.10
67.	Citrine Wagtail	24	0.10
68.	White-breasted Kingfisher	22	0.09
69.	Mallard	19	0.08
70.	Greater Scaup	19	0.08
71.	Purple Moorhen	19	0.08
72.	Darter	18	0.08
73.	Common Snipe	18	0.08
74.	Ferruginous Pochard	15	0.07
75.	Yellow Wagtail	14	0.06
76.	Tawny Eagle	12	0.05
77.	Blue-cheeked Bee-eater	11	0.05
78.	Common Greenshank	8	0.04
79.	Curlew Sandpiper	8	0.03
80.	Northern House Martin	7	0.03

Table 2. Contd.

Sl. No	Name of the species	Estimated number of individuals	Dominance
81.	Yellow-legged Gull	7	0.03
82.	Lessar Pied Kingfisher	7	0.03
83.	Small Blue Kingfisher	7	0.03
84.	Western Marsh-Harrier	6	0.03
85.	White-necked Stork	6	0.03
86.	Black Ibis	6	0.03
87.	Shikra	6	0.02
88.	Pallas's Gull	5	0.02
89.	Egyptian Vulture	4	0.02
90.	Pallid Harrier	4	0.02
91.	Common Crane	4	0.02
92.	Pheasant-tailed Jacana	3	0.01
93.	Black Kite	3	0.01
94.	Black Winged Kite	3	0.01
95.	Eurasian Curlew	3	0.01
96.	Osprey	3	0.01
97.	Glossy Ibis	2	0.01
98.	Cotton Teal	2	0.01
99.	Indian Cursor	2	0.01
100.	Little Green Heron	2	0.01
101.	Black Kite	2	0.01
102.	Wire-tailed Swallow	2	0.01
103.	Paddyfield Pipit	2	0.01
104.	White-breasted Waterhen	2	0.01
105.	Broadbilled Sandpiper	2	0.01
106.	White-eyed Buzzard	1	+
107.	Marsh Sandpiper	1	+
108.	Indian White-backed Vulture	1	+
109.	Comb Duck	1	+
110.	Common Shelduck	1	+
111.	Bronze-winged Jacana	1	+
112.	Buff-breasted Sandpiper	1	+
113.	Black-crowned Night Heron	1	+
114.	Black Bittern	1	+
115.	Chestnut Bittern	1	+
116.	Eurasian Sparrow-hawk	1	+
117.	Great Spotted Eagle	1	+
118.	Eastern Imperial Eagle	1	+
119.	Gull-billed Tern	1	+
120.	White-tailed lapwing	1	+

Table 3. Order wise richness and abundance of wetland birds in the Thar Desert

Order	Richness	Abundance
Anseriformes	20	2491
Charadriiformes	35	5323
Ciconiiformes	18	1711
Coraciiformes	4	139
Falconiformes	14	47
Pelecaniformes	7	965
Phoenicopteriformes	2	1718
Passeriformes	12	1171
Podicipediformes	1	385
Gruiformes	7	9026

Table 4. Wetland wise richness and abundance of wetland birds in the Thar Desert

Sl. No.	Name of the wetland	Species richness	Species Abundance
1.	Kailana Lake	47	2856
2.	Pachpatra	48	2032
3.	Kharda Dam	19	2008
4.	Hemavas Dam	40	1783
5.	Phulad Dam	21	1705
6.	Khejri Pond	4	1511
7.	Badopal	19	1365
8.	Sardar Samand Dam	16	1243
9.	Jawai Dam	33	1234
10.	Gajner Lake	15	950
11.	Lakhotia	23	791
12.	Didwana	5	718
13.	Kharda Dam	30	605
14.	Gadisar Lake	17	577
15.	Guda	25	564
16.	IGNP canal area	84	503
17.	Ummaid Bhawan lake	20	489
18.	Bhawatra (Luni River)	18	451
19.	Kumahara Tank	11	349
20.	Digha lake	18	281
21.	Jaziwal Dam	22	251
22.	Gundoj Dam	17	166
23.	Kukkadra (Rann of Kachchh)	13	87
24.	Sultana Lake	11	64
25.	Tal Chhaper	29	57
26.	Gajner Lake	6	50

Table 5. Diversity indices of wetlands birds in the Thar Desert

Richness indices		Diversity indices		Hill's Numbers		Evenness indices	
R1	R2	Simpson	Shannon	N1	N2	E1	E2
11.85	0.79	0.16	2.99	19.94	6.32	0.63	0.17

The diversity indices of birds in different wetlands were presented in Table 6. Highest diversity of Shannon Index was observed in Pachpatra, followed by Tal Chaper and Jawai Dam. Similarly the Richness indices of R1 and R2 also higher in IGNP canal area, Tal chapper, and Patchpatra.

Wetlands have been distinctively described as "biological supermarket" because of the exclusive food webs and rich biodiversity (Mitch and Gosselink, 1993). Wetlands dependent species are often rare, threatened or found only in a very restricted geographical area. Freshwater wetlands and rivers contain 0.008 per cent of the world's water but are of great importance for biodiversity as they hold 12 per cent of all animal species (Shine and de Klemm, 1999). Species richness and abundance of birds showed high values in the wetlands of Thar Desert, which is comparable to other wetlands in India and other countries (Sampath, 1989; Saikia and Bhattacharjee, 1990; Natarajan, 1991; Dann, 1994; Balachandran, 1995; Kurup, 1996; Nagarajan and Thiyagesan, 1996; Kar and Sahu, 1996; Nazarov and Mukhina,

1996; Shuford *et al.*, 1998; Jayson and Easa, 2000; Verma *et al.*, 2002) (Table 7).

Species richness in an area is dependent on the availability of food, climate evolutionary history and predation pressure. Diversity indices are dependent on two factors, species richness and evenness. It is directly correlated with the stability of the ecosystem. It will be higher in the biologically controlled systems and low in disturbed ecosystem. In the wetlands of Thar Desert, diversity indices were higher. As the evenness measures also showed high values, it could be concluded that species of individuals uniformly presented and this indicated the conservation value of the wetlands.

The wetlands in the Thar Desert served many avian species for a wide variety of purposes such as nesting and roosting and act as wintering ground. Maintenance of habitat diversity is essential for avian diversity, which requires various natural water regimes and plant communities. The present study showed that the wetlands in the Thar Desert are one of the important regions in the western India for winter visitors.

Table 6. Diversity indices of wetlands birds in different wetlands in the Thar Desert

Name of the wetlands	Richness indices		Diversity indices		Hill's Number		Evenness indices	
	R1	R2	Simpson	Shannon	N1	N2	E1	E2
Kailana Lake	5.78	0.88	0.60	1.26	3.51	1.66	0.33	0.07
Pachpatra	6.17	1.06	0.06	3.18	24.06	18.06	0.82	0.50
Kharda Dam	2.37	0.42	0.34	1.38	3.96	2.91	0.47	0.21
Hemavas Dam	5.21	0.95	0.31	1.98	7.23	3.25	0.54	0.18
Phulad Dam	2.69	0.51	0.77	0.69	2.00	1.29	0.23	0.10
Khejri Pond	0.41	0.10	0.98	0.05	1.05	1.02	0.04	0.26
Badopal	2.49	0.51	0.16	2.18	8.84	6.13	0.74	0.47
Sardar Samand Dam	2.11	0.45	0.13	2.30	9.94	7.71	0.83	0.62
Jawai Dam	4.49	0.94	0.11	2.60	13.41	8.78	0.74	0.41
Gajner Lake	2.04	0.49	0.80	0.57	1.76	1.25	0.21	0.12

Table 6. Contd.

Name of the wetlands	Richness indices		Diversity indices		Hill's Number		Evenness indices	
	R1	R2	Simpson	Shannon	N1	N2	E1	E2
Lakhotia	3.30	0.82	0.58	1.08	2.96	1.71	0.35	0.13
Didwana	0.61	0.19	0.77	0.47	1.60	1.30	0.29	0.32
Kharda Dam	4.53	1.22	0.15	2.39	10.96	6.67	0.70	0.37
Gadisar Lake	2.52	0.71	0.39	1.49	4.43	2.54	0.52	0.26
Guda	3.16	0.88	0.36	1.44	4.21	2.77	0.47	0.20
IGNP Canal area	8.84	2.50	0.17	2.74	15.55	5.72	0.68	0.28
Ummaid Bhawan lake	3.07	0.90	0.19	2.18	8.82	5.33	0.73	0.44
Bhawatra (Luni River)	2.78	0.85	0.20	2.00	7.38	4.91	0.69	0.41
Kumahara Tank	1.71	0.59	0.41	1.18	3.27	2.42	0.49	0.30
Digha lake	3.01	1.07	0.13	2.26	9.56	7.50	0.78	0.53
Jaziwal Dam	3.78	1.37	0.17	2.15	8.56	5.96	0.69	0.39
Gundoj Dam	3.13	1.32	0.14	2.27	9.72	7.35	0.80	0.57
Kukkadra (Rann of Kachhh)	2.69	1.39	0.22	1.83	6.26	4.45	0.72	0.48
Sultana Lake	2.40	1.38	0.20	1.85	6.33	4.99	0.77	0.58
Tal Chhaper	6.90	3.81	0.12	2.73	15.40	8.58	0.81	0.53
Gajner Lake	1.28	0.85	0.34	1.35	3.87	2.95	0.76	0.65

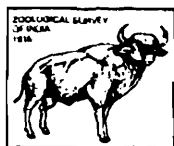
Table 7. Comparison of present study with other wetland in India and other countries

Habitat type	Number of species	Reference
Kole wetlands, Kerala	182	Sivaperuman, 2004
Thar Desert, Rajasthan	120	Present study
California Central Valley	33 (Shore birds)	Shuford <i>et al.</i> 1998
Mahul Creek, Mumbai	112	Verma <i>et al.</i> 2002
Brahmaputra Valley, Assam	57	Saikia and Bhattacharjee, 1990
Coastal Victoria	33 (Shore birds)	Dann, 1994
Gulf of Mannar, Tamil Nadu	187	Balachandran, 1995
Point Calimere, Tamil Nadu	38 (Shore birds)	Natarajan, 1991
Chilika Lake, Orissa	111	Kar and Sahu, 1996
Uzbekistan	422	Nazarov and Mukhina, 1996

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POPULATION FLUCTUATIONS OF SHOREBIRDS IN THE VEMBANAD-KOLE RAMSAR SITE, SOUTHERN INDIA

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INTRODUCTION

Shorebirds belong to the order Charadriiformes and members occupy wide range of environments. Habitat includes coastal, saline and freshwater wetlands, flooded agriculture fields, interior grasslands and arctic tundra. A great deal of attention has been paid and significant studies were made in the past on migratory shorebirds in the world. They are amongst the world's longest migrants and considered as "truly international" species, as most of them nest in one country, migrate long distances and spend non-breeding period in another country (Howes and Bakeswell, 1989).

Previous information on shored birds studies in Palearctic and Australian waders in the Coastal Victoria (Dann, 1994), bird species richness and seasonality in Texas Estuarine Wetland in U.S.A. (Weller, 1994), Population of Avocet in Humboldt Bay, California (Evans and Harris, 1994), Species composition and abundance in Playa Lakes, Texas (Davis and Smith, 1998), population dynamics in California's Central Valley, Western North America (Shufford *et al.*, 1998), population and

migration of Red Shank in Gulf of Gdansk, Poland (Meissner, 2000).

A small number of studies have been conducted in India, ecology and biology of selected species (Krishna Raju, 1980), ecology of shorebirds at Great Vedaranyam Swamp (Sampath and Krishnamurthy, 1989; Sampath 1989 and 1991), status, population, arrival and departure at the Mandapam and Marine National Park in Gulf of Mannar (Balachandran, 1990 and 1995), habitat use in the Pichavaram Mangroves (Nagarajan and Thiyagesan, 1995, 1996 and 1998), status and population in Chilika Laka (Acharya, 2000). Based on the above fact no systematic studies have been conducted in the Kole wetlands of Thrissur which is the part of Vembanad Kole Ramsar site other than the sighting and occurrence reports. The aim of this paper was to describe the population fluctuation of selected species of shorebirds in relation to environmental factors.

STUDY AREA

The Kole wetlands lie between 10°20' and 10°40' N latitudes and 75°58' and between 76°11' E longitudes. The Kole wetlands with

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an extent of 13,632 ha are spread over Thrissur and Malappuram Districts in Kerala State. It extends from the northern banks of Chalakudy River in the South to the southern banks of Bharathapuzha River in the North. Eastern side of Kole wetlands is Thrissur town and western side extends up to Arabian Sea.

The climate of the area is moderate and there are three different distinct seasons. The dry season (December to April), wet season-I (May to August) during the period of southwest monsoon and wet season-II (September to November) during northeast monsoon. About 60 per cent of the rainfall is obtained during the southwest monsoon, 30 per cent during the northeast monsoon and the remaining 10 per cent in summer. The average annual rainfall is 3,200 mm and there is a variation in the temporal distribution of rainfall. Maximum rainfall is received during the month of June followed by July. Extremes of heat or cold are not felt and the temperature varied from 28°C to 31.5°C. Atmosphere is always damp along the coastal belt due to high humidity.

METHODS

The study was conducted from November 1998 through October 2001 and it was mainly based on direct observational methods (Altman, 1974). Total count method was used for census the birds (Hoves and Bakewell, 1989). In this method, representative blocks were identified and birds in the blocks were counted using a telescope (15x - 45x). The census was conducted from 0700 to 1000 hour. Birds were identified based on physical features with the help of field guides and reference books (Ali and Ripley, 1983; Grimmett *et al.*, 1998).

Estimation of benthic fauna : The mud samples were collected from different microhabitats viz. shallow water, mud flats and paddy fields during the migratory seasons by Naturalist's dredge method (size 32.14 cm, depth 32 cm) in the intensive study areas. The dredge was towed at a minimum speed and for a distance of 30 cm. The mud samples were collected from the plots identified for censusing

the birds. From each plot 5 samples were collected and the collected mud was sieved through 0.5 mm sieve and the fauna were filtered and preserved in 5 per cent formaldehyde (Strin, 1981). The benthic animals were identified up to Class by using Ward and Whipple (1945) and Hyman (1967).

Estimation of macro fauna : Macro fauna was collected from the shallow water, mudflats and paddy fields using quadrat method. The size of the quadrat was 1 m × 1 m at the intensive study areas and the frequencies of each animal category for each microhabitat were recorded. Samples were collected from the plots uniformly representing all the areas. The collection was done only during migratory season. In each month, five samples (Quadrat) were collected from each identified plots in the intensive study areas. Prey items were identified up to broad taxonomic categories such as Crabs and Snails (Hafner *et al.*, 1986). The collected organisms were preserved in 20 per cent formaldehyde. Sampling was done in all habitats in each month and the abundance of each category for each habitat was recorded.

Analysis of variance (ANOVA) (Gomez and Gomez, 1984) was performed to examine the variation of abundance in benthic and macro fauna over the years in different habitats. The analysis was carried out with log-transformed data.

RESULTS

Influence of the microhabitat and year on the abundance

Benthic fauna

Two way analysis of variance (ANOVA) was performed on abundance of benthic fauna to detect significant difference between the habitats and the year. There was significant difference between the habitat and year in the abundance of Insecta, Polycheta, Gastropoda and Crustacea. Interaction between the habitat and year indicated that the abundance of Insecta in different habitats varied significantly over the years. (Table 1).

Table 1. Analysis of Variance for benthic fauna

	DF	SS				MSS				F			
	Insecta - Crustacea	Insecta	Polycheta	Gastropoda	Crustacea	Insecta	Polycheta	Gastropoda	Crustacea	Insecta	Polycheta	Gastropoda	Crustacea
Habitat	2	0.537	1.365	0.642	30.416	0.268	0.268	0.321	15.208	3.316*	10.633***	3.731*	5.773*
Year	2	0.737	1.612	0.41	2.275	0.369	0.369	0.205	1.137	4.553**	12.559***	2.386*	0.432 ^{NS}
Habitat* Year	4	1.57	0.348	0.591	9.141	0.393	0.393	0.148	2.285	4.849**	1.356 ^{NS}	1.718 ^{NS}	0.867 ^{NS}
Error	36	2.915	2.31	3.097	94.844	0.08	0.08	0.086	2.635				
Total	44	5.759	5.635	4.74	136.676								

** = <0.01; * = 0.05; *** = <0.001; NS = Not significant

Macro fauna

Two way analysis of variance (ANOVA) was performed on abundance of macro fauna to test the significant difference between the habitats and the year. There was no significant difference between the habitats and year in the abundance of Snail. Macro fauna of Crab showed that significant difference between the habitats. However there was no significant difference between the years and interaction between the year and the habitat (Table 2).

Population fluctuations of shorebirds in relation to benthic fauna

Common Sandpiper (*Actitis hypoleucos*)

The Common Sandpiper was recorded in the Kole wetland from September to March and the population size differed annually. Highest number of birds was recorded in the second year (1999-2000) (Table 3). The abundance of

Common Sandpiper and benthic fauna was negatively correlated with Crustacea ($r = -0.68$, $P < 0.05$, $n = 7$) in the mudflats. However, there was no significant correlation with Insecta, Polycheta and Gastropoda. This was correlated with Polycheta ($r = 0.57$, $P < 0.10$, $n=7$) in shallow water and not significant with Insecta, Gastropoda and Crustacea. Insecta, Polycheta, Gastropoda and Crustacea were not significantly correlated with the abundance of Common Sandpiper in the Paddy fields.

Curlew Sandpiper (*Calidris ferruginea*)

Curlew Sandpiper was recorded only in two seasons (1999-2000 and 2000-2001). Highest abundance was recorded in December (1999) and January (2001) and the lowest was in March (2001) (Table 3). The population size of Curlew Sandpiper showed significant correlation with Insecta ($r = 0.72$, $P < 0.02$, $n = 7$) in Mud flats and there was no significant correlation with

Table 2. Analysis of Variance for macro fauna

Source	DF	SS		MSS		F	
	Snail & Crab	Snail	Crab	Snail	Crab	Snail	Crab
Habitat	2	0.150	11.432	0.075	5.716	0.500 ^{NS}	10.690***
Year	2	0.188	2.189	0.094	1.095	0.626 ^{NS}	2.047*
Habitat* Year	4	0.435	0.641	0.109	0.160	0.725 ^{NS}	0.300 ^{NS}
Error	36	5.401	19.250	0.150	0.535		
Total	44	6.173	33.512				

*** = 0.001; * = <0.05; NS = Not significant

Table 3. Abundance of shorebirds during the three migratory seasons in the Kole wetlands

Species name	Season	Month						
		Sept	Oct	Nov	Dec	Jan	Feb	Mar
Common Sandpiper	98-99	0	0	79	141	25	1	29
	99-00	8	239	266	974	27	52	130
	00-01	576	12	14	32	18	22	264
Curlew Sandpiper	98-99	0	0	0	0	0	0	0
	99-00	0	24	764	1278	21	0	0
	00-01	579	158	289	0	1172	0	0
Little Ringed Plover	98-99	0	0	0	30	2	46	7
	99-00	0	0	2234	984	722	0	0
	00-01	89	214	1006	179	508	12	371
Eurasian Curlew	98-99	0	0	0	0	0	56	0
	99-00	0	28	286	429	312	0	0
	00-01	332	240	697	0	8	0	0
Little Stint	98-99	0	0	0	66	0	0	0
	99-00	0	15	2981	1710	278	0	0
	00-01	4244	67	2456	12	440	0	0
Wood Sandpiper	98-99	0	0	0	92	111	76	39
	99-00	1	228	1245	3674	1368	68	60
	00-01	1834	1034	1778	611	316	65	476
Red Shank	98-99	0	0	7	0	0	1	0
	99-00	0	0	26	0	8	0	0
	00-01	4	0	0	4	0	0	0
Green Shank	98-99	0	0	0		30	0	5
	99-00	0	15	50	30	8	56	14
	00-01	0	12	0	0	24	16	147
Green Sandpiper	98-99	0	0	0	0	0	3	3
	99-00	0	138	144	0	42	0	0
	00-01	582	0	0	0	0	0	0
Small Pratincole	98-99	0	0	0	0	18	0	0
	99-00	0	0	356	426	1176	0	0
	00-01	22	0	0	0	0	0	0
Blackwinged Stilt	98-99	0	0	0	0	5	0	0
	99-00	0	11	58	202	42	0	0
	00-01	0	0	8	0	0	4	182
Marsh Sandpiper	98-99	0	0	0	0	0	0	0
	99-00	0	0	213	40	19	0	0
	00-01	0	0	913	0	12	0	0
Lesser Sand Plover	98-99	0	0	0	0	0	0	0
	99-00	0	0	0	126	0	0	0

Polychaeta, Gastropoda and Crustacea. There was significant correlation with Crustacea ($r = -0.65$, $P < 0.05$, $n=7$), but no significance was observed with Insecta, Polychaeta and Gastropoda in Shallow water and Paddy fields.

Little Ringed Plover (*Charadrius dubius*)

There were monthly variations in the abundance of Little Ringed Plover. There were two peaks in the population in November and January during 2000-2001 (Table 3). A significant correlation was found between the population size of Little Ringed Plover and abundance of Insecta and Crustacea ($r = 0.70$, $P < 0.02$, $n=7$), ($r = -0.58$, $P < 0.10$, $n=7$) in Mud flats, however there was no correlation was found with Polychaeta and Gastropoda. It was significantly correlated with Polychaeta (-0.59 , $P < 0.10$, $n = 7$), Crustacea ($r = -0.77$, $P < 0.02$, $n=7$) in the Shallow water and it was not correlated with Insecta and Gastropoda. No significant correlation was found with Insecta, Polychaeta, Gastropoda and Crustacea in the Paddy fields.

Eurasian Curlew (*Numenius arquata*)

Eurasian Curlew arrived in the study area during September in the second (1999-2000) and third year (2000-2001) mainly attracted to the shallow water habitat. The highest abundance was recorded in November (1998-99) and in December (1999-2000) (Table 3). The population of Curlew was significantly correlated with Insecta ($r = 0.69$, $P < 0.05$, $n=7$) in Mud flats and it was not correlated with Polychaeta, Gastropoda and Crustacea. There was significant correlation with Crustacea ($r = -0.76$, $P < 0.02$, $n=7$) in the shallow water and correlation was not significant with other groups like Insecta, Polychaeta and Gastropoda. The population of Curlew was significantly correlated with Gastropoda ($r = -0.57$, $P < 0.10$, $n=7$) in the Paddy fields, and there was no correlation with Insecta, Polychaeta and Crustacea.

Little Stint (*Calidris minuta*)

The emergence of mud flats attracted this species into the Kole wetlands. The highest number of birds was observed in November

(1999-2000) and September (2000-2001) (Table 3). During the year 2001, two peaks of population were observed. The first one was in September and the second in November. The change of the preferred microhabitat into non-preferred one showed the decline in number of birds, which happened in February and March throughout the study period. Population size of Little Stint was found significantly correlated with Crustacea ($r = 0.59$, $P < 0.10$, $n=7$) in the Mud flats. It was also correlated with Crustacea ($r = -0.54$, $P < 0.10$, $n=7$) in the Shallow water and there was no significant correlation with other groups in other habitats.

Wood Sandpiper (*Tringa glareola*)

Wood Sandpiper is the common wader species in the Kole wetlands and they arrived much earlier than the other species. The peak in the population was observed in December (1999-2000) and in November (2000-2001) (Table 3). Abundance of Wood Sandpiper was found significantly correlated with Insecta ($r = 0.70$, $P < 0.02$, $n=7$) in Mud flats and was not correlated with Polychaeta, Gastropoda and Crustacea. Significant correlation was observed with Crustacea ($r = -0.82$, $P < 0.01$, $n = 7$) in the Shallow waters and no correlation with Insecta, Polychaeta and Gastropoda. Significant correlation was found between population of Wood Sandpiper and Insecta ($r = 0.61$, $P < 0.05$, $n=7$), Gastropoda ($r = -0.51$, $P < 0.10$, $n=7$) in the paddy fields, whereas it was not significant with Polychaeta and Crustacea.

Common Redshank (*Tringa totanus*)

This species was recorded in the Kole wetland from September to March in all the year. The population size fluctuated every month and a decline was observed in February and March (Table 3). Two peaks in population were observed, one was in November and the other in January during 1999-2000. The population size of Common Red Shank was significantly correlated with the population of Insecta ($r = 0.58$, $P < 0.10$, $n=7$), Crustacea ($r = 0.68$, $P < 0.05$, $n = 7$) in mud flats, whereas no significant correlation was observed with Polychaeta and Gastropoda. Similarly,

significant correlation was observed with Polychaeta ($r = -0.63$, $P < 0.05$, $n = 7$) and Crustacea ($r = -0.74$, $P < 0.02$, $n = 7$), but the correlation with Insecta and Gastropoda was not significant in shallow water and paddy fields.

Common Greenshank (*Tringa nebularia*)

This species was observed in the Kole wetlands from September to March and the species utilised shallow waters and mud flats. The peaks were in November and February during 1999-2000 (Table 3). Significant correlation was found with the abundance of Common Green Shank and Gastropoda ($r = 0.60$, $P < 0.05$, $n = 7$) in mud flats and it was not significant with Insecta, Polychaeta and Crustacea. Similarly, significant correlation was found with Insecta ($r = 0.55$, $P < 0.10$, $n = 7$) in the paddy fields and there was no significant correlation with other groups in the shallow water and paddy fields.

Green Sandpiper (*Tringa ochropus*)

Green Sandpiper was recorded from September to March during the second (1999-2000) and third year (2000-2001), but no bird was observed in the first year. The peak population was observed in September (2000) (Table 3). The population abundance of Green Sandpiper was significantly correlated with Gastropoda ($r = -0.92$, $P < 0.01$, $n = 7$) in the mud flats. Significant correlation was observed with Insecta ($r = 0.55$, $P < 0.10$, $n = 7$) and Gastropoda ($r = 0.74$, $P < 0.02$, $n = 7$) in the shallow waters. Significant correlation was obtained with Polychaeta ($r = -0.66$, $P < 0.05$, $n = 7$), Gastropoda ($r = -0.53$, $P < 0.10$, $n = 7$) and Crustacea ($r = -0.54$, $P < 0.10$, $n = 7$) in the paddy fields.

Small Pratincole (*Glareola lactea*)

Small Pratincole was observed throughout the study period, but highest population was recorded in January during 1999-2000 (Table 3). Significant positive correlation was observed with Polychaeta ($r = 0.72$, $P < 0.02$, $n = 7$) in the mud flats. The correlation with Crustacea ($r = 0.58$, $P < 0.10$, $n = 7$) was also significant in the

shallow waters. There was significant correlation between abundance of birds with Insecta ($r = 0.72$, $P < 0.01$, $n = 7$), Polychaeta ($r = 0.6$, $P < 0.05$, $n = 7$), Crustacea ($r = 0.80$, $P < 0.01$, $n = 7$) and Gastropoda ($r = -0.55$, $P < 0.10$, $n = 7$) in the paddy fields.

Blackwinged stilt (*Himantopus himantopus*)

They were found in the Kole wetlands from September to March in all the migratory seasons. The peak population was recorded in December (1999-2000) and March (2000-2001) (Table 3). Abundance of Blackwinged Stilt was found significantly correlated with Insecta ($r = 0.59$, $P < 0.10$, $n = 7$) and Crustacea ($r = -0.67$, $P < 0.05$, $n = 7$) in the mud flats. No significant correlation was found with other groups in the shallow water and paddy fields.

Marsh Sandpiper (*Tringa stagnatilis*)

Marsh Sandpiper arrived in the Kole wetlands after the appearance of mud flats and shallow water and the highest peak was in November (2000) decreasing gradually from January in all years (Table 3). Significant correlation was observed between the abundance of birds with Insecta and Crustacea ($r = 0.64$, $P < 0.05$, $n = 7$). However, no significant correlation existed between the abundance of Polychaeta and Gastropoda in mud flats. Similarly significant correlation was found with Polychaeta ($r = -0.65$, $P < 0.05$, $n = 7$), ($r = -0.71$, $P < 0.02$, $n = 7$) in the shallow water.

Lesser Sand Plover (*Charadrius mongolus*)

Lesser Sand Plover arrived in September after the emergence of mud flats and shallow water. The peak population was observed in September and November during the year 2000-2001. The highest population was recorded in September (2000-2001) and the species was not recorded in February and March (Table 3). Abundance of Lesser Sand Plover was found significantly correlated with Insecta ($r = 0.63$, $P < 0.05$, $n = 7$) and Crustacea ($r = 0.66$, $P < 0.05$, $n = 7$) in mudflats. Similarly, significant correlation was also observed in the bird abundance with Polychaeta ($r = -0.65$, $P < 0.05$, $n = 7$) and Crustacea ($r = -0.69$, $P < 0.05$, $n = 7$) in

shallow water. No significant correlation was found between benthic fauna in the paddy fields with the abundance of Lesser Sand Plover.

DISCUSSION

Migratory species showed an increase in population size during November, December and January. Shorebirds feed on a wide variety of foods such as Insecta, Crustacea and Polychaeta. Invertebrates formed the main food of waders. Shorebirds were opportunistic in feeding and fed on suitable items as they are encountered. The size of prey eaten by shorebirds generally increases with the size of the shorebirds. At the Kole wetlands, the abundance of Curlew Sandpiper is closely related to Insecta and Crustacea. Curlew Sandpiper is tactile forager and prey on nerids of different sizes in proportion to their relative abundance in the substratum, avoiding only the smallest nerids (Kalejta, 1993). The lack of prey size selectivity in Curlew Sandpiper implies that their foraging density will be determined by prey abundance, but they should forage preferentially in areas where nerids are large and abundant. The Curlew Sandpiper fed on a wider variety of food items and the importance of benthic fauna in their diet has been reported previously (Kalejta, 1993). Little Stint fed on a wide variety of intertidal invertebrates generally Insecta and Crustacea. Little Stints favoured areas of mud flats, because of the high abundance of benthic fauna.

Population of Little Ringed Plover and Lesser Sand Plover were significantly correlated with Insecta, Polychaeta and Crustacea, which is comparable with the study of Kalejta (1993). Occurrence of shorebirds species like Common Sandpiper was significantly correlated with the abundance of the Crustacea and Polychaeta. Abundance of Curlew was found significantly positively correlated with Insecta, and negatively correlated with Crustacea and Gastropoda. Wood Sandpiper was found significantly correlated with Insecta Crustacea and Gastropoda.

Population of Common Red Shank was found to be significantly positively correlated with population of Insecta and Crustacea, negatively correlated with Polychaeta. Significant correlation was also found between the abundance of Common Green Shank with Gastropoda and Insecta. The population abundance of Green Sandpiper was found significantly negatively correlated with Gastropoda. However, a positive significant correlation was found with Insecta. The abundance of Small Indian Practincole was found to be significantly positive correlated with Polychaeta, Gastropoda, Crustacea and Insecta.

Mud flats greatly influence the distribution, abundance and behaviour of soil organisms (Connors *et al.*, 1981). For shorebirds mud flats was good site of foraging and availability of prey (Puttick, 1981; Evans and Dugan, 1984). Similar habitat preference was shown in shorebirds at the Berg River Estuary, South Africa (Kalejta and Hockey, 1994); at Iceland (Gudmundsson and Gardarsson, 1993); at Chilika Lake (Acharya, 2000). The high density of benthic fauna in shallow water serves as a foraging habitat of waders, which has also been recorded by Sampath *et al.* (1995) in Great Vedaranyam Salt Swamp and Pichavaram mangroves.

The wader species fed mostly in mud flats, shallow waters and water edge, presumably because many species were more active in the microhabitats. Optimal foraging theory predicts that predators should aggregate in areas where their net rate of energy gain is maximal. In the case of waders, it appears that the numerical abundance of prey is a more important determinant of foraging dispersion than the demography of the prey population. Sediment characteristics and penetrability may also influence the availability of estuarine polychaetes of birds (Myers *et al.*, 1980).

This Ramsar site is one of the important staging and wintering areas for migratory shorebirds in the Central Asian Indian Flyway. This region supported transcontinental migratory shorebirds similar to the known

other wetlands and Ramsar sites such as Chilka Lake, Orissa, Pulicate Lake, Andhra Pradesh and Point Calimere, Great Vedaranyam Swamp, Gulf of Mannar, Pichavaram Mangroves, Tamil Nadu.

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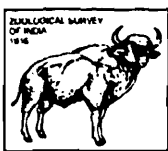
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MARINE NATIONAL PARK AND SANCTUARY, GUJARAT-AN IMPORTANT AVIAN CONGREGATION SITE IN INDIA

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INTRODUCTION

The Marine National Park and Sanctuary (MNP & S) protects a fragile ecosystem as the sea-waters inundate the intertidal zone every day and the change in the quality of sea-water has a direct bearing on the ecosystem. The PA has a great diversity of habitats. The mangroves, coral reefs, degraded reefs, lower and higher inter-tidal mudflats, creeks, estuaries, sandy strands, saline grassland, marshy areas and rocky islands are some of the representative habitat diversity that harbours variety of sea life and bird fauna. The biotic life here is intricately woven. The diversity of colourful sponges and corals, giant sea anemone, tube anemone, bonellia, crabs and prawns, oyster, pearl oyster, sepia, lobster, sabela, jelly fish, sea horse, octopus, portugese man of war, starfish, shark and other fishes, sea turtle, dolphin, dugongs, porpoise keep the life pulsating in perfect ecstasy and harmony.

As per biogeographic classification, the area of the PA's lies in biotic province 10A West Coast biogeographical zone of the Coasts in Indo-Malayan Realm. Recently, the International Union for Conservation of Nature and Natural Resources (IUCN) has declared this Park as Protected Area Category-II in the list

of important national park of the world. It is also an important IBA site (IN-GJ-08). It was declared as National Park in August, 1980. The MNP & S includes three categories of areas i.e. (i) Reserve forests (12.82 km²), (ii) unclassified forests notified under Sec. 4 of IFA, 1927 (347.90 km²) and (iii) territorial waters (98.20 km²) of the Government of India.

The protected area (PA) falls under 6B-Northern Tropical Thorn Forest and mangroves forest. Vegetation in the region is broadly divided into island vegetation and coastal vegetation. The *Acacia senegal* and *Euphorbia* sp. constitute the main element of the thorn forest whereas *Avicennia marina* is the main species of mangrove forest. The island forest mainly occurs on islands in Gulf of Kachchh. Soil is deep, loamy and muddy as well as sandy on fringe area. All age groups of mangrove trees are found on creeks and fringe areas while thorny species like *Acacia senegal* and *Commiphora wightii* are common on sandy coast. Coastal forest occurs all along the coastline of the PA from Okha to Navlakhi. The soil type is mostly clayey to loamy clayey. *Prosopis chilensis* is predominant species along with *Acacia senegal* and *Acacia nilotica*. All along the southern coast of the Gulf *Acacia senegal*, *Acacia*

nilotica, *Acacia leucopholea*, *Commiphora wightii*, *Maytenus emarginata* are common in association with exotic species *Prosopis chilensis* at Jodiya, Balachhadi, Singach, Jakhar and Poshitra. *Euphorbia neriifolia* and *Zizyphus nummularia* also contribute significantly in this region. In intertidal areas, the main species are *Avicennia marina*, *Avicennia alba*, *Rhizophora mucronata*, *Ceriops tagal* and *Aegiceras corniculatum*.

Mangroves both dense and sparse, sand dune vegetation, mudflat with or without vegetation and rocky habitat are the main land cover classes in the coastal area. The whole coastline in the Gulf is fringed with luxuriant growth of mangroves predominantly *Rhizophora*, *Avicennia* and *Ceriops* sp. At present mainly seven species of mangrove are commonly represented in this area, i.e. *Avicennia marina*, *Avicennia alba*, *Avicennia officianlis*, *Rhizophora mucronata*, *Ceriops tagal*, *Aegiceras corniculatum* and *Acanthus ilicifolius*. Sporadic presence of *Salvadora* spp., *Tamarix dioica* and *Commiphora wightii* is also observed on islands.

STUDY AREA

Marine National Park and Sanctuary is located in the Gulf of Kachchh from 22°15' to 23°40' N latitude and 68°20' to 70°40' E longitude in Gujarat state. The Gulf is a semi-enclosed coastal indentation formed by a large bay of the Arabian Sea between coast of Kachchh in north and Saurashtra in the south with predominance of coral reefs and mangrove ecosystem. The area of the park and sanctuary is situated in the inter-tidal zone along the coastal area of Jamnagar district, extending to nearly 150 km on the southern coast of Gulf of Kutch. The intertidal zone of Dwarka, Kalyanpur, Khambalia, Lalpur, Jamnagar and Jodiya talukas along with an archipelago of 42 islands constitutes the area of the Marine National Park and Sanctuary (Fig. 1).

The total area of the two contiguous PA's is 458.92 km², which includes 150.28 km² area of islands and 308.64 km² of intertidal zone along the coast. Out of the total area, the Marine National Park is spread over an area of 162.89

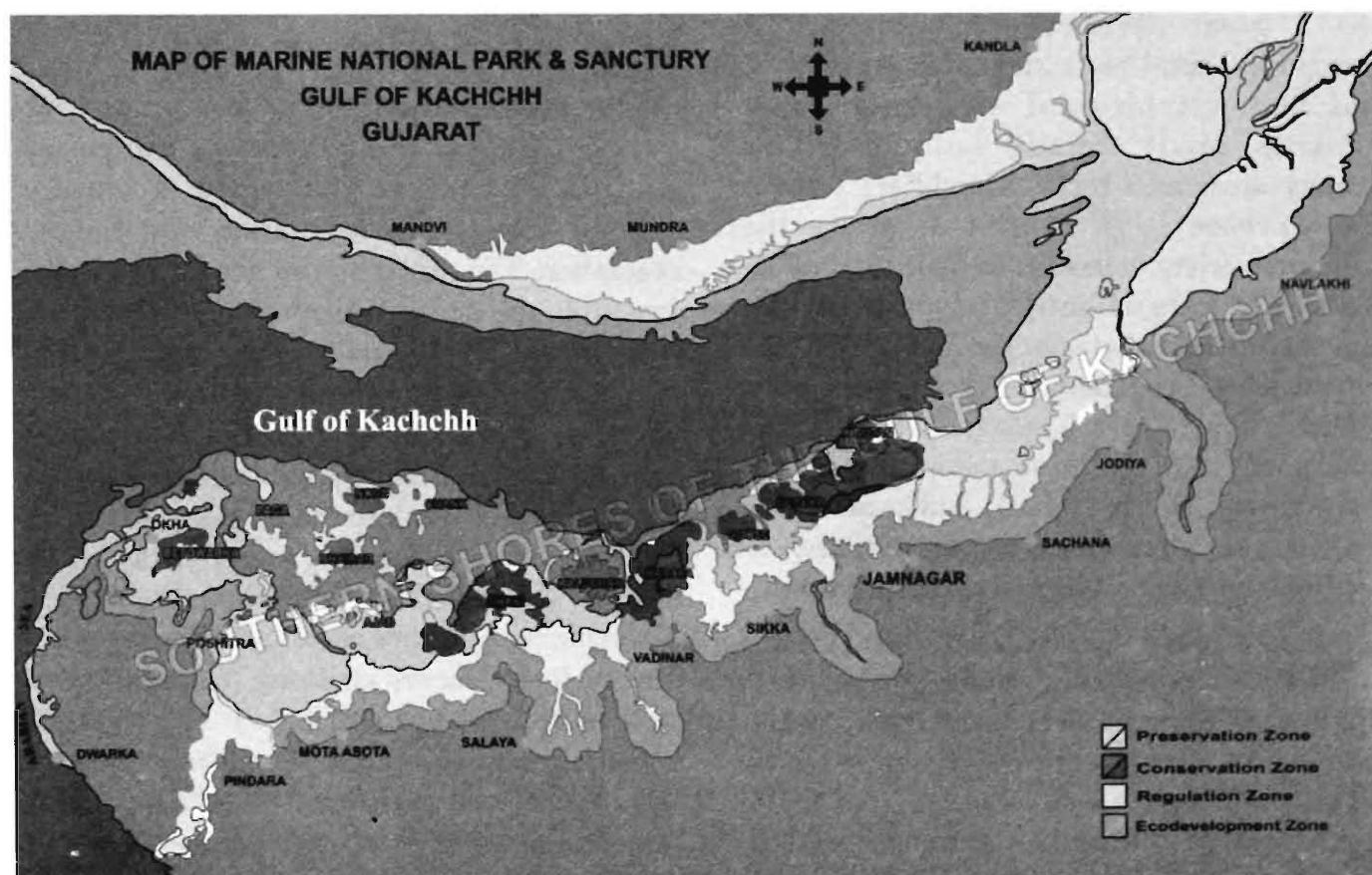


Fig. 1. Map of the Marine National Park and Sanctuary, Dist. Jamnagar, Gujarat

km² of which islands cover 131.36 km² and coast 31.53 km². Similarly Marine Sanctuary covers a total area of 296.03 km² of which islands have very small portion of 18.92 km² and coast covers major 277.11 km² in Jamnagar District, Gujarat.

MATERIALS AND METHODS

The avian diversity was recorded from 22 localities of MNP & S using random method, line transect and point count method. Birds were identified based on physical features with the help of field guides and reference books using binoculars and telescope (Ali and Ripley, 1989; Grimmett *et al.*, 1998). Bird species classification has been followed that of Manakadan and Pittie (2001).

Field data sheets were prepared to record all the relevant information pertaining to habitat, type of ecology, vegetation, topographical features, point and area coordinates, species diversity and population, threats and disturbances. Observations were made from the intertidal zone exposed during low tide where avian congregation was recorded. Apart from direct sightings, the high tidal area of islands and the coast was also surveyed to find out any dead specimens, skeleton or skull that may have come along with floating with tides. The dead body and skeletal parts were also carefully observed and the measurements were taken.

Tide tables for a period from January-December, 2005-2007 for the southern coast of Gulf of Kachchh from Dwarka to Navlakhi in the Jamnagar district, Gujarat were procured from Marine Biology Regional Centre, Zoological Survey of India, Chennai. The coastal zone of the marine area was approached during low tide to observe the avian fauna. The islands were approached by boat and worked out during hours of low tide when maximum coastal zone area gets exposed. The avian congregation was observed during both low and high tide when congregation of species builds up and moves towards sea ward side as the tide recedes.

Global Positioning System (GPS) handset was used to record the coordinates (WGS 84 format) of different study sites of the two PA's (Table 1). The land area of the two PA's along with accessible coastline was approached by Jeep: Gypsy on motorable tracks.

RESULTS AND DISCUSSION

A total of 22 major congregation sites were surveyed in the Marine National Park and Sanctuary out of which ten were islands; ten are coastal areas and two were freshwater coastal wetlands. Large population of wetland birds represented by 196 species was recorded from these 22 rich avian congregation sites of the MNP & S. The name and point co-ordinates of different congregative bird localities are given in Table 1.

Balachandran (1995) had reported 84 species of waterfowls from Marine National Park in the Gulf of Mannar whereas Naik *et al.* (1991) has earlier reported a total of 170 species from Marine National Park and Sanctuary in the Gulf of Mannar of birds of which 94 species are wetland birds and 76 species terrestrial birds. Singh *et al.* (2004) has also reported 122 waterfowl and 85 terrestrial birds from the area.

The present paper records 196 species of birds belonging to 17 orders, 52 families and 123 genera of which 112 are wetland birds and 84 wetland dependant and other passerines. A total of 84 residents, 57 migratory and 55 species hold both resident and migratory status. The locality-wise distribution of number of species is given in Table 2 and 3. The systematic list of birds species recorded from the 2005-2007 surveys of MNP & S is given in Table 4 and 5.

Avian species diversity varied from maximum of 92 species reported from Charkhala to minimum of 31 species reported from Mithapur coastal waters. Jodiya, Balachadi and Positra coast had almost similar range of avian species varying from 66, 67 and 71 respectively. Ohka coast was represented by 50 species and KPT Jetty & Salt Pans by 36 species. Among the avian species diversity recorded from the ten islands surveyed,

minimum number of 8 avian species was recorded from Samiyani Island and maximum number of 70 species from Narara Bet followed by 51 species from Ajad Island. Bet Dwarka, Bhaidar Island, Chank and Pirotan Island, had avian species diversity ranging from 46-49 species. Noru Island was represented by 30 species and 19 species were reported from Khara-Meetha Chusna Island. Locality wise distribution of avian species recorded from all 22 localities is shown in Fig. 2. Chank Island had the maximum population density of wetland birds recorded among the islands surveyed. Maximum number of wader species were seen but abundance was low in numbers at Charkhala. It was also observed that their

population increases as the winter advances in this region.

The coastal area exposed after a high tide becomes a feeding ground for most wetland birds of this region as it is left with large number of marine food elements such as sponges, zoantharians, jelly fish, sea anemone, sea flower, reef crab, shore crab, spider crab, sand crab, anemone shrimp, barnacles, fan mussel, pearl oyster, nudibranch worms gastropods, octopus, feather star, sea urchin, brittle star, sea cucumber, bonnelia, *Physalia* sp.

Number of birds was also found breeding in different islands and coastal waters during the study period. Breeding colonies of painted

Table 1. List of Major Avian Congregation Sites with GPS data

Locality No.	Bird Congregation Site (s)	WGS 84 GPS Coordinates
Marine National Park and Sanctuary (MNP & S)		
1.	Pirotan Island	N 22°37.107' E 69°57.760'
2.	Balachadi	N 22°36.067' E 70°11.836'
3.	Jodiya	N 22°40.903' E 70°17.483'
4.	Charkhala	N 22°12.013' E 69° 06.985'
5.	Positra Coast	N 22°23.278' E 69°11.874'
6.	Chank Island	N 22°31.511' E 69°24.300'
7.	Noru Island	N 22°30.742' E 69°21.809'
8.	Okha coast	N 22°28.649' E 69° 04.784'
9.	Mithapur coastal waters	N 22°25.199' E 68° 59.548'
10.	Narara Bet	N 22°29.147' E 69° 42.937'
11.	Singach coastal wetland	N 22°28. 216' E 69° 43.338'
12.	Jakhar Talao- coastal wetland	N 22°21.857' E 69° 46.749'
13.	KPT Jetty and Saltpans around Narara Island	N 22°26.566' E 69° 40.729'
14.	Kalubar Island	N 22°26.874' E 69° 38.357'
15.	Sachana coast	N 22°34.146' E 70° 10.798'
16.	Balambha (Sagapala Extension)	N 22°49.795' E 70° 20.603'
17.	Sikka	N 22°26.348' E 69° 51.325'
18.	Bhaidar Island	N 22°27.982' E 69° 16.724'
19.	Ajad Island	N 22°22.248' E 69° 19.532'
20.	Khara-Meetha Chusna Island	N 22°24.817' E 69° 16.912'
21.	Bet Dwarka	N 22°27.115' E 69° 05.725'
22.	Samiyani Island	N 22°29.451' E 69° 05.043'

Table 2. Number of avian species shown locality-wise in MNP & S. (Survey, 2005-2006)

Families	Localities													
	Pirotan Island	Balachadi	Jodiya	Charkhala	Positra Coast	Chank Island	Noru Island	Okha Coast	Mithapur Coastal Waters	Narara Bet	Singach Coastal Wetland	KPT Jetty & Saltpan area	Jakhar Talao-Coastal Wetland	Kalubar Island
Podicipedidae				2							1	1	2	
Pelecanidae				2		2					1	2	1	
Phalacrocoracidae	2	2	1	2	2	2	2	1	1	2	2		1	2
Anhingidae			1	1	1	1	1				1		1	1
Ardeidae	3	4	4	5	5	5	2	3	2	4	4	2	3	4
Ciconiidae	1	1	2	2	1	1	1	1	1	1	1	1	1	1
Threskiornithidae	2	1	2	3	1	2	1	1	1	2	1	1	1	2
Phoenicopteridae	1		1	2		1		1	1		1	1	1	1
Anatidae	1	3	2	4	1		1	2		1	3	2	2	3
Accipitridae	1	2	2	2	3	1	1	2	1	2	3	1	2	3
Falconidae		1		1	1			1		1				1
Phasianidae		2	2		2			1	1		2		2	
Gruidae		1	2	2	1		1	1	1	1	2		2	1
Rallidae	1	3	1	1	2	2				3	3	1	2	2
Jacaniidae			1								1		1	
Rostratulidae				1			1			1				1
Haematopodidae	1	1		1		1			1	1				1
Charadriidae	3													
Scolopacidae	2	2	1	4	2	6	1		1	4	2		1	3
Recurvirostridae	1	2		2		1	1	2		1	1		2	1
Dromadidae				1		1		1		1	1	1	1	1
Burhinidae		1	1					1		1		1		1
Laridae	2			3	1	3		2		2		1	1	3
Rynchopidae				1										
Pteroclididae					1								1	
Columbidae	1	3	2	2	3			3	3	1	2	1	3	1
Psittacidae	1		1	1	1			1	1	1	1	1	1	1
Cuculidae			2	1	2	2	2	1	1	3	3	1	2	2
Strigidae				1							1			
Caprimulgidae			1		1					1				
Apodidae		1	1	1	1			1		1		1		

Table 2. *Contd.*

Families	Localities													
	Pirotan Island	Balachadi	Jodiya	Charkhala	Positra Coast	Chank Island	Noru Island	Okha Coast	Mithapur Coastal Waters	Narara Bet	Singach Coastal Wetland	KPT Jetty & Saltpan area	Jakhar Talao-Coastal Wetland	Kalubar Island
Alcedinidae	1	2	2	3	2	1	1	2		2	1	1	3	2
Meropidae	1	1	1	1	1			1	1	1	1	1	1	1
Coraciidae	1	2	2	2	2	1	1	1	1	2	1	1	1	1
Upupidae			1	1	1					1	1		1	
Picidae			1		1									
Alaudidae	2	3	3	3	2	2	1	2	1	3	2	1	2	1
Hirundinidae	1	2	3	2	2		1	2	1	2	1	1	1	1
Motacillidae	2	2	2	3	3	2		2	2	2	1	1		2
Campephagidae		1	2	2	2	1	1			1	1		1	1
Pycnonotidae	2	2	2	2	2	1	1	2	2	2	1	2	1	1
Laniidae	1	2	1	3	3		1	1	1	1		2	1	1
Muscicapidae														
<i>Turdinae</i>	3	5	1	5	3	2	2	2	1	3	2	2	2	4
<i>Timaliinae</i>	1	2	2	2	2	1		2	1	3	1		1	1
<i>Sylviinae</i>	2	2	1	2	1		1	1		2	3	1	1	1
<i>Muscicapinae</i>			1	1	1					1				1
<i>Monarchinae</i>														1
<i>Rhipidurinae</i>				1	1									1
Nectariniidae	1	1	1	1	1					1	1		1	
Zosteropidae	1	1	1	1	1	1	1			1				1
Passeridae														
<i>Passerinae</i>	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>Ploceinae</i>			1	1	1								1	
Sturnidae	3	4	3	4	3	2	1	2	2	3	2	1	2	3
Dicruridae	1	1	1	1	1	1	1	1		1	1	1	1	1
Corvidae	2	3	3	2	2	1	1	2	1	2	1	1	1	1

Table 3. Number of avian species shown locality-wise in MNP & S. (Survey, 2006-2007)

Families	Localities															
	Sachana	Balachadi	Jodiya	Balambha	Sikka	Narara Coast	KPT Jetty & Salt pan area	Charkhala	Pirotan Island	Bhaidar Isl.	Ajad Isl.	Meetha Chusna Isl.	Bet Dwarka	Samiyani Isl.	Okha Coast	Mithapur coastal waters
Podicipedidae			1	1	1	1		3								
Pelecanidae	1	1	2	2	2	2	1	2		1	1		2			
Phalacrocoracidae	1	2	2	1	2	2	1	2	1	1	1	1		1	1	1
Anhingidae	1		1	1	1	1		1		1		1				
Ardeidae	4	4	5	4	3	4	2	5	4	2	2	3	1	1	1	1
Ciconiidae	1	1	3	1	2	1	1	3	2	1	1				1	
Threskiornithidae	2	2	3	2	2	1		3	2	1	2		1		1	
Phoenicopteridae	1	1	1	2	2	2	1	2	2	1			1		1	
Anatidae	3	5	5	3	2	1	1	6	2	2	2		1		1	1
Accipitridae		1	1	2	2	1	2	2	1	1	1		1		1	
Falconidae		1	1	1	1			1			1					1
Phasianidae		1	1	2	1			1	1	1		1			1	1
Gruidae		2	2	2	2	1		1	1		1				1	1
Rallidae	3	2	3	2	2	2	1	2	2	1	2	1	1		1	
Jacaniidae			1	1	1											
Rostratulidae						1			1		1				1	
Haematopodidae		1		1	1	1									1	
Charadriidae	3	1	2		2	2	1	1	1	1		1	1	1		1
Scolopacidae	4	3	2	4	3	4	2	5	3	2	1	1	2	2	1	1
Recurvirostridae	2	2	2	2	2	2	1	1	2	1	1		1		2	2
Dromadidae	1			1	1	1	1			1	1			1	1	
Burhinidae				1	1	1	1			1	1					
Laridae	3	1	2	3	4	3	1	4	2	3	3			1	4	1
Rynchopidae	1							1								
Pteroclididae		1	1	1	1				1							
Columbidae	2	3	3	2	3	1	1	1	1	1	1	1	1		1	1
Psittacidae		1	1	1	1				1	1	1	1	1			
Cuculidae	1		2	3	1	1	1		2	2	2				1	1
Strigidae			1	1									1			
Caprimulgidae						1			1						1	
Apodidae	1	1	1		2		2					1	1		1	

Table 3. Contd.

Families	Localities															
	Sachana	Balachadi	Jodiya	Balambha	Sikka	Narara Coast	KPT Jetty & Salt pan area	Charkhala	Pirotan Island	Bhaidar Isl.	Ajad Isl.	Meetha Chusna Isl.	Bet Dwarka	Samiyani Isl.	Okha Coast	Mithapur coastal waters
Alcedinidae	1	1	2	3	3	2		1	1		1					
Meropidae	1		1	2				2	2	1	1		1		1	1
Coraciidae	1	2	2	2	2	1	1	2	2	1	1		1		1	1
Upupidae		1	1	1	1			1	1				1		1	
Capitonidae Barbets			1	1	1								1			
Picidae			1													
Alaudidae		1		1		1	1	2	2	4	4		3		2	
Hirundinidae		2	2	2	1	2	1	1	1		2		2			1
Motacillidae	1	2	3	2	2	3	1	3	2	1	1	1	2		1	1
Campephagidae			1			1			1				1			
Pycnonotidae	1	2	2	1	2	1	1	2	1		1	1				1
Laniidae		2	2	1	1			3	1	1			1		1	
Muscicapidae																
<i>Turdinae</i>	4	5	4	3	3	2	1	5	4	2	2	1	3		1	3
<i>Timaliinae</i>		2	2	3	2	1		2	1				1			
<i>Sylviinae</i>	2	3	1	2	2	1	1	1	2	1	2		2			
<i>Muscicapinae</i>			1		1			1					1			
<i>Monarchinae</i>			1							1			1			
<i>Rhipidurinae</i>		1	1	1	1				1		1		1		1	
Nectariniidae	1	1	1	1	1	1	1	1	1	1	1				1	1
Zosteropidae			1		1	1			1	1	1					
Estrildidae		1	2	2	1			1	1	1	1		1			
Passeridae																
<i>Passerinae</i>	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1
<i>Ploceinae</i>		1	1		1			1	1		1		1			
Sturnidae	2	3	4	3	3	2	1	4	2	2	2	1	3		2	1
Oriolidae			1	1					1							
Dicruridae	1	1	1	2	2	1			1	1	1	1	1	1	1	1
Corvidae	2	1	3	3	2	1	1	2	2	1	1	1	1		1	1

Table 4. List of Wetland Birds of Marine National Park and sanctuary recorded from 2005-2007

Family	Scientific Name	Common Name	Status
Podicipedidae	<i>Tachybaptus ruficollis</i> (Pallas, 1764)	Little Grebe	R
	<i>Podiceps cristatus</i> (Linnaeus, 1758)	Great Crested Grebe	M
	<i>Podiceps nigricollis</i> Brehm, 1831	Black-necked Grebe	M
Pelecanidae	<i>Pelecanus onocrotalus</i> Linnaeus, 1758	Great White Pelican	RM
	<i>Pelecanus philippensis</i> Gmelin, 1789	Spot-billed Pelican	RM
	<i>Pelecanus crispus</i> Bruch, 1832	Dalmatian Pelican	M
Phalacrocoracidae	<i>Phalacrocorax niger</i> (Vieillot, 1817)	Little Cormorant	RM
	<i>Phalacrocorax fuscicollis</i> Stephens, 1826	Indian Shag	RM
	<i>Phalacrocorax carbo</i> (Linnaeus, 1758)	Great Cormorant	RM
Anhingidae	<i>Anhinga melanogaster</i> Pennant, 1769	Darter	RM
Ardeidae	<i>Egretta garzetta</i> (Linnaeus, 1766)	Little Egret	R
	<i>Egretta gularis</i> (Bose, 1792)	Western Reef-Egret	RM
	<i>Ardea cinerea</i> Linnaeus, 1758	Grey Heron	RM
	<i>Ardea purpurea</i> Linnaeus, 1766	Purple Heron	RM
	<i>Casmerodius albus</i> (Linnaeus, 1758)	Large Egret	RM
	<i>Mesophoyx intermedia</i> (Wagler, 1829)	Intermediate Egret	RM
	<i>Bubulcus ibis</i> (Linnaeus, 1758)	Cattle Egret	RM
	<i>Ardeola grayii</i> (Sykes, 1832)	Indian Pond-Heron	R
	<i>Butorides striatus</i> (Linnaeus, 1758)	Little Green Heron	R
	<i>Nycticorax nycticorax</i> (Linnaeus, 1758)	Black-crowned Night-Heron	R
	<i>Ixobrychus cinnamomeus</i> (Gmelin, 1789)	Chestnut Bittern	RM
	<i>Dupetor flavicollis</i> (Latham, 1790)	Black Bittern	RM
Ciconiidae	<i>Mycteria leucocephala</i> (Pennant, 1769)	Painted Stork	RM
	<i>Anastomus oscitans</i> (Boddaert, 1783)	Asian Openbill-Stork	R
	<i>Ephippiorhynchus asiaticus</i> (Latham, 1790)	Black-necked Stork	R
Threskiornithidae	<i>Plegadis falcinellus</i> (Linnaeus, 1766)	Glossy Ibis	RM
	<i>Threskiornis melanocephalus</i> (Latham, 1790)	Oriental White Ibis	R
	<i>Pseudibis papillosa</i> (Temminck, 1824)	Black Ibis	R
	<i>Platalea leucorodia</i> Linnaeus, 1758	Eurasian Spoonbill	RM
Phoenicopteridae	<i>Phoenicopeterus ruber</i> Linnaeus, 1758	Greater Flamingo	RM
	<i>Phoenicopeterus minor</i> (Geoffroy, 1798)	Lesser Flamingo	RM
Anatidae	<i>Dendrocygna javanica</i> (Horsfield, 1821)	Lesser Whistling-Duck	R
	<i>Tadorna ferruginea</i> (Pallas, 1764)	Brahminy Shelduck	RM
	<i>Sarkidiornis melanotos</i> (Pennant, 1769)	Nakta or Comb Duck	RM
	<i>Anas strepera</i> Linnaeus, 1758	Gadwall	M
	<i>Anas penelope</i> Linnaeus, 1758	Eurasian Wigeon	M
	<i>Anas poecilorhyncha</i> J. R. Forester, 1781	Spot-billed Duck	RM
	<i>Anas clypeata</i> Linnaeus, 1758	Northern Shoveller	M
	<i>Anas acuta</i> Linnaeus, 1758	Northern Pintail	M
	<i>Anas querquedula</i> Linnaeus, 1758	Garganey	M
	<i>Anas crecca</i> Linnaeus, 1758	Common Teal	M
	<i>Aythya ferina</i> (Linnaeus, 1758)	Common Pochard	M
Accipitridae	<i>Circus macrourus</i> (S.G. Gmelin, 1770)	Pallid Harrier	RM
Pandionidae	<i>Pandion haliaetus</i> (Linnaeus, 1758)	Osprey	RM
Gruidae	<i>Grus virgo</i> (Linnaeus, 1758)	Demoiselle Crane	M
	<i>Grus grus</i> (Linnaeus, 1758)	Common Crane	M

Table 4. Contd.

Family	Scientific Name	Common Name	Status
Rallidae	<i>Amaurornis phoenicurus</i> (Pennant, 1769)	White-breasted Waterhen	R
	<i>Porphyrio porphyrio</i> (Linnaeus, 1758)	Purple Moorhen	R
	<i>Gallinula chloropus</i> (Linnaeus, 1758)	Common Moorhen	RM
	<i>Fulica atra</i> Linnaeus, 1758	Common Coot	RM
Jacanidae	<i>Hydrophasianus chirurgus</i> (Scopoli, 1786)	Pheasant-tailed Jacana	R
	<i>Metopidius indicus</i> (Latham, 1790)	Bronze-winged Jacana	R
Haematopodidae	<i>Haematopus ostralegus</i> Linnaeus, 1758	Eurasian Oystercatcher	M
Charadriidae	<i>Pluvialis fulva</i> (Gmelin, 1789)	Pacific Golden-Plover	M
	<i>Pluvialis squatarola</i> (Linnaeus, 1758)	Grey Plover	M
	<i>Charadrius hiaticula</i> Linnaeus, 1758	Common Ringed Plover	M
	<i>Charadrius dubius</i> Scopoli, 1786	Little Ringed Plover	RM
	<i>Charadrius alexandrinus</i> Linnaeus, 1758	Kentish Plover	RM
	<i>Charadrius mongolus</i> Pallas, 1776	Lesser Sand Plover	RM
	<i>Charadrius leschenaultii</i> Lesson, 1826	Greater Sand Plover	M
	<i>Vanellus indicus</i> (Boddaert, 1783)	Red-wattled Lapwing	R
	<i>Vanellus malabaricus</i> (Boddaert, 1783)	Yellow-wattled Lapwing	R
	<i>Vanellus leucurus</i> (Lichtenstein, 1823)	White-tailed Lapwing	M
Scolopacidae	<i>Gallinago gallinago</i> (Linnaeus, 1758)	Common Snipe	RM
	<i>Lymnocyrtus minimus</i> (Brünnich, 1764)	Jack Snipe	M
	<i>Limosa limosa</i> (Linnaeus, 1758)	Black-tailed Godwit	M
	<i>Limosa lapponica</i> (Linnaeus, 1758)	Bar-tailed Godwit	M
	<i>Numenius phaeopus</i> (Linnaeus, 1758)	Whimbrel	M
	<i>Numenius arquata</i> (Linnaeus, 1758)	Eurasian Curlew	M
	<i>Tringa erythropus</i> (Pallas, 1764)	Spotted Redshank	M
	<i>Tringa totanus</i> (Linnaeus, 1758)	Common Redshank	M
	<i>Tringa stagnatilis</i> (Bechstein, 1803)	Marsh Sandpiper	M
	<i>Tringa nebularia</i> (Gunner, 1767)	Common Greenshank	M
	<i>Tringa ochropus</i> Linnaeus, 1758	Green Sandpiper	M
	<i>Tringa glareola</i> Linnaeus, 1758	Wood Sandpiper	M
	<i>Xenus cinereus</i> (Guldenstadt, 1774)	Terek Sandpiper	M
	<i>Actitis hypoleucos</i> Linnaeus, 1758	Common Sandpiper	RM
	<i>Arenaria interpres</i> (Linnaeus, 1758)	Ruddy Turnstone	M
	<i>Calidris tenuirostris</i> (Horsfield, 1821)	Great Knot	M
	<i>Calidris canutus</i> (Linnaeus, 1758)	Red Knot	M
	<i>Calidris alba</i> (Pallas, 1764)	Sanderling	M
	<i>Calidris temminckii</i> (Leisler, 1812)	Temminck's Stint	M
	<i>Calidris alpina</i> (Linnaeus, 1758)	Dunlin	M
	<i>Calidris ferruginea</i> (Pontoppidan, 1813)	Curlew Sandpiper	M
	<i>Limicola falcinellus</i> (Pontoppidan, 1763)	Broad-billed Sandpiper	M
	<i>Philomachus pugnax</i> (Linnaeus, 1758)	Ruff	M
Recurvirostridae	<i>Himantopus himantopus</i> (Linnaeus, 1758)	Black-winged Stilt	R
	<i>Recurvirostra avosetta</i> Linnaeus, 1758	Pied Avocet	RM
Phalaropidae	<i>Phalaropus lobatus</i> (Linnaeus, 1758)	Red-necked Phalarope	M
Dromadidae	<i>Dromas ardeola</i> Paykull, 1805	Crab-Plover	M
Burhinidae	<i>Esacus recurvirostris</i> (Cuvier, 1829)	Great Stone-Plover	R
Glareolidae	<i>Glareola pratincola</i> (Linnaeus, 1766)	Collared Pratincole	RM
	<i>Glareola lactea</i> Temminck, 1820	Small Pratincole	R

Table 4. Contd.

Family	Scientific Name	Common Name	Status
Laridae	<i>Larus heuglini</i> Bree, 1876	Heuglin's Gull	M
	<i>Larus cachinnans</i> Pallas, 1811	Yellow-legged Gull	M
	<i>Larus ichthyaetus</i> Pallas, 1773	Pallas's Gull	M
	<i>Larus brunnicephalus</i> Jerdon, 1840	Brown-headed Gull	M
	<i>Larus ridibundus</i> Linnaeus, 1766	Black-headed Gull	M
	<i>Larus genei</i> Breme, 1839	Slender-billed Gull	RM
	<i>Gelochelidon nilotica</i> (Gmelin, 1789)	Gull-billed Tern	RM
	<i>Sterna caspia</i> Pallas, 1770	Caspian Tern	RM
	<i>Sterna aurantia</i> J.E. Gray, 1831	River Tern	R
	<i>Sterna bengalensis</i> Lesson, 1831	Lesser Crested Tern	R
	<i>Sterna bergii</i> Lichtenstein, 1823	Large Crested Tern	R
	<i>Sterna hirundo</i> Linnaeus, 1758	Common Tern	RM
	<i>Sterna albifrons</i> Pallas, 1764	Little Tern	R
	<i>Sterna saundersi</i> Hume, 1877	Saunders's Tern	RM
	<i>Chlidonias hybridus</i> (Pallas, 1811)	Whiskered Tern	RM
	<i>Chlidonias leucopterus</i> (Temminck, 1815)	White-winged Black Tern	M
Rynchopidae	<i>Rynchops albigollis</i> Swainson, 1838	Indian skimmer	R
Alcedinidae	<i>Halcyon capensis</i> (Linnaeus, 1766)	Stork-billed Kingfisher	R
	<i>Halcyon pileata</i> (Boddaert, 1783)	Black-capped Kingfisher	R

Table 5. List of Wetland Dependant and other Passerines recorded from 2005-2007 from MNP & S, Gujarat

Family	Scientific Name	Common Name	Status
Accipitridae	<i>Elanus caeruleus</i> (Desfontaines, 1789)	Black-shouldered Kite	R
	<i>Milvus migrans</i> (Boddaert, 1783)	Black Kite	R
	<i>Haliastur indus</i> (Boddaert, 1783)	Brahminy Kite	R
	<i>Haliaeetus leucoryphus</i> (Pallas, 1771)	Pallas's Fish-Eagle	RM
	<i>Circus aeruginosus</i> (Linnaeus, 1758)	Western Marsh-Harrier	M
	<i>Circus pygargus</i> (Linnaeus, 1758)	Montagu's Harrier	M
	<i>Accipiter badius</i> (Gmelin, 1788)	Shikra	R
	<i>Aquila clanga</i> Pallas, 1811	Greater Spotted Eagle	RM
Falconidae	<i>Falco tinnunculus</i> Linnaeus, 1758	Common Kestrel	R
	<i>Falco peregrines</i> Tunstall, 1771	Peregrine Falcon	R
Phasianidae	<i>Francolinus pondicerianus</i> (Gmelin, 1789)	Grey Francolin	R
	<i>Pavo cristatus</i> Linnaeus, 1758	Indian Peafowl	R
Glareolidae	<i>Cursorius coromandelicus</i> (Gmelin, 1789)	Indian Courser	R
Pteroclididae	<i>Pterocles exustus</i> Temminck, 1825	Chestnut-bellied Sandgrouse	R
Columbidae	<i>Columba livia</i> Gmelin, 1789	Blue Rock Pigeon	R
	<i>Streptopelia orientalis</i> (Latham, 1790)	Oriental Turtle-Dove	R
	<i>Streptopelia senegalensis</i> (Linnaeus, 1766)	Little Brown Dove	R
	<i>Streptopelia decaocto</i> (Frisvaldszky, 1838)	Eurasian Collared-Dove	R
Psittacidae	<i>Psittacula krameri</i> (Scopoli, 1769)	Rose-ringed Parakeet	R
Cuculidae	<i>Clamator jacobinus</i> (Boddaert, 1783)	Pied Crested Cuckoo	RM
	<i>Eudynamis scolopacea</i> (Linnaeus, 1758)	Asian Koel	R
	<i>Centropus sinensis</i> (Stephens, 1815)	Greater Coucal	R

Table 5. Contd.

Family	Scientific Name	Common Name	Status
Strigidae	<i>Athene brama</i> (Temminck, 1821)	Spotted Owlet	R
Apodidae	<i>Cypsiurus balasiensis</i> (J.E. Gray, 1829) <i>Apus affinis</i> (J.E. Gray, 1830)	Asian Palm Swift House swift	R RM
Alcedinidae	<i>Alcedo atthis</i> (Linnaeus, 1758) <i>Halcyon smyrnensis</i> (Linnaeus, 1758) <i>Ceryle rudis</i> (Linnaeus, 1758)	Small Blue Kingfisher White-breasted Kingfisher Lesser Pied Kingfisher	RM R R
Meropidae	<i>Merops orientalis</i> Latham, 1801 <i>Merops philippinus</i> Linnaeus, 1766	Small Bee-eater Blue-tailed Bee-eater	R RM
Coraciidae	<i>Coracias garrulus</i> Linnaeus, 1758 <i>Coracias benghalensis</i> (Linnaeus, 1758)	European Roller Indian Roller	RM R
Upupidae	<i>Upupa epops</i> Linnaeus, 1758	Common Hoopoe	RM
Capitonidae	<i>Megalaima haemacephala</i> (P.L.S. Müller, 1776)	Coppersmith Barbet	R
Picidae	<i>Dendrocopos mahrattensis</i> (Latham, 1801) <i>Dinopium benghalense</i> (Linnaeus, 1758)	Yellow-fronted Pied Woodpecker Lesser Golden-backed Woodpecker	R R
Pittidae	<i>Pitta brachyura</i> (Linnaeus, 1766)	Indian Pitta	R
Alaudidae	<i>Eremopterix nigriceps</i> (Gould, 1839) <i>Eremopterix grisea</i> (Scopoli, 1786) <i>Calandrella cheleensis</i> (Swinhoe, 1871) <i>Galerida cristata</i> (Linnaeus, 1758)	Black-crowned Sparrow-Lark Ashy-crowned Sparrow-Lark Asian Short-toed Lark Common Crested Lark	R R M R
Hirundinidae	<i>Hirundo concolor</i> Sykes, 1833 <i>Hirundo rustica</i> Linnaeus, 1758 <i>Hirundo smithii</i> Leach, 1818 <i>Hirundo daurica</i> Linnaeus, 1771	Dusky Crag-Martin Common Swallow Wire-tailed Swallow Red-rumped Swallow	R RM R RM
Motacillidae	<i>Motacilla maderaspatensis</i> Gmelin, 1789 <i>Motacilla citreola</i> Pallas, 1776 <i>Motacilla flava</i> Linnaeus, 1758 <i>Motacilla cinerea</i> Tunstall, 1771 <i>Anthus campestris</i> (Linnaeus, 1758) <i>Anthus trivialis</i> (Linnaeus, 1758)	Large Pied Wagtail Citrine Wagtail Yellow Wagtail Grey Wagtail Tawny Pipit Eurasian Tree Pipit	R RM M M M M
Pycnonotidae	<i>Pycnonotus jocosus</i> (Linnaeus, 1758) <i>Pycnonotus cafer</i> (Linnaeus, 1766)	Red-whiskered Bulbul Red-vented Bulbul	RM R
Irenidae	<i>Aegithina tiphia</i> (Linnaeus, 1758) <i>Chloropsis cochinchinensis</i> (Gmelin, 1788) <i>Chloropsis aurifrons</i> (Temminck, 1829)	Common Iora Jerdon's Chloropsis Gold-fronted Chloropsis	R R R
Laniidae	<i>Lanius cristatus</i> Linnaeus, 1758	Brown Shrike	M
Muscicapidae : Turdinae	<i>Copsychus saularis</i> (Linnaeus, 1758) <i>Saxicoloides fulicata</i> (Linnaeus, 1776) <i>Phoenicurus ochruros</i> (Gmelin, 1774) <i>Saxicola torquata</i> (Linnaeus, 1766) <i>Oenanthe deserti</i> (Temminck, 1825) <i>Oenanthe isabellina</i> (Temminck, 1829)	Oriental Magpie-Robin Indian Robin Black Redstart Common Stonechat Desert Wheatear Isabelline Wheatear	R R RM RM RM RM
Muscicapidae : Timaliinae	<i>Turdoides caudatus</i> (Dumont, 1823) <i>Turdoides striatus</i> (Dumont, 1823)	Common Babbler Jungle Babbler	R R
Muscicapidae :	<i>Cisticola juncidis</i> (Rafinesque, 1810)	Streaked Fantail-Warbler	R

Table 5. Contd.

Family	Scientific Name	Common Name	Status
Sylviinae	<i>Prinia buchanani</i> Blyth, 1844	Rufous-fronted Prinia	R
	<i>Prinia socialis</i> Sykes, 1832	Ashy Prinia	R
	<i>Prinia inornata</i> Sykes	Plain Prinia	R
	<i>Acrocephalus scirpaceus</i> (Hermann, 1804)	Eurasian Reed-Warbler	R
	<i>Orthotomus sutorius</i> (Pennant, 1769)	Common Tailorbird	R
	<i>Sylvia curruca</i> (Linnaeus, 1758)	Common Lesser Whitethroat	M
Nectariniidae	<i>Nectarinia asiatica</i> (Latham, 1790)	Purple Sunbird	R
Zosteropidae	<i>Zosterops palpebrosus</i> (Temminck, 1824)	Oriental White-eye	R
Estrildidae	<i>Lonchura malabarica</i> (Linnaeus, 1758)	White-throated Munia	R
Sturnidae	<i>Sturnus malabaricus</i> (Gmelin, 1789)	Grey-headed Starling	R
	<i>Sturnus roseus</i> (Linnaeus, 1758)	Rosy Starling	M
	<i>Acridotheres tristis</i> (Linnaeus, 1766)	Common Myna	R
	<i>Acridotheres ginginianus</i> (Latham, 1790)	Bank Myna	R
Dicruridae	<i>Dicrurus macrocercus</i> Vieillot, 1817	Black Drongo	R
Corvidae	<i>Dendrocitta vagabunda</i> (Latham, 1790)	Indian Treepie	R
	<i>Corvus splendens</i> Vieillot, 1817	House Crow	R
	<i>Corvus macrorhynchos</i> Wagler, 1827	Jungle Crow	R
	<i>Corvus corax</i> Linnaeus, 1758	Common Raven	R

Table 6. Systematic List of Globally Threatened Avian Species at MNP & S, Gujarat

Family	Scientific Name	Status
Pelecanidae	<i>Pelecanus philippensis</i>	Vulnerable
	<i>Pelecanus crispus</i>	Conservation Dependant
Anhingidae	<i>Anhinga melanogaster</i>	Near Threatened
Ciconiidae	<i>Mycteria leucocephala</i>	Near Threatened
	<i>Ephippiorhynchus asiaticus</i>	Near Threatened
Threskiornithidae	<i>Threskiornis melanocephalus</i>	Near Threatened
Phoenicopteridae	<i>Phoenicopiterus minor</i>	Near Threatened
Accipitridae	<i>Circus macrourus</i>	Near Threatened
	<i>Aquila clanga</i>	Vulnerable
Rhynchopidae	<i>Rynchops albicollis</i>	Vulnerable
Coraciidae	<i>Coracias garrulus</i>	Near Threatened

stork, grey heron, cormorants, great egret, black-crowned night heron, little heron, oriental white ibis and spoonbill were seen on the islands. Black necked stork was seen breeding at number of places in the MNP & S especially on vilayati babool, tamarind and neem trees. Of the 196 birds, 11 globally threatened species as per different conservation norms were sighted throughout the study period. Three species are vulnerable, one species conservation

dependant and seven species fall under the category of near threatened. The list of globally threatened species is given in Table 5.

The Marine National Park and Sanctuary with its islands holds rich wetland bird diversity. The birds visiting the area are facing serious threats from the industries in the area as Gujarat ranks second in the top industrialized state in India. It is inevitable that the effect of this do not fall on this areas also

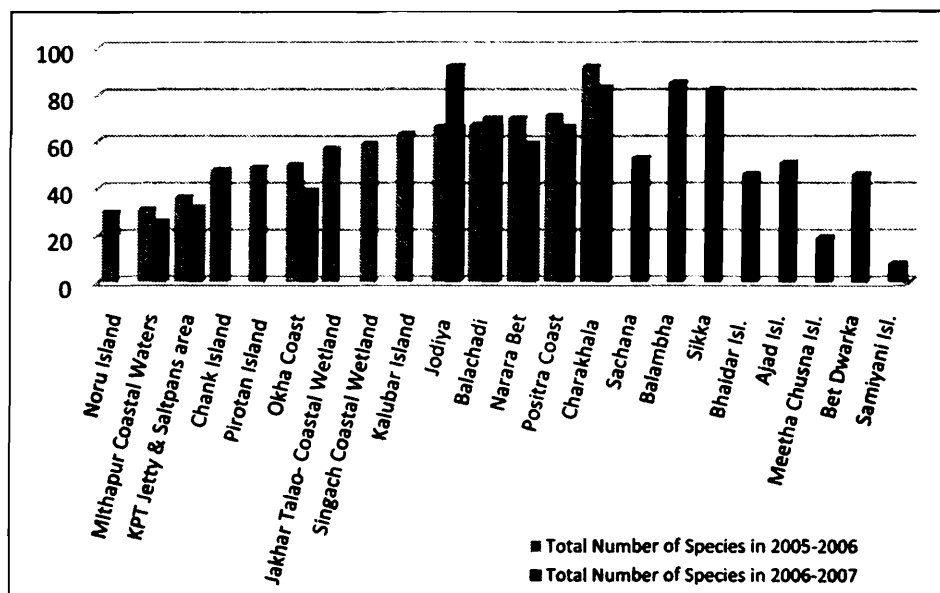


Fig. 2. Localities wise total number of species in Marine National Park & Sanctuary, Gujarat during 2005-2007

whatsoever may be the status given to this region for the biodiversity conservation purposes. Tourism, salt and cement industries, ports, harbors and jetties, petrochemical industries, ship building industries, thermal power station, Tata chemical (soda industry) at Mithapur, mining, agricultural and industrial runoff, coastal population, urbanization, ship traffic at ports and the movement of fishermen's diesel engine boats are some of the serious issues and threats for the PA's at present. The spread of electric wires at low height throughout marine national park and sanctuary especially in the Narara, Charkhala and Balambha area resulting into mortality of large size birds as they strike these high tension electric transmission wires. Any development in this region should be synchronized in a way that it does not disturb the existing habitats of the region. Release of industrial waste in sea water, construction of new industrial base and human population dependence on sea resources

including transportation should be strictly regulated and monitored by an environmental agency.

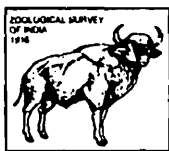
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ROLE OF *CYNOPTERUS BRACHYOTIS* (LESSER DOG FACED FRUIT BAT), *CYNOPTERUS SPHINX* (SHORT NOSED FRUIT BAT) IN FOREST RESTORATION OF KALAKAD MUNDANTHURAI TIGER RESERVE

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INTRODUCTION

Bats are unique, fascinating and are the only true flying mammals under the order Chiroptera. Dietary variations classified them into two sub-orders namely, Megachiroptera (fruit bats) and Microchiroptera (insect eating bats). Fruit bats depend heavily on plant resources throughout the year (Gardner, 1977; Marshall, 1983, 1985; Dobat and Peikert-Holle, 1985; Fleming, 1986, 1988, 1993; Richards, 1995; Utzurrum, 1995; Tan *et al*; 1998; Kalko *et al*; 1996; Banack 1998). Frugivorous bats play a vital role as thus helps in the maintenance of species rich tropical forest and their dispersal role in accordance to the type of forest. Because of their unique life styles, defecating in flight while commuting between their day roosts and feeding grounds, bats are long distance seed dispersers (Fleming, 1987).

Bat mediated seed dispersion is very important in fragmented and on very disturbed forest habitats (Galetti and Morellata, 1994) to promote plant recolonization (Whittaker and Jones, 1994). In tropical forest bats are known to be the pollinators of more than 300 plant

species, many of which are economically important. The species specific food selection and processing various parts of the plants helps in the forest restoration (Marinho-Filho, 1991).

The forest of the Kalakad Mundanthurai Tiger Reserve has a distribution of the six fruit bat species (Vanitharani, 2006; Vanitharani *et al.*, 2005). *Cynopterus sphinx* is a very common frugivorous species found in lower altitudes known from the foot-hills. The tropical plain, dry and moist deciduous forests of the hill slopes provide a forging ground for *C. sphinx*.

Cynopterus brachyotis is the common fruit bat of the forest distributed above 600m elevation. Similarity between *C. sphinx* and *C. brachyotis* suggest both the members show a close evolutionary relationship and these *Cynopterus spp.* roost in small harem constructing elaborate tents with the palm leaves (Medway, 1978; Balasingh *et al.*, 1995).

Both the species can carry large and small sized fruits with even hard nuts, weight range from 3 to 28 gm, to a remote feeding roost to consume (Godinez-Alvarez *et al.*, 2002; Kunz and Fenton, 2003). The smaller seeds are often

swallowed and excreted unharmed or dropped during food processing (Fleming, 1982). Fruit processed by the tongue and palate of the mouth and gut benefits the seeds by removing germination inhibitors and leaving them viable and induce them for quick germination (Thomas, 1991).

MATERIALS AND METHODS

Kalakad Mundanthurai Tiger Reserve, a part of southern Western Ghats (hot spot) treasures the diversity of bat species starting from the foothills and the adjoining plains to the highest elevation 4000 ft. The distribution studies of Vanitharani (2006, 2007) and Jeyaprabha (2008) has shown the fruit bat *C. sphinx* is restricted to the foot hill and the adjoining area of forest below 600 ft elevation whereas *C. brachyotis* is a forest bat which shows its distribution above 600ft elevation. Information about the feeding habits was obtained by direct observation, mist netting within and above canopy near the fruiting trees and flowering trees and on their feeding path at evening hours. Mist netted bats were kept in cages for one hour in a darkened room. Fruits were offered and their feeding behaviour was observed. The germination studies of the mist netted bat's defecation also documented bat-plant interaction.

Identification of feeding roosts like caves, old building verandas and trees to which the bats flew with fruit before consumption were recorded. Once in fortnight plastic sheets were spread on the floor of the feeding roosts to collect the remains of the food items and faeces. Examination of left-over, spits and faeces help to find out the feeding habit, dietary selection (core species of plants) and the seed dispersal role of each fruit bat species. The seedlings from the feeding roost also helped to identify the plants benefited dispersal through bats.

Faeces samples were collected from plastic sheets placed under the mist nets and also by placing under their flight paths to collect the defecation in flight.

Identification of bat interacting plant species where made by Dr. V. Chelladurai, Botanist

after careful examination of the characters of the plants and checked with the literatures and the authentic herbarium of southern Western Ghats flora, available at the Research Center of the Central Council for Research in Ayurvedha and Siddha (Govt. of India), Palayamkottai.

RESULTS

C. sphinx and *C. brachyotis* are selected as common fruit bat species of Kalakad Mundanthurai Tiger Reserve. The mist netting rate of *C. sphinx* in the foot hill and the adjoining forest area is 95 per cent when compared to other bat species. Similarly *C. brachyotis* shows 85 per cent mist netting rate in all the elevations above 600 ft in all the forest types of Kalakad Mundanthurai Tiger Reserve (Jeyaprabha, 2008). The foraging trees and shrubs preferred by each species of these bats are recorded. Core plant species of both *C. sphinx* and *C. brachyotis* with their phenology and economic importance are listed in tables 1 and 2. This shows the species specificity in their food selection. Table 3 shows the plants which depend on both the species of *Cynopterus* for their reproduction. Figure 1 shows the percentage of plant species depending on *Cynopterus* spp. at Kalakad Mundanthurai Tiger Reserve for propagation and seed dispersal. Figure 2 represents the plant families depending on bats for pollination and seed dispersal. The out come of the study represents a few chiropterophilic plants which are species specifically dependent on these two bats for their reproduction (pollination and seed dispersal).

DISCUSSION

Frugivorous bats play a vital role in the maintenance of species richness in tropical forests. The bats species *C. sphinx* and *C. brachyotis* feeds on fruits, nectar and pollen helps many tropical plants mutually for its propagation (Kunz and Fenton, 2003; Vanitharani, 2007). These two species play an important ecological role in the forest through their affinity for certain plants. This specificity is mainly based on its nutrient requirement. Both the members spend a higher portion of

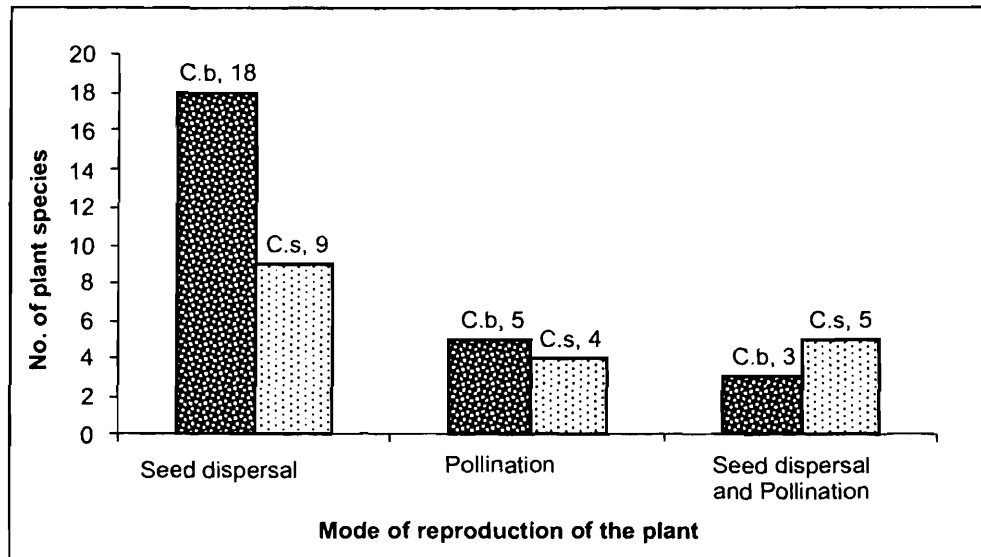


Fig. 1. Number of Plant families depending on *Cynopterus* spp. for Propagation

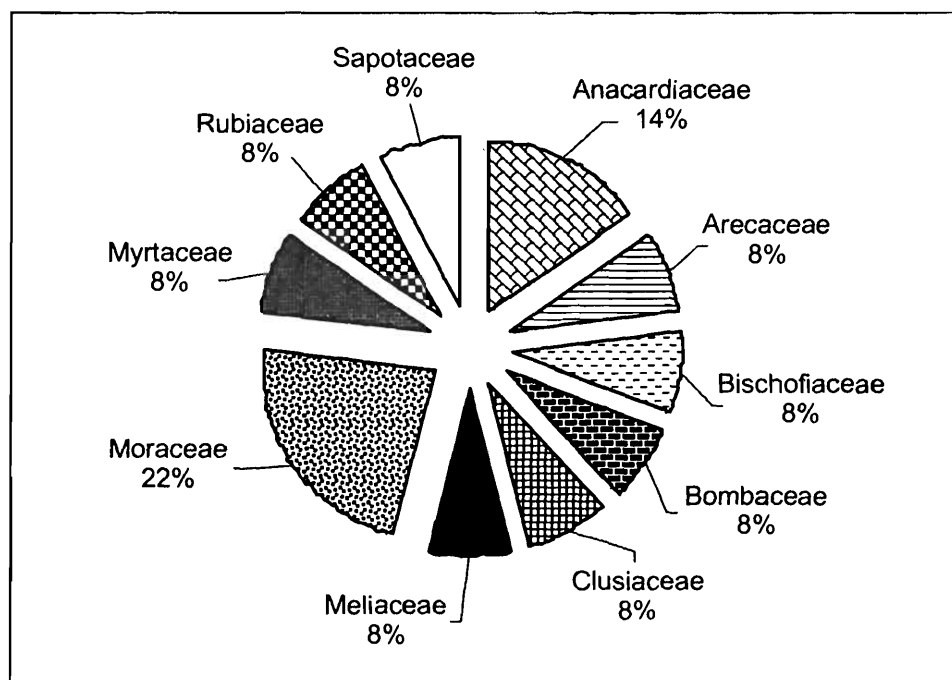


Fig. 2. Percentage of Plant families depending on *Cynopterus* spp. for Propagation

their daily activity budget for searching, processing and eating a variety of food items. Variation in their distribution made them to depend on varied food selection. This behavioral distribution enhances the seed dispersal and pollination role on both the species at various elevations in the tropical forests.

The vertebrate frugivores preference varies according to the fruit colour, display and odour. Bat fruits are dark or pale in colour, displayed

openly by plants, so that they are easily accessed by bats in flight and have distinct odour. Since fruit bats use olfactory cues to locate fruits (Bloss 1999).

In the forest ecosystem the nectar source from the Bombacaceae members are very important resources during January and February when both the food resource and water are scarce. Thus the members of the Bombacaceae family contribute nectar to the bats in the dry seasons and attract the bats and

enjoy the benefits of cross pollination (Heianthus, *et al.*, 1975). Similarly *Ficus* spp. at all elevations by providing bat preferred sweet aromatic fruits with high calcium and other essential mineral content throughout the year and attracts these fruit bat species. The individuals of the *F. benghalensis* of the forest belt bear fruits asynchronously and thus support the *Cynopterus* spp. with preferred food resource. Generally *Cynopterus* spp. handle larger fruits like *Terminalia cattapa*, *Syzygium mundagam* with exocarp and mesocarp which they mostly prefer to consume. These bats have a habit of spending time to remove the exocarp to consume the inner pulp (Bannack, 1998). This processing gives mechanical inducement and chemical salivary treatment for quick germination and the maintenance of healthy growth in seedlings (Vanitharani 2005). The dietary adaptations of bats are commonly reflected in the morphology of their skull and wing (Neuweiler, 2001). Fruits used by bats vary greatly in their hardness depending upon the bite force is important for transporting larger fruits to the feeding sites (Dumont, 1999). Robust skull with wide open jaws and broad palate of *Cynopterus* spp. illustrate that these bats prefer large fruits (Jeyaprabha, 2008).

In plant species the germination rate of the seeds greatly depend on the dispersal agent and the way in which the fruits are processed (Corlett, 1998). Processing of the fruit involves several steps depending on the size and morphology of the fruit. If the fruits are smaller they are swallowed after mastication and the large seeds are dropped undamaged on the feeding roost after cleaning up the exocarp and mesocarp. Swallowed seeds retained in the gut for a longer time experience the enzyme treatment and get defecated. Such seeds germinate faster and escape from insect predation and microbial attack. This treatment provides good growth for seedlings from the accumulated rejecta pellet and the bat droppings under the feeding roost of the bats. Both the species prefer to feed on figs by spending a long period of time in chewing and spitting out less digestible materials increase the extracting maximum nutrients, proteins,

calcium and other minerals (Dumont, 1999; Ruby *et al.*, 2000).

The fruit bats fly long distance nightly between roosting and feeding places (Marshall, 1983). The body size and the broad wing enable them to carry fruits from the fruiting tree. This mechanical efficiency influences the dispersal rate in plant species (Dumont, 1999; Biknivicus and ruff, 1992). When the fruits are larger to be eaten rapidly, they carry them to their distant shelter place and feed safely. This behavior of the bats helps the long distance seed dispersal even to hundreds of feet away from the fruiting trees.

CONCLUSION

The present study has confirmed both the species of *Cynopterus* by their richness, high biomass, feeding habits and mobility play an important role as seed dispersers in the tropical forest ecosystem where they are habituated. These bats differ from the other frugivores by eating the ripe fruits by swallowing matured seeds and excrete unharmed seeds in dropping seeds far away from the parent tree while processing the gut passage treat the seeds through their bats digestive juice improves the germination rate. These characters confirm both the *Cynopterus* spp. are reliable seed dispersers and play significant role in the evolution and in the maintenance of forest ecosystem.

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Table 1. *Cynopterus brachyotis* interacting plant species of Kalakad Mundanthurai Tiger Reserve

Sl. No.	Botanical Name	Family Name	Phenology	Morphology of Fruits	Bat dependancy	Importance of the Plant (Economic and Ecological)
1	<i>Alangium salvifolium</i>	Alangiaceae	March	Soft, pale brown in colour	Seed dispersal	Seeds used in haemorrhages
2	<i>Capparis zeylanica</i>	Capparaceae	February	White	Seed dispersal	Bark used to treat cholera Chiropterophilic fruit
3	<i>Careya arborea</i>	Barringtoniaceae	August	Hard, Green	Seed dispersal	Fibre is used for Cordage and pollination and Sacking
4	<i>Dillenia indica</i>	Dilleniaceae	October	Soft, Purple in colour	Seed dispersal	Fruit used as tonic
5	<i>Diospyros malabarica</i>	Ebenaceae	March	Brown	Pollination	Bark used in rheumatism and swellings
6	<i>Erythroxylum monogynum</i>	Erythroxylaceae	September	Soft red fruit	Seed dispersal	Useful to treat dyspesia and fever
7	<i>Actephilla excelsa</i>	Euphorbiaceae	December	Hard, Greenish white in colour	Seed dispersal	Bats feed on fruits
8	<i>Mallotus philippensis</i>	Euphorbiaceae	December	Reddish brown	Seed dispersal	Fruit used to treat cutaneous infections
9	<i>Strychnos cinnamifolia</i>	Loganiaceae	July	Soft brown fruits	Seed dispersal	Chiropterophilic fruit, roots used to treat ulcers
10	<i>Agalia elaeagnoides</i>	Meliaceae	October	Brownish grey	Seed dispersal	Seeds used to treat painful micturition, Edible fruits for birds, bats
11	<i>Artocarpus communis</i>	Moraceae	May, June, July	Soft, yellowish colour	Seed dispersal	Bats feed on fruits
12	<i>Ficus tashahela</i>	Moraceae	September	Greenish red soft fruit	Seed dispersal	Chiropterophilic fruit Bark used to treat diabetes
13	<i>Ficus benghalensis</i>	Moraceae	May, June, July	Red soft fruit	Seed dispersal	Latex used to treat rheumatism, bark for diarrhoea. Edible fruit for mammals and birds
14	<i>Ficus racemosa</i>	Moraceae	December	Pinkish red soft fruit	Seed dispersal	Edible fruit for mammals and birds Bark used to treat Liver disease

Table 1. Contd.

Sl. No.	Botanical Name	Family Name	Phenology	Morphology of Fruits	Bat dependancy	Importance of the Plant (Economic and Ecological)
15	<i>Ensete superbm</i>	Musaceae	November, December	Flowers reddish purple with high nectar yield	Pollination	Chiropterophilic fruit
16	<i>Syzygium mundagam</i>	Myrtaceae	September	Soft reddish brown pink fruit	Seed dispersal and pollination	Fruits feed for bats and primates, Flower yield nectar for birds and bats
17	<i>Syzygium rubicundum</i>	Myrtaceae	December	White soft fruits, flowers white in terminal branched racemes	Seed dispersal and pollination	Chiropterophilic fruit, Barks used as gargles and mouthwashes
18	<i>Eugenia calcadensis</i>	Myrtaceae	May	Soft, pink in colour	Seed dispersal	Bats feed on fruits
19	<i>Erythrina variegata</i>	Papilionaceae	March, April	Coral red flowers	Pollination	Flower yield nectar for birds and bats, Leaves used as diuretic
20	<i>Canthium parviflorum</i>	Rubiaceae	October	Greenish white flowers with slender follicles	Seed dispersal	Roots used as anthelmintic. Chiropterophilic flowers
21	<i>Pavetta indica</i>	Rubiaceae	July, September, August	Soft, greenish white fruits	Seed dispersal	Roots used tonic and diuretic, Edible fruit for bats Edible fruit for animals and bird
22	<i>Atalantia monophylla</i>	Rutaceae	December	Hard, light orange in colour	Seed dispersal	Used to rheumatism
23	<i>Pallaquium ellipticum</i>	Sapotaceae	September	Hard green fruit	Seed dispersal	Tall tree dominating the mountain evergreen forest, chiropterophilic fruit
24	<i>Madhuca longifolia</i>	Sapotaceae	May, June	White flowers in fascicle	Seed dispersal	Flower yield nectar for birds and bats, Seeds used to treat rheumatism
25	<i>Gordonia obtusa</i>	Ternstomataceae	May	Yellowish white flowers in axillary terminal racemes	Pollination	Flowers yield nectar for birds and bats

Table 2. *Cynopterus sphinx* interacting plant species of Kalakad Mundanthurai Tiger Reserve

Sl. No.	Botanical Name	Family Name	Phenology of the plant species	Morphology of Fruits	Bat dependancy for plant reproduction	Economic and Ecological Importance of the Plant
1	<i>Alangium salvifolium</i>	Alangiaceae	April	Pale brown soft fruit white flowers in fascicles	Seed dispersal and pollination	Edible fruits and flowers for birds and bats, seeds used to treat haemorrhages
2	<i>Annona squamosa</i>	Annonaceae	February	soft fleshy greenish white fruit with hard grid, green flowers	Seed dispersal	Seeds used as abortifacient, edible fruit for bats and birds
3	<i>Polyalthia longifolia</i>	Annonaceae	February	Fruits are clustered, greyish brown hard fruit, flowers yellowish green	Seed dispersal and pollination	Bark used as febrifuge, chiropterophilic plant
4	<i>Alstonia scholaris</i>	Apocynaceae	March	Greyish white flowers in terminal racemes	Pollination	Bark used as medicine for diarrhoea, asthma, ulcers, edible fruit for bats
5	<i>Calophyllum inophyllum</i>	Clusiaceae	July, August	Hard yellow fruit, yellowish white flowers	Seed dispersal and pollination	Resin used as emetic and purgative, Chiropterophilic plant
6	<i>Anogeissus latifolia</i>	Combretaceae	May, June	Red fruits, small greenish yellow flowers	seed dispersal and pollination	Flower and fruit food for Endemic endangered bats and Primates Bark used in tonic
7	<i>Terminalia catappa</i>	Combretaceae	February	Hard grid pink soft fruit	seed dispersal	Juice used to treat scabies and cutaneous infections Chiropterophilic fruit
8	<i>Actephilla excelsa</i>	Euphorbiaceae	December	Hard greenish white fruit, white colour flowers	Seed dispersal	Chiropterophilic plant
9	<i>Diospyros ebenum</i>	Ebenaceae	August	Hard red fruit, pinkish flowers	Seed dispersal	Trees used for ornamental work Chiropterophilic plant
10	<i>Pithicolobium dulce</i>	Mimosaceae	May, June	Soft red fruit	Seed dispersal	Bark used as febrifuge, chiropterophilic plant

Table 2. Contd.

Sl. No.	Botanical Name	Family Name	Phenology of the plant species	Morphology of Fruits	Bat dependancy for plant reproduction	Economic and Ecological Importance of the Plant
11	<i>Ficus benghalensis</i>	Moraceae	June, July	Red soft fruit	Seed dispersal	Latex used to treat heumation, bark for diarrhoea. Edible fruit for mammals and birds
12	<i>Psidium guajava</i>	Myrtaceae	March May	Soft yellowish green fruit	Seed dispersal and pollination	Bark used to treat diarrhoea, asthma, ulcers, Edible fruit
13	<i>Syzygium cumini</i>	Myrtaceae	September	Black (or) purple soft fruit, flowers greenish white racemes	Seed dispersal and pollination	Seed used to treat diabetes, ulcers. Edible fruit
14	<i>Erythrina vaiegata</i>	Papilionaceae	December	Coral red flowers in dense racemes	Pollination	Flower yield nectar for birds and bats, Leaves used as diuretic
15	<i>Morinda tinctoria</i>	Rubiaceae	May-March	Greenish white hard fruit	Seed dispersal	Chiropterophilic fruit
16	<i>Glycomis pentaphylla</i>	Rutaceae	October	Elongate white flowers	Pollination	Leaves used to treat fever and liver complaints, chiropterophilic plant
17	<i>Achras Sapota</i>	Sapotaceae	May-March	Brown fruits, white colour flowers	Seed dispersal	Juicy edible fruit, bark used as tonic

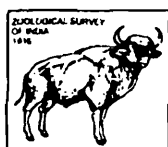
Table 3. Plants depending on both the species of *Cynopterus* for their reproduction

Sl. No.	Botanical Name	Family Name	Phenology of the plant species	Morphology of Fruits	Bat dependancy for plant reproduction	Economic and Ecological Importance of the Plant
1	<i>Anacardium accidentalae</i>	Anacardiaceae	May, June	Hard red fruit	Seed dispersal	Seed used to treat diabetes, ulcers Edible fruits for birds and bats
2	<i>Mangifera indica</i>	Anacardiaceae	May, June	Soft, orange in colour	Seed dispersal	Bark used in Uterine haemorrhage, Seed used in asthma
3	<i>Areca catechu</i>	Arecaceae	July	Hard, Reddish brown	Seed dispersal	Used as mastifactory
4	<i>Bombax malabaricum</i>	Bombaceae	March, April	Red wide open flowers	Pollination	Flower yield nectar for birds and bats. Bark and fruits used as tonic
5	<i>Mesua ferrea</i>	Clusiaceae	August	Red flowerswith high nectar yield	Pollination	Flowers used it treat Cough and buds for dysentery Chiropterophilic flower
6	<i>Bischofia javanica</i>	Euphorbiaceae	May	Flowers greenish black	Seed dispersal	Bark used to treat throat troubles
7	<i>Azardiracta indica</i>	Meliaceae	May, June	Soft yellowish green fruit, white flowers	Seed dispersal	Bark used in troubles
8	<i>Ficus hispida</i>	Moraceae	April	Pinkish red soft fruit	Seed dispersal	Fruits used as tonic and emetic Chiropterophilic fruit
9	<i>Ficus amplissima</i>	Moraceae	December	Soft pinkish red fruit	Seed dispersal	Edible fruit for mammals and birds, Gum used in pharmaceutical preparation
10	<i>Artocarpus heyerophyllus</i>	Moraceae	April	Soft large sized yellow fruit with hard grid	Seed dispersal	Leaves used as tonic, Edible fruits for birds, bats
11	<i>Syzygium jamboss</i>	Myrtaceae	September	Soft whit or pink fruits, flowers white in terminal branched racemes	Seed dispersal and pollination	Chiropterophilic fruit, Barks used as gargles and mouthwashes
12	<i>Canthium dicocum</i>	Rubiaceae	March	Cream coloured flowers.	Pollination	Bark used as a febrifuge and applied externally to fractures
13	<i>Bassia latifolia</i>	Sapotaceae	January	Soft reddish yellow fruit, cream colored flowers	Seed dispersal and pollination	Bark used for adjunct in dyeing

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A PROBE INTO CHEMICAL SIGNALING IN FRUIT BATS FOR QUICK FOREST RESTORATION IN FOOT HILL RESERVES OF SOUTHERN WESTERN GHATS

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INTRODUCTION

Chemical communication is found in nearly all organisms. 'Chemical signaling' tops the rank of all communication skills. Chemical communication enables a living form to achieve top rank in the evolutionary tree (Schmidt, 1985; Kamran and Kerth, 2003). 'Bat-Plant interaction' through chemical signals is a phenomenon restricted to the tropics. Being a 'Hot Spot' southern Western Ghats provide a platform for this study. Benefits through bat propagation are unrivaled, unique and distinct. Being the only flying mammal they alone can carry larger fruits even equivalent to 1/3 of its own body weight to longer distance (Marshall, 1983; Norberg and Rayner, 1987 and Donald, 1991). The fruits handled and processed (bat bitten fruits-saliva, faecal seeds-intestinal juices) by fruit bats show quick germination, retrieve seed dormancy and have resistance against insect and microbial attacks (Omaston, 1965; Janzen 1970; Thomas, 1982; Howe and Smallwood, 1982; Augsburger 1984; Bizerril and Raw 1998; Iudica and Bonaccorso 1997; Lobova, *et al.*, 2003 and Tang *et al.*, 2005). Fruit bats are catholic in food selection. Each fruit bat species has its own core plant species for dietary selection (Kalko *et al.*, 1996). Chiropterophilic

plant resources are with specific strong odours and peculiar chemical composition which restricts species competitions among the other seed dispersers and pollinators (Kunz and Fenton, 2003). Identification of the chemical stimulants of bats for successful propagation and the product of olfactory and dietary preference of fruit bats will help to synthesis synonymous chemical compounds.

Documentation and cataloging of the chemical requirements of plants from bats and bats from plants are the out come of this present study. Identified the chemicals involved in the bat's saliva and digestive juices for the quick germination, purge seed dormancy and protection of seeds from insect predation and microbial attack (Lobova *et al.*, 2003). Identified the chemical cues involved in the Chiropterophilic plants to attract and satisfy the quest of the bat to get balanced diet (nutrition), nutritive additives and secondary metabolites to survive and reproduce (Helvesen *et al.*, 2000). These cataloging of chemicals are very important for the propagation of many rare, endangered, endemic plants and implementing Conservation Management Action Plans for forest restoration and the survival of the dependent diversity of species.

MATERIALS AND METHODS

Cynopterus sphinx (Short Nosed Fruit Bat), is a commonly available fruit bat in the tropical ecosystem of India. Probe into the chemical signal from the fruit bat's saliva, gut and faecal samples were collected from *C. sphinx*. Fresh saliva, gut content and liquid faecal matters were collected from the mist netted bats and dissolved in Dichloromethane and stored in air tight containers at -20°C until they were analyzed under GC-MS (Rosell and Sundsdal, 2001). A fused silica capillary column 125m × 0.25mm i.d) on Shimadzu 17A equipped with mass spectrometer (Shimadzu QP 5000) was used to separate and identify the volatiles of the samples. The initial column temperature was set to 70°C for 2 minute, increased to 250°C by 30°C per minute and held for 30 minute. Helium was used as a carrier gas at a flow rate of 0.6 ml per minute. The transfer line temperature and electron ionization was set at 300°C and 70°C respectively. The Mass spectrometer was operated in scan mode over a mass range of 25 to 700 amu. Their identity was determined by comparing the mass spectrum obtained with the computer database. Salivary samples were collected from 8 male and 8 female bats. The gut contents were collected from two male and one female sacrificed bats. Mist netted bats defecate immediately as soon as they caught into the net. Fresh faeces were collected from 5 males and 5 females during foraging between 07.30 pm and 9 pm inside our Sarah Tucker college campus. Saliva, gut and faecal samples were also tested for other chemical compounds like enzymes and non odorous major composition with the auto analyzer using the identification kits for the specific samples. The same methodology was repeated to identify the chemical signals from a few chiropterophilic fruits namely (*Terminalia catappa*, *Ficus bengalensis*, *Cordia oblique urilld*, *Syzygium cumini*, *Psidium guajava*, *Murraya koengii*, *Morinta tinctoria*, *Pithecolobium dulce*, *Azardiracta indica*). The identified chemicals of bat and plant samples were referred for their specific functions. The identified functions were confirmed through the literature collections to

study the impact of these chemicals in earlier studies.

RESULTS

The earlier laboratory studies proved the early germination of seeds than the normal seeds this made a probe into the present ongoing project. The chemistry of the saliva, gut and the faeces analyzed through GC-MS and auto analyzer are listed in Table 1-3. The following chemicals dominated the composition of the bat sample Alkanes (Methane, Decane and Cosane), Fatty Acids, Alcohols, Aromatic Compounds like Esters Ether, Silicon, Enzymes like-Amylase, Acid and Alkaline phosphatase.

Among the compounds alkanes dominated the composition and are listed in Table 4. The notable odoriferous compound of the peak analysis of GC-MS study on the plants *T. catappa*, *F. bengalensis*, *C. urilld*, *S. cumini* and the nutrient composition of the selected chiropterophilic fruits which attracted the bats are tabulated in Table 5, High Density Lipoproteins (HDL), Low Density Lipoproteins (LDL) Triglycerides (TGL) T. Cholesterol, Proteins, Glucose, Iron, Calcium, Phosphate are the prime compounds present in the selected chiropterophilic fruits are given in Table 6.

DISCUSSION

Seeds germinate when the seed falls in a suitable ground with all required conditions necessary for germination. Every seed takes a particular time for germination resting time and growth phase. It has been proved that bat saliva, gut and faeces treated seeds germinate faster than that of the normal seeds. (Omaston, 1965; Janzen 1970; Thomas, 1982; Howe and Smallwood, 1982; Augsburg, 1984; Thomas, 1991; Douglas, 1979; Utzurum and Heideman, 1991; Figueiredo and Perin, 1995; Zhaki *et al.*, 1995; Taylor *et al.*, 1997 and Shilton, 1999). Our laboratory and field case studies on few bat eaten fruits enable quick germination. In addition to this the bats process the fruits by biting scrapping, and nibbling in such way that the pericarp, seed coat and part of the mucilaginous layer breaks to reduce the seed

Table 2. Probable chemicals of fruit bat gut inducing seed germination

Alkane		Acid		Alcohol	
Male	Female	Male	Female	Male	Female
2-(Carbomethoxy)- 2-(carbo-tert-butoxymethyl)- 3-(3-bromo-5, 6-dihydronaphth-7-yl)cy Pentadecane Nonadecane Hexadecane 1-chloro- Octadecane Isooctane, (ethenyloxy)	Tetracosane, 12-decyl-12-nonyl	Docosanoic acid Hexadecanoic acid Octadecanoic acid Palmitic acid	Cyclopentane undecanoic acid	Farnesyl alcohol Lup-20(29)-en-3-ol, (3.beta.)	

Alk.Po4 (IU/L)	Amylase	Acid.Po4 (IU/L)
423	112	12
1089	26	19
492	47	8
599	23	15

The highest amount of Alk.Po4 1089 (IU/L), Acid.Po4 19 (IU/L) and Amylase 112 (IU/L) present in the Alimentary tract composition

Table 3. Probable chemicals of fruit bat faecal inducing seed germination

Alkane		Acid		Alcohol	
Male	Female	Male	Female	Male	Female
1-Chloro Octadecane	1-Undecane	Docosanoic acid	Hexadecanoic acid	2-butyl1-Octanol	1-Hexadecanol
4-Decane	14,16 Hentriacontanedione	Hexadecanoic acid		4-Octanol	4-Octanol
3-Methylheptyl acetate	2-propoxy-butane	Nonanoic acid		Acetyl-hydro-	
6-methyl-Octadecane	2,4-Dimethylundecane	Octadecanoic acid		hydroxyl	
Decane, 2,4-dimethyl	4 - Methyloctane	Palmitic acid			
Heptacosane	Cyclonexane				
Hexadecane	Cycloundecane				
Hexane	Dotriacontane	Dilauroyl peroxide fatty acid derivative			
Octane, 6-ethyl-2-methyl	Hentriacontane				
	N-Octyl acetate	Methyl ester	Ester		
	Tetradecane				
Alkane Present in Both Sexes		Silane	Silicon compound		
Octadecane 2,6-Dimethylheptane Pentadecane					

Alk. Po4 (IU/L)	Amylase(IU/L)	Acid. Po4 (IU/L)
68	445	175
56	0	17
231	0	6

The highest amount of Alk.Po4 231 (IU/L), Acid.Po4 175 (IU/L) and Amylase 445 (IU/L) present in the faecal composition

Table 4. Alkane composition of saliva, gut and faeces

Saliva		Gut	
Male	Female	Male	Female
2,2,3-Trimethyl butane	2,2-dimethyl butane	2-(Carbomethoxy)-2-(carbo-tert-butoxymethyl) -3-(3-bromo-5,6-dihydronaphth-7-yl)cy	Tetracosance, 12-decyl-12-nonyl
2,4-Dimethyl decane	2,3,4-Trimethylheptane	Pentadecane	
2,9-Dimethyl decane	3,3-Dimethyl hexane	Nonadecane	
3,3- Dimethylhexane	3,4-Dimethyl heptane	Hexadecane	
3,5-Dimethyloctane	2,2,3,3- Tetra methyl hexane	1-chloro- Octadecane	
3-Methyl-2 butanone	4,5 - Dimethyl - 1- hexane	Isooctane, (ethenyloxy)	
2-N- propyl- oxetan	4,5-dimethyloctane		
2-Propyl oxetan	4,6,8-Trimethylnonene		
Octane, 3-ethyl-2,7-dimethyl	5- Methyl - 5 - hexane - 2- one		
Pentacosane,	Pentane, 1,3-epoxy-4-methyl		
Pentane	Octane		
Decane	2-Amino-5 methylheptane		
Tetradecane	2- Heptanamine, 5-methyl- 2 Amino-5 methylheptane		
Undecane	Isopropylloxetan 1,3,5 Triethyl		
4-ethyltetradecane	1,1,3,5,5 Pentabutoxy trisiloxane		
Beta -D-Glucopyranose, 2 deoxy 2[tetrachloroethylidene) amino] 1,3,4,6	1,4-Cyclohexadiena		
Neo-30-norgamma cerane-3,22 - dione	Cyclohexane		
	Tetracosane, 3-ethyl		
	Triacontane		
Alkane Present in Both Sexes			
4-Octen-3-One		Alkane Present in Both Sexes	
Octane, 3-ethyl-2,7- dimethyl, 2,7-Dimethyl octane		Octadecane 2,6-Dimethylheptane Pentadecane	

Table 5. Olfactory preference of fruit bat or aromatic chemical compound used by the plants to attract bat visitors

Plant Species	Ester Derivatives	Azo Compound	Halo Compound	Aliphatic acid	Aliphatic hydrocarbons (Alkane, Alkene)	Aliphatic Ether	Aliphatic alcohol	Aldehyde Derivatives	Ketone Derivatives	Amino acid derivatives	Heterocyclic Compound
<i>Terminalia catappa</i>	7-Methyl-4-octyl acetate 1,2-Benzene dicarboxylic acid-bis (2-methyl) propyl ester	Benxene,1-azido-4 methyl	Butane,1,3-dichloro 3methyl	Hexadecanoic acid			1,6-Diphenyl-1,5-hexadiene-3,4-diol	2-Nonenal	-		Pyrrolidine 1-(1-Oxo 2,5-Octa decadienyl
<i>Ficus bengalensis</i>	1,2-Benzene dicarboxylic acid-bis (2-methyl) propyl ester			Octadecanoic acid Hexadecanoic acid	Tetradecane	Octadecyl Vinyl ether Lauryl glycidyl ether			3,4-Dimethyl acetaphenone		
<i>Cordia oblique urilld</i>	1,2-Benzene dicarboxylic acid-bis (2-methyl) ester Iso butyl pthalate						3-Hexyne-2,5-diol	Cis-4-Decanal	3,4-Dimethyl acetaphenone	Glycine,N-methyl-1-oxododacyl	
<i>Syzygium cumini</i>	Dihydrocarvyl acetate 1,2-Benzene dicarboxylic acid-bis (2-methyl) ester Iso butyl pthalate		1-Iodo-2-methyl undecane	Decanoic acid Hexadecanoic acid Octadecanoic acid	2,2-Dimethyl butyl cyclohexane		1-Trideryn-4-ol 7-Hydroxy 1-3 di methyl prop-enyl		-		

Table 6. Chemical Composition of a few bat preferred fruits

Bat Fruit	Common name	T.Cholesterol (mg/dl)	HDL (mg/dl)	LDL (mg/dl)	TGL (mg/dl)	Calcium (mg/dl)	Po4 (mg/dl)	Iron (mg/dl)	Glucose (mg/dl)
<i>Azardiracta indica</i>	Neem	1	0	1	10	5.7	2.2	68	678
<i>Terminalia catappa</i>	vadham	5	1	1	24	5.1	4.2	83	696
<i>Ficus bengalensis</i>	Alampalam	6	0	2	50	4.9	3.8	88	634
<i>Psidium guajava</i>	Guava	16	0	1	34	5.7	4.3	5	703
<i>Murraya koengii</i>	Karuveppilai	9	2	3	35	5.4	9	98	606
<i>Morinta tinctoria</i>	Manjanathi	12	1	2	35	5.7	5	115	656
<i>Pithecolobium dulce</i>	Kodukapuli	5	1	1	14	5.6	5.7	40	675

dormancy period. It also prevents the seed from insect predation, microbial infection and climatic injuries. Bats being a mammal maintains body temperature, the passage of seeds through the alimentary canal induces the seed with gut and rectal temperature, decreasing imbibition time.

The studies of Souza and Lio (2001), Traveset and Verdu (2002), Lobova *et al.* (2003), Naranjo *et al.* (2003), Nyhagen *et al.* (2005), Tang (2005) and Mcconkey and Drake (2006) have proved the presence of certain chemicals present in the bat enhance germination. The present analysis have proved Alkanes, Fatty Acids, Alcohol, Aromatic Compounds like Esters Ether, Silicon, Enzymes like-Amylase, Acid and Alkaline phosphatase were the dominant chemical compounds of the saliva, gut and the faeces.

Major composition of bat's saliva, gut and faeces are a variety of alkanes. These alkanes perform significant role in seed germination. Bats saliva, alimentary track and fecal composition coat the seed with Alkane Seeds assimilate alkane from the saliva and the gut and enables them with high energy source essential for quick germination (Sengupta, 2005). Alkanes metabolic role helps in seed coat breakage during germination by providing a firm layer of wax over cuticle and protect the seed from the and the sprouting cotyledon of plant is exposed to the air, thus prevents the seeds from water loss, prevents the leaching of important minerals and microbial attack (Kolmer, 2006). Some alkanes like cosane, decane, acontane etc. help to produce important pheromones, chemical messenger materials and protect the seeds till it germinates. Methane improves the texture of the seed for quick germination, vapor deposition helps post-growth and controls density of the micro voids in the seed coat (Stoner, 2004). Decane derivatives of the bat samples namely Tetradecane Pentadecane Noanadecane, undecane helps in protein isolation and stores it as a stable emulsion on the seed coat by precipitation. Cosane derivative Tetracosane of the bat sample increases adsorption which is a major physiological step involved during

germination by increasing the invasion capacity of nanopores in seeds (Galarneau, 2008).

Earlier seed germination Researches have proved the agronomic importance of certain weak acids help in plant development by way of promoting seed desiccation tolerance and inhibiting the phase transitions from embryonic to germinative growth and from vegetative to reproductive growth (Keeley, 1998) present study on salival and gut composition has proved the presence of the weak acids like Nonanoic acid, Hexadecanoic acid, Palmitic acid, Capric acid, Butanoic acid, Benzene dicarboxylic acid.

Aliphatic acid compounds present in the gut (Hexadecanoic acid, Palmitic acid, Octadecanoic acid, Cyclopentane undecanoic acid, Docosanoic acid) and saliva (Isobutanoic acid) of bats act as a coenzyme which helps the seed to recover dormancy and improves catabolic activity during germination.

The science has already proved the alcohols in general supports cellular regeneration, by guarding cells from disease causing pathogens and prevent detoxification produces Glutathione, a natural source of antioxidant that protects the seed from cell damage caused due to oxidation by free radicals thus support the germination of healthy plants (Trubin, 2006). The present study has proved bat possesses alcohols such as 5-Alpha-cholesta-7,9 (11)-dien, 3 beta-ol, Nonacosanol 2,6-Diiodo-3-pyridinol in the saliva; Farnesyl alcohol, Lup-20(29)-en-3-ol, (3.beta.) in the gut ; and 2-butyl1-Octanol 1-Hexadecanol, 4-Octanol 4-Octanol and Acetyl-hypro-hydroxyl in the faecal composition.

The aromatic compounds like ester derivatives prevent the seeds from insect predation (Graven, 1996). The presence of similar ester derivatives are reported in the bat samples of the present study. Phosphatase enzymes in general help to up take organic compounds. Alkaline Phosphatase located in the externals of the bacterial cell membrane helps bacteria during phosphate starvation (Estevez, 2001) the bat treated seeds with salivary phosphatase

enzyme enables the seed to access organically bound phosphate nutrients.

The earlier reports have proved amylase enzymes degrade starch into sugar and it is present prior to seed germination (Maarel, 2001). α -amylase in the saliva breaks starch into sugar, this results in early ripening with sweet flavor. When the fruit bat bites an unripe fruit that fruit ripens faster than the rest of the unripened fruits of that cluster eg. Banana, *Ficus* sp. etc. the bat faecal seeds also has the advantage of amylase treatment which aids germination. The bats provide therapeutic treatment an additional protection for the germinating seeds from infection through Octamethyl cyclotetra silazane and Ticosyl trichlorosilane silicon compounds present in the salival composition and Silane of faecal composition (Prescott, 1999).

The research wing of Seed Centre Forest Genetic Division, Tamil Nadu Forest Department has proved pre treatments like smoke treated seeds, boiled water, hot water and cold water soaking, heat and, acid treatment promote germination a bit early than the estimated time to germinate in certain plant species. The seeds get similar high carbon compound treatment by passing through the gut of bat the seed retention in the gut of bat and the buccal cavity might have given this thermal inducement for the seeds.

Being a flying mammal it needs enormous energy to support its locomotion. To get a balanced diet they prefer eating diverse energy rich dietary items. The results of the analysis of the chiropterophilic fruits possess the following compounds namely Ketone group, HDL, LDL, Azo group, T Cholesterol, Aromatic Compounds, Aldehydes, Proteins, Glucose, Iron, Calcium, Phosphate as major components.

In animals, Ketone group acts as an Antioxidant which prevents cell damage caused by pathogens, helps to acclimatize to climatic condition variations and helps in the transport of minor nutritive components (Nahar, 2005). Studies have proved ketone bodies are needed for the usage of fatty acids in brain (Puma,

2000) in the present study it has been proved *Ficus bengalensis* and *Cordia oblique* have high ketone group in their composition.

High Density Lipoproteins HDL are Essential Fatty Acids referred as "good fats" These cholesterol derivatives minimize the consumption of Trans fats from food and grab bad cholesterol the LDL (Low Density Lipoprotein) to liver for excretion (Mahley, 1988). The following chiropterophilic fruits possess HDL in the following levels *Terminalia catappa* (vadham) 1mg/dl, *Morintatinctoria* (Manjanathi) 1mg/dl, *Pithecolobium dulce* (Kodukapuli) 2 mg/dl, and *Murraya koengii*, (Karuveppilai) 2 mg/dl. This may be the reason for the attraction of fruit bats.

The possession of LDL in animals generally causes internal transport: fatty acids and cholesterol from the body tissues to the liver, thus helps in storage and energy production. To get this facility the bat prefers the following fruits with LDL Content *Ficus bengalensis* (Alampalam) 2 mg/dl, and *Murraya koengii*, (Karuveppilai) 3 mg/dl.

Terminalia catappa (vadham) is one among the favorite food items of *C. sphinx*. (Vanitharani, 2007). *Terminalia catappa* possesses Benzene, 1-azido-4methyl which is an azo component that deposits bulk of copper and Tocopherol cholesterol which helps to maintain the integument in high quantity. *F. bengalensis* (Alampalam) 6mg/dl, *M. koengii* (Karuveppilai) 9 mg/dl, *M. tinctoria* (Manjanathi) 12mg/dl, *P. guajava* (Guava) 16 mg/dl, these results suggest possession of this high level Tocopherol may be the reason for the food preference.

Presence of Hexadecanoic acid in; *Terminalia catappa*, Octadecanoic acid and Hexadecanoic acid in *Ficus bengalensis*, Decanoic acid, Hexadecanoic acid and Octadecanoic acid in *Syzygium cumini* regulate functions like blood-pressure, lipid levels, and clotting. In addition it helps bats to produce hormones that facilitate immune and inflammation response to injury and infection (Tubitak 2004).

Triglycerides, as major components of all the chiropterophilic fruits play an important role in metabolism as energy sources and transporters of dietary fat. They contain more than twice as much energy (9 kcal/g) as carbohydrates and proteins (Takeishi, 1995).

Calcium and phosphates are critical nutrients and top macro minerals which help in building and maintenance of bones and teeth, regulation of muscle tone and heartbeat, initiatives for blood clotting, assists transport of chemicals across cell membranes, and assist in functioning of protein, hormones and enzymes.

The present chemical analysis has proved almost all the tested Chiropterophilic fruits possess high calcium and phosphate content. The earlier studies about the foliage and nectar feeding bats have also confirmed the high requirement for calcium and phosphates for the flight maintenance and reproductive requirements in bat life style (Karl, 2004).

Iron is an important mineral that helps red blood cells deliver oxygen to the rest of the body and perform the vital functions like cell diffusion in immune and central nervous systems. (Richard, 2007). The present chemical analysis has proved almost all the tested Chiropterophilic fruits possess high iron content. Among which *M. tinctoria* tops the rank with 115 (µg/dl) and other favorite fruits like *A. indica*, *T. catappa* and *F. bengalensis* possess iron content more than 85 (µg/dl). This is one of the main reasons for the attraction of bats to these fruits.

Analyzed the chemical composition of saliva, gut and faecal is a new record in the chemical biotechnology for environment and biodiversity conservation by providing the chemical clues for quick germination by retrieving dormancy, prevent insect predation and microbial infection.

The catholic food selection of fruit bats helps to reason out the nature of their food selection and to identify the chemical signals evolved by the chiropterophilic plants to attract the fruit bats to enhance the propagation. The results can also be used to study the growth promoting chemical substances and bat attractants. The outcome of the confirmation study will be a boon for the conservation and propagation of rare and endemic plant species.

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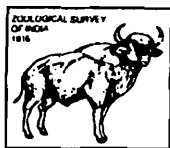
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IMPACT OF ANTHROPOGENIC PERTURBATION THROUGH SCIENCE AND DEVELOPMENTS ON THE COMPLEX NETWORKS OF BAT DIVERSITY AND THEIR INTERACTIONS IN AGASTHIYAMALAI BIOSPHERE RESERVE

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INTRODUCTION

Nearly one quarter of mammalian species are bats. Bats belong to one of the most successful mammalian orders (Chiroptera) and probably the most diverse (Kunz and Pierson, 1994; Mickleburgh *et al.*, 2002 and Simmons, 2005). Their diversity is shown by their appearance, their dietary habits, social organization and their choice of places of roost (Kunz, 1982). Yet they remain creatures of mystery, and subject of more prejudice. The news media, legends, folk lore, television, movies and storybooks perpetuate myths (CAMP report, 2002). Chiropterans carry a lot of misinformation than any other group of animals (Fujita and Tuttle, 1991).

Their role in the ecology of certain habitats and in the affairs of man is often a paramount importance. Microchiropteran bats do an important service as biocontrol agent consuming the insect pests of Lepidopteran, Dipteran, Orthopteran, Hemipteran, Homopteran, Trichopteran and Coleopteran orders (Rydell, 1986; Swift and Racey, 1985; Whitaker, 1993, 1995 a,b; Whitaker *et al.*, 1996, 1997, 1999) and megachiropteran bats play an

essential role as eminent pollinators and seed dispersers (Marshall, 1985; Fleming, 1988; Cox *et al.*, 1992; Gorchov *et al.*, 1993; Rainey *et al.*, 1995 and Kunz and Fenton, 2003).

The increasing human population brings extra demands for land, food and other resources which often result in the degradation and destruction of certain habitat types (Mickleburgh *et al.*, 2002). This environmental upset poses serious threats to the existence of bat populations. (Jeyapraba and Vanitharani, 2003; Vanitharani, 2004 and Vanitharani *et al.*, 2004). This paper is an attempt to focus on the threats for bat species survival and the need for their conservation. According to IUCN 2003 Version 3.1 there is a continuous decline and fluctuation in bat population. Many species show restricted distribution and some of them are about to reach the point of extinction.

MATERIALS AND METHODS

Study area

The Agasthiyamalai Biosphere Reserve Parts of southern Western Ghats are an abode for a wide array of flora and fauna and are internationally recognized for the richness of

their biodiversity. They are also known to have a rich bat fauna (Bates and Harrison, 1997; Hutson *et al.*, 2001; Vanitharani, 2007a, 2007d). The Agasthiar hill range is incorporated in two of the W.W.F. Global 200 Ecoregions (No. 20: South-western Ghats Moist Forests and No. 171: Western Ghats Rivers and Streams).

Methodology

Initial broad chiropteran species survey of the Agasthiyamalai Biosphere Reserve, was started by the author in early 2002, and then after intensive survey and monitoring, programmes were carried out in seven various research stations in the southern Western Ghats incorporating the Podigai hill range, Servalar hill range, Upper Kodayar hill complex, Kalakad hill range, Couttalam hill range, Sivagiri hill complex, Kadayam Hill Range and Mahandrgiri Hill Range. The survey work included the identification and location of day and night roosts of bat species, monitoring and recording of bat activity patterns with mist nets and logging of ecological data. The authenticated bat species identification was confirmed by the Harrison Institute, Center for Systematics and Biodiversity Research, UK. Once bat colonies were located, they were periodically visited with threats to their roosting sites and their foraging area and continuously monitored by direct observations and by collecting information from local people. Based on the prevalence of these little creatures the conservation measures and management action plans were drafted.

RESULTS

The completed bat survey from seven research sites incorporated eleven forest types from Agasthiyamalai Biosphere Reserve says, their distribution varies in accordance to the elevation and the forest type. The results represent the first published bat data for this area with a collection of 34 bat species belonging to 8 families (Vanitharani, 2006). The distribution status has classified 30 bat species as forest bats and 23 bat species as bats of foothills and the adjoining tropical plains. Among them 12 bat species are distributed both

in the forest and plain (Fig. 1). Majority of the bats of the forest area are the cave dwellers. In the foot hill tropical plain most of the bat species prefer abandoned anthropogenic structures.

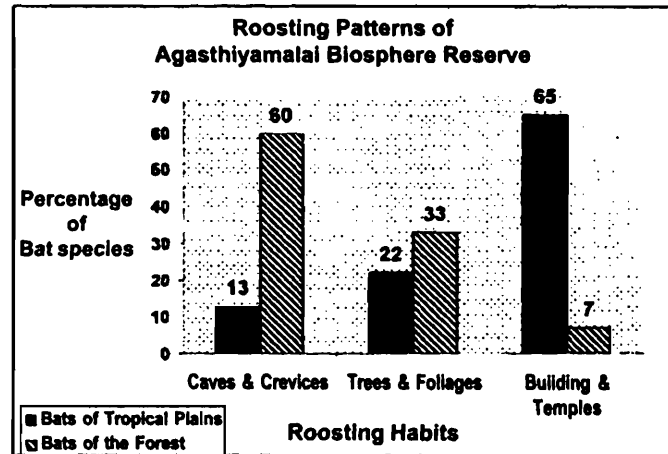


Fig. 1. The distribution status of Agasthiyamalai Biosphere Reserve

Two microchiropteran bats, *Rhinolophus beddomei* and *Kerivoula lenis* (Vanitharani *et al.*, 2003a) reached the NT (Near Threatened) state. The chiropteran assemblage has four representatives of endemic bat species of South Asia, an Endangered megachiropteran, *Latidens salimalii* (Vanitharani *et al.*, 2003b, 2004 and Vanitharani, 2005a.) and 3 microchiropterans, *Rhinolophus beddomei* (Near Threatened), *Hipposideros speoris* (Least Concerned) and *Pipistrellus dormeri* (Least Concerned) are the valuable representatives (Vanitharani *et al.*, 2005c, 2007a).

Identification of left outs from the feeding roosts of megachiropterans and faecal pellet analysis of the microchiropterans documented their role in the forest ecosystem (Vanitharani, 2007b). Observations with video recording and mist-netting in the foraging areas were taken as documentary data for their interactions in the ecosystem (Vanitharani, 2007c). The species specific dietary preferences of these species immensely helped to identify and bat-plant interdependence and their role to retain the community structures and long time survival of specific taxa in the forest ecosystem.

The major reason for the decline in bat population is due to the problems and threats

caused to the habit and habitats of various bat species (Fig. 2). Environment degradation and habitat loss due to human activities and settlements have a major impact on bat populations. The growth of large urban areas, construction activities, renovation of old buildings, industrialization, deforestation, monoculture practices, lopping of trees for management purpose like construction of dams, roads to private estates, encroachments in forest lands and mining operations are the major threats for the habitat of bat species. Disturbances to roosts and food sources are the important factors which had restricted the distribution of bats. Intensive agricultural practices are the main human interferences in the foot hill area, which holds about 20 species of these unrecognized beneficiaries of the ecosystem.

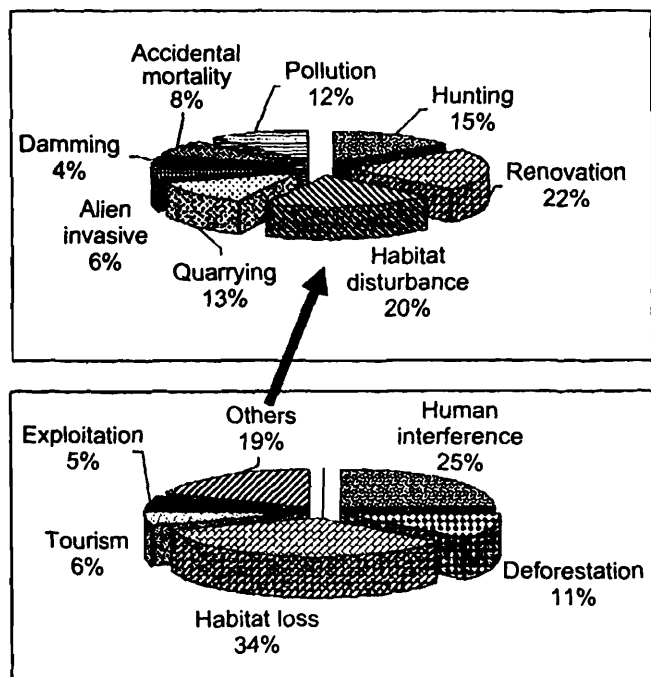


Fig. 2. Major reason for the bat population decline in India.

DISCUSSION

The forest ecosystem with varied types of the trees in different elevations provides roosting and foraging sites for the Indian fruit bats and forest micro bats. The National Remote Sensing Agency (NRSA) reports that India is losing 1.3 million hectares of forests every year. Lakhs of trees are being cut for management purposes. According to Annamalai (2004) the

per capita recorder forest area of Tamil Nadu is showing a decreasing trend from 0.063 ha in 1961 to 0.036 ha in 2001. In Tamil Nadu 1405 villages covering 9% of the total villages are having recorded forest area as land use. Forest area encroachments in Tamil Nadu are 20900 ha. The difference of recorded forest area and actual forest cover in Tamil Nadu 1389 Sq. km. If the habitats disappear in this rapidity, that will subsequently followed by the loss of the fauna (Soule, 1986).

Loss of Foraging Sites

Deforestation often leads to the fragmentation of forests and causes loss of food resources, loss of foraging habitat and killing of the tree and foliage dwelling bat species such events can wipe out the entire species from the ecosystem (Cosson *et al.*, 1999 and Fathom, 2005). The identified cause for the fragmentation of habitats in Western Ghats are human encroachments in the natural habitats, construction of dams, roads, multi purpose hydel projects, plantations and other developmental activities (Balakrishnan, 2002). Mid elevation forests of the Western Ghats are highly fragmented due to tea, coffee, cardamom plantations and due to the construction of dams across the rivers (Pascal, 1988). Construction of roads to link dam sites with townships also enhanced the depletion of habitats (Mistry, 2003). In the heart of the Kalakad Mundanthurai Sanctuary exists a commercial estate leased by the Bombay Burmah Trading Corporation which manages tea, coffee, clove and cardamom plantations. The workers, numbering over 10,000, have been supplied with their requirement of fuel wood illegally from the reserve forest for decades (Sahgal, 2000). This affects the feeding and roosting needs of bats.

Change in the plantation of crops during reforestation in the degraded lowland forests for timber and firewood plant species (teak forests of Manimuthar and Kalakad hills), replacement of exotic trees (Silver oak and wattle) in the estate boundaries (Kodayar and Mahendragiri hills) and monoculture practices (Rubber, Teak, Casuarina and Mango) caused

the disappearance of natural bat foraging trees. Similar impact of change in vegetation causing population reduction has been noticed in Mexico big-eared bat (*Plecotus townsendii*). This bat population showed a strong preference for Noctuid moths which in turn depend on the lentic vascular hydrophytes. Loss of these host plant species in the vegetation reduces the population of the prey/moth which in turn reflect on the reduction of big eared bat (*P. townsendii*) of that area. (BISON Version 1/2000). Similarly in Kodayar and Mahendragiri hills important fruiting trees like *Elaeocarpus* sp., *Syzygium* sp. and *Ficus* sp. from the edge crops boundaries of tea estates are replaced by silver oak trees.

Livestock grazing practices in the foothill area has been responsible for large scale conversion of riparian habitat to more xeric upland habitats (Whitford, 1999 and Tasker *et al.*, 2006). This creates considerable restriction to the foraging and activity patterns of bat species. Forest fire is often man made (Bryant and Colleen, 2008). The foothill villagers have the regular practices of firewood cutting in these forest areas and their negligence cause this heavy loss. Yearly incidents of forest fire in the hills of Kalakad, Courttalam and Sivagiri affected many acres of land (Nowpublic.com/environment/forest-fire-india-needs-special-attention, 2007). The bat survey records show, about 5 species of fruit bats and 20 species of microbats depend on this part of the forest for their roosting and foraging. Storm and flood are the natural disturbance to the bat foraging ground of the forest. Even the trees which are left out, during storm and blow over, face the problem of soil erosion (Annamalai, 2004). This creates a problem for the stable growth of plants which sustain bats population.

Loss of Roosting Sites

The roost provides the bats a place for dwelling, mating, rearing young ones and other social activities (Kunz, 1982). Many bat species are vulnerable to disturbance at their roosting sites. Being sensitive creatures, bats prefer to stay away from human disturbances. The disturbance experienced in their day roost

during day time cause diurnal predation and affects the survival of the population. 15 forest insectivorous bat species depend on the cracks, hollows and cavities in tree barks and trunk as roost. Profound disturbance occurs through traders of honey, resin (Parvati, 2002) and bamboo (Sanker and Ganeshaiah, 1996). In secured such rare microbats are *Pipistrellus coromandra*, *Miniopterus schreibersii* (NT), *Murina pusillus* (VU), *K. lenis* (DD) and the only forest carnivorous bat *Megaderma spasma*.

More than 20 chiropteran species occupy crevices, cracks and domes of anthropogenic structures like historical temples, old archeological monuments, abandoned estate buildings as their favorite roosting sites. Few ecologically important temple bat species are *Rousettus leschenaulti*, *Taphozous melanopogon*, *Pipistrellus dormeri*, *P. ceylonicus*, *P. tenuis*, *Tadarida aegyptiaca*, *H. speoris*, *H. ater* and *Megaderma lyra*. These bats face mass destruction during renovation of old temples. The Cheranmahadevi-(Appan Koil built around 1250 AD) temple outer corridor provided a roosting site for more than 10,000 individuals of *R. leschenaulti* (Vanitharani, 1998). This bat population experienced a sharp decline due to film shooting 'Athma', a Tamil movie in 1994, during the breeding period of the bats. The same bat population completely vanished during temple renovation at 2000 (Jeyaprabha and Vanitharani, 2003; Jeyaprabha, 2008). A similar incident has happened during 2003 to the temple bat species *H. speoris*, *T. melanopogon* and *R. leschenaulti* of Sri Kallapiran Swamy Thirukoil at Srivaikundam and Nellaiappar Koil at Tirunelveli.

Caves provide shelter for 22 microchiropteran forest bat species. In the forest interiors along the state boundaries or border of southern Western Ghats, poachers, illegal traders of forest produce and the pilgrims to the Agasthiyar peedam very often use caves as their night halt and illuminate the cave with fire. This disturbs the cave roost of the megachiropteran cave bats *L. salimalii* (Endangered, Endemic), *R. leschenaulti*, *Eonycteris spelaea* (only available nectarivores

bat species) *Megaderma spasma* (only available carnivores bat species) and the *Rhinolophus affinis*, *R. beddomei* (NT), *R. rouxii*, *Hipposideros pomana*, *Myotis montivagus* (NT), *M. horsfieldii*, *Miniopterus schreibersii* (NT), *M. pusillus* (VU). The Salim Ali's fruit bat (*L. salimalii*) very often share their cave roost entrance with the swiftlets *Collocalia unicolor*. These birds fix their nest with the cave wall by their salivary gum rich in protein, which brings high value in the market abroad (US\$ 2,000-4,000 per kg) (Sankaran, 2001). Uncontrolled bird nest collection from these caves cause severe disturbances to *L. salimalii* population.

Quarrying and mining, particularly for limestone, is another major threat to cave bats of hillocks. Vibration and constant rumbles from stone quarries cause sliding of stones and rocks inside the cave and block the passage. *H. speoris*, *R. hardwickii* and *T. melanopogon* bat colonies with thousands of members are greatly affected by bomb blast and are strangled to death in mass. Such incidents are very common in hillocks around Tirunelveli (Parappadi, Ambasamuthram, Manimuthar and Courtallum a part of southern Western Ghats). Some of the cave roosts become a recreation spot for village urchins.

Indian bats share 'Caves and Crevices', 'Trees and Foliages', Buildings and Temple' as roosting habitats (Vanitharani, 2004). According to the author 64 per cent of the red listed bats of Tamil Nadu prefer to roost in caves (Vanitharani, 2007a). This rate is very high when compared to other roosting habitats. If the Indian Government gives special protection to the cave roosts of bats, the state of Tamil Nadu can save 4 per cent of the red listed bat diversity from extinction.

Pollution and pesticides reduce the diversity of insect food source to insectivorous bat. From 1951, insecticide fumigation has been employed to control the insect vectors such as mosquitoes and other crop pests (Krishnan, 1993). Every year, India produces 66,400 tons of pesticides including the banned pesticide of developed countries like DDT and BHC to treat crop pests. Such insecticides kill both the targeted and non

targeted insect population. Bats forage in this agro-ecosystem are poisoned and accumulate in their body through bioaccumulation. These accumulated pollutants cause bat mortality especially when the fat tissues breakdown during weaning period (Fenton, 1992). Additionally these chemical poisons are passed from mother to offspring through milk, thus causing additive effects to next generation (Mc Cracken, 1986). High organo chlorine content was reported from the tissue of bats foraging in the agro-ecosystem world wide (Riede, 2001). Dramatic decline of Mexican free tailed bats at Eagle Creek Cave and Arizona are due to the high content of DDT and its metabolites (Tuttle, 1994). The drastic reduction of bat population during recent years in UK is due to the usage of lindane pesticide to kill wood boring beetles (Fathom, 2005). Even though similar analysis is not done on Indian bat species, obviously the effect of similar pesticide usage will be the same on bats as well as with other related animals of their food-chain.

The bigger sized bats like flying foxes *Pteropus faunulus*, *P. giganteus*, fulvous fruit bat *R. leschenaulti*, false vampire bat *Megaderma lyra* are being driven towards extinction in certain parts of India. These animals are hunted for food and sports (Hill and Smith, 1984 and Nowak, 1991). Flying foxes in South India are mainly hunted for medicine to treat asthma, back aches, chronic pains etc. Oil extractions from bat flesh are believed to cure arthritis. Tribes of southern Western Ghats relish the meat of forest fruit bats including the endemic bat *L. salimalii* (EN) (Jeyaprabha and Vanitharani, 2003). Indian orchard farmers consider fruit bats as pests and menace for their trade. Actually, a very few species of bat visit orchards to forage and they prefer to consume ripened fruits, which cannot be marketed (Singaravelan, 2002; Singaravelan and Marimuthu, 2008).

The excellent water medium is very essential for the normal life of every organism including bat species. Pollutants cause a severe impact on bats even up to the level of mass killing. After the long starving hours (5 a.m. to 6.30 p.m.) the bats start their activity by drinking

water from the nearby source of their day roost (Bates and Harrison, 1997 and Fenton 1997). Contaminated water causes immediate impact on the physiology of bats. In South India, the contaminated water (fertilizers and pesticides) of our agro-ecosystem, surface runoff from the field (ponds, pools, ditches), microbial contaminated stagnant sewage and the industrial waste contaminated rivers and streams with poisonous pollutants provide the drinking water source for the bats. Occurrence of the microbial pathogens like *Vibrio cholerae*, *Salmonella* spp., as one of the normal microbial flora of certain bat species *H. speoris*, *Scotophilus heathii* and *P. dormeri*, are due to drinking water contamination (Rajkumar *et al.*, 2003 and Pushparani, 2009).

Indian Government legislations and policies are giving poor recognition and the Indian fruit bats are kept under Schedule V (along with Vermin) of the Indian Wildlife (Protection) Act, 1972. There was no change even in the 1991 revision. They can be captured or killed with impunity. However, legislation in India is still based on false economic principles and political salvation without sufficient attention to genuine scientific information from active field biologists.

Understanding the importance of bats in the ecosystem is a key to conserve these species. The decline of bats raises serious ecological and economic concerns. In agro-ecosystem, loss of bats increases our reliance on chemical alternatives which often threaten both environmental and human health. Revision in the Indian Wildlife Protection Act should be made to remove fruit bats from Schedule V (vermin category). Legislations should be formulated to protect the key roosting sites of endemic species, trees and caves in which large number of bats are roosting. Law should be

extended to prevent trading and hunting of bats for food, medicine, sports and also to unintentional killing. Before venture into the renovation of old buildings and temples, engineers should consult bat conservation specialists to prevent indiscriminate mass killing of bats (Vanitharani, 2004). NGOs involved in Wildlife conservation activities should coordinate with the Chiroptera specialists to discuss and formulate various broad conservation issues. Strict legislation should be implemented to control the indiscriminate use of pesticides. Educational materials should be provided and prescribed in school curriculum to remove misconceptions about bats. This will ensure the youngsters to grow up with an awareness to preserve the environment which will ultimately lead to the appreciation of Wildlife in general and bats in particular. The National Wildlife Action Plan, Forest Management Plans, National Biodiversity Strategy, Environmental Impact Assessment (EIA) and other similar policies, plans and strategies should be incorporated on the interests of Chiroptera.

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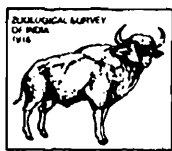
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GENETIC DAMAGES DEVELOPED BY THE AGRO-CHEMICAL RESIDUES LIKELY TO BE PRESENT IN THE AGRICULTURE LAND SOIL

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INTRODUCTION

Toxicity always refers to an adverse effect on some biological mechanism. Genotoxicology has developed as a result of the concern that environmental genes can cause genetic damages in living organisms. The advent of agriculture, the usage of pesticides is constantly increasing. Because they are playing a vital role in protecting vegetable, fruits and food grains right from the seed stage through germination to growth and then to storing (Mann, 1977). But the pesticides are very serious hazard to which the common man is exposed they have been recognized as one of the major source of toxic chemicals present in the environment. All over the world 900 basic chemicals contribute about 10,000 varieties of pesticides (Khitcherskaya, 1980). In India more than 100 pesticides are being used in agriculture which is ever increasing. It has many advantages like low cost easy to handle good chromosome condition to help study of chromosome abnormalities during cell division and evaluation on aneuploidy, also good correlation with prokaryotic and eukaryotic test systems. The microscopic level tests include the *Allium* micronucleus assay. In the present work, an attempt has been made to analyze the genotoxicity induced by the pesticide residues present in the agricultural land soil polluted

with pesticide of different kinds that were used during cultivation practices. It was evaluated using one of the best plant test system *Allium cepa*.

MATERIALS AND METHODS

Test sample

Four soil samples were collected from the agricultural lands that are highly polluted by the usage of pesticide for regular agricultural practices. Sand collected from stream was used as control. Totally five sample were maintained at room temperature for the experimental purposes.

Test system

Within the number of test systems *Allium cepa* L. has been selected to monitor the Karyotoxic effect of chemical residues and useful in screening of mutagens (Stich *et al.*, 1975) that left in the soil.

Preparation of the test system

Healthy, i.e., disease free onion bulbs have been selected. It is necessary to scrap the base of the bulb, so that fresh root primordial would be exposed. The selected 20 bulbs were planted in the sample soils containing plastic trays. Replicated were maintained using plastic bows

containing 150 gm of soil in each. The experiment was performed under the room temperature and watered using tap water.

Preparation of fixation

In early morning, samples and control root tips from the bulbs were cut off (1-2 cm length) and kept in Carnoy's fluid for 15 min. After fixation, washed with distilled water and stored in 70% alcohol at 4°C in refrigerator.

Carnoy's fluid (Sharma and Sharma, 1980)

It is prepared by the mixing of 60 ml of alcohol, 10 ml of acetic acid and 30 ml of chloroform

Acetocarmine solution (Sharma and Sharma, 1980)

It was prepared by mixing 55 ml of distilled water with 45 ml of glacial acetic acid (boiled). Add slowly 0.5g of carmine and stirred. After cooling the solution it was filtered and few drops of ferric acetate were added until it becomes wine red and stored in bottle.

Preparation of root squash

i) Hydrolysis

The fixed root tip cells taken from 70% alcohol and washed in distilled water then hydrolyzed in 1N HCl by incubating them in a hot air oven at 60°C for 1minuts. It clears the cytoplasm and leaving only the nucleus by changing the pH.

ii) Staining

Hydrolyzed root tips were washed with distilled water and placed individually in clean dry slides and stained with Acetocarmine for 8-10 minutes.

iii) Preparation of slides

After staining the root tips were squashed under the cover slip and excess stain were cleaned. Then slides were viewed under microscopes and the number of divided cells was observed counted and tabulated (Table 1).

Mitotoxicity, Karyotoxicity, Clastogenecity, Turbagenecity are calculated by the following formulas.

$$\text{Mitotic index} : \frac{\text{Number of divided cell}}{\text{Total number of cells}} \times 100$$

$$\text{Karyotoxicity} : \frac{\text{No of aberrated cells}}{\text{Total number of cells}} \times 100$$

(Percentage of aberrated cells)

$$\text{Clastogenecity} : \frac{\text{Number of Clastogenetic cells}}{\text{Total number of cells}} \times 100$$

$$\text{Turbagenecity} : \frac{\text{Number of Turbagenetic cell}}{\text{Total number of cells}} \times 100$$

RESULTS AND DISCUSSION

Physiological effects were evaluated by observing and calculating the germination percentage of bulbs growing in soil sample (Table 2) Cytological aspects namely mitotoxicity, turbogenicity, clastogenecity was studied in the present work. The study was taken by four soil samples which likely to contain different pesticides. The test was carried out to 3 weeks period and root tips were harvested at regular interval of 7 days to monitor the genotoxic effects of the pesticide residues that are persisting in the soil. Different

Table 1. Germination percentage affected by the chemical residues present in the agricultural land soil

Duration	Control	Sample A	Sample B	Sample C	Sample D
I Week	55%	30%	25%	30%	25%
II Week	75%	60%	50%	40%	60%
III Week	100%	90%	75%	65%	95%
IV Week	100%	100%	100%	100%	100%

Table 2. Genetic damage induced by the chemical residues present in the agricultural land soil in *Allium cepa* root meristem cells

Different soil samples	Mitotic Indices			Clastogenicity			Turbagenicity			Karyotoxicity		
	I Week	II Week	III Week	I Week	II Week	III Week	I Week	II Week	III Week	I Week	II Week	III Week
Control	11.99 ±4.7	13.54 ±2.11	13.66 ±3.2									
Sample A	12.66 ±1.9	9.92 ±3.5	14.28 ±3.69	1.08 ±1.02	1.02 ±1.61	2.3 ±0.57	3 ±1.49	3.9 ±2.23	4.1 ±1.35	4.01 ±1.27	4.49 ±0.98	6.41 ±2.05
Sample B	11.62 ±2.73	9.22 ±2.15	15.23 ±4.7	1.36 ±1.36	1.87 ±1.41	1.7 ±0.91	3.25 ±1.37	3.75 ±1.95	5.88 ±1.74	4.3 ±1.31	5.1 ±1.85	9.38 ±2.61
Sample C	13.07 ±2.52	10.6 ±4.35	13.14 ±5.05	1.28 ±1.25	1.14 ±1.1	2.16 ±1.18	4.28 ±3.7	3.5 ±1.12	4.69 ±1.33	7.22 ±2.43	4.64 ±1.27	6.88 ±2.36
Sample D	11.88 ±4.17	10.97 ±4.13	16.02 ±5.43	1.2 ±1.15	1.72 ±0.95	2.54 ±0.77	4.74 ±1.58	4.92 ±3.1	6.29 ±2.06	5.96 ±1.9	6.53 ±3.33	8.87 ±3.34

types of chromosomal abnormalities were observed in the root meristem of *Allium cepa*.

Mitotic activity

It depends upon the rate of cells turn over in somatic cells especially in the apical meristem. The cell division is higher in control but in polluted soil cell division is low, this indicates that the test samples were mitodepresent.

Mitotic Aberrations

The soil sample induced various chromosomal aberrations. The pesticide caused aberration in *Allium cepa* and effect was more in the duration of treatment (Sinha *et al.*, 2004). Different types of aberration such as bridge formation, disturbed anaphase, bimetaphase, chromosome breakage, crumbled chromosome, chromatid gap, and vacuolated nuclei were observed.

Clastogenecity

All the soil samples produced several types of chromosomal abnormalities manifested as fragmentations, laggards, clumping, forward, micronuclei and anaphase bridges. The higher clastogenic effects were noticed during I and II Weeks of the sample B. In sample D, it was noticed maximum at III Week, when compared to other samples.

Turbagenecity

Mitosis disruptive such as multipolar spindles, disturbed metaphase, anaphase, cytokinesis and multinucleated cells are observed in the samples. The turbagenic effect was observed in all the four samples. Sample D included maximum turbagenic effects than other three samples throughout the experimental period.

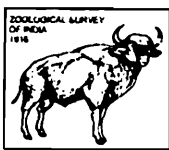
Karyotoxicity

Karyotoxicity was more in the sample C during the I Week. It was noticed maximum in sample D and B during II and III followed by samples B and D Week respectively.

The biota of the soil is also disturbed. The most of the microbes population are found to be absent. Only certain resistance microbes found in the soil. In the population the non-pathogens microbes which are help to increase the quality and the yield are not present. Due to which the population of the microbes and the concentration of the pesticide are inversely proportional to each other. Sometimes this destroys the microbes since most of the microbe population were unexplored. Using the pesticide which effects the microbe population in the soil, it damages the genetic material of the crop, if it prolonged the mutation which makes the evolution and dramatic changes. It is advised to avoid the chemical pesticides and chemical fertilizers in the conservation aspect.

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MICROBIAL BIODIVERSITY-AN OVERVIEW ON CHITINOLYTIC MICROBES

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INTRODUCTION

Microbes are the hidden powers on planet earth. They are by far the most abundant life form, drive biogeochemical cycles and are essential partners in biological interactions with other organisms. Yet our knowledge of microbial diversity and function is only limited. Many marine organisms contain dense, highly diverse microbial communities. Collectively, these organisms exhibit an enormous diversity of metabolic traits of potential use to the host, including nitrification, photosynthesis, anaerobic metabolism and secondary metabolite production. Chitin is the insoluble polymer of the amino-sugar N acetylglucosamine (NAG) and in marine environments large amounts are produced by Crustacea. Present knowledge of the microbial degradation of polysaccharides in anoxic marine environments is scant, especially with respect to the structure of the communities involved and the relationships among the species present in such mixed populations.

This study aims to characterize Chitinase from chitinolytic microbial species from the shells of different crustaceans. The screening method is based on degrading ability of the isolated microbial species towards chitin in colloidal form by Agar overlay method. Over all 8 chitinolytic bacteria were screened from a total of 15-20 microbial species. It comprises

both gram +ve and -ve while majority of being *vibrio* species. They are differentiated on the basis of Biochemical tests and protein pattern being visualized through gel electrophoresis. The assay has been carried out using commercial GlcNAc as the standard by Dinitro salicylic acid (DNS) method (Miller, 1959). One unit of chitinase activity was defined as the amount of enzyme that released 1 μ mol GlcNAc from colloidal chitin per minute under the specified condition. An extra cellular chitinase released by all the 8 chitinolytic isolates were purified by ammonium sulfate precipitation, ion-exchange and gel filtration chromatography. Chitin, is a homopolymer of N-acetylglucosamine, (GlcNAc) residues linked by β -(1,4) glycosidic linkage. It is a very abundant natural polymer widely distributed in nature as a principal structural component in the cell wall of fungi and, in the exoskeleton of crustacean and arthropods (Patil *et al.*, 2000). Chitinase are of great Biotechnological interest. A great deal of interest has been generated on chitinase because of its applications in the biocontrol of plant pathogenic fungi (Ordentlich *et al.*, 1988), molting process of insects, mosquito control (Mendonsa *et al.*, 1996), single cell protein (Vyas and Deshpande, 1991) and mycolytic enzyme preparation (Vyas and Deshpande, 1989). Chitinase is widely distributed in bacteria, actinomycetes, and plants. Chitinase-producing marine bacteria

play an important role in the degradation of chitin in the oceans. Chitinases from marine bacteria have been isolated and their properties reported. However, chitinases produced by marine bacteria isolated from coastal areas have not been studied extensively.

In this paper, we describe the isolation of chitinase producing microbial strains from the shell wastes of crustaceans (Lobsters, Shrimp and Crab) thereby concentrating on the marine microbial diversity with chitinoclastic ability. Further, the purification and characterization of the enzyme Chitinase from these sources may be exploited for the control of fungal and insect pathogens of plants.

MATERIALS AND METHODS

Sample collection and screening of Chitin-degrading microorganisms

Shrimp and crab shell waste and Wild type Lobsters were used as a source. They were obtained from a local market and Kovalam respectively. The samples were collected at different time intervals and the process is repeated atleast 5 times to get good strains. Exoskeletal bacterial isolates were obtained by abrasion of shell-disease lesion and non-lesion areas of both dorsal and ventral surfaces using a sterile scalpel. Each scraping was transferred into 600 µl sterile 3.2% NaCl solution, homogenized briefly and spread-plated in triplicate onto MA and chitin agar (comprising an underlay containing 20 g/l Difco agar, 1 g NH_4Cl l⁻¹, 75mg $\text{K}_2\text{HPO}_4 \cdot 3\text{H}_2\text{O}$ l⁻¹, 25 mg $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ l⁻¹, 50 ml 1 M Tris}HCl, 500 ml sea water and 450 ml H_2O , pH 7.5, plus an overlay containing 10 g Difco Noble agar, 75 mg $\text{K}_2\text{HPO}_4 \cdot 3\text{H}_2\text{O}$ l⁻¹, 25mg $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ l⁻¹, 50 ml 1 M Tris}HCl, 500 ml colloidal chitin and 450 ml H_2O , pH 7.5) (Vogan *et al.*, 2001). Pure cultures from randomly chosen colonies were placed on MA slopes and stored at 4°C until use. After incubation for 5-7 days at room temperature, clearance zone forming bacteria were selected as the chitinase producer. Those strains were selected for the production and characterization of chitinase.

Identification of the Isolate

The isolates were identified through its morphological and physiological properties according to Bergey's manual of Systematic Bacteriology. The nearly complete nucleotide sequence of 16S rDNA was determined as described previously (17). The 16S rDNA sequence was compared to the sequences in the GenBank nucleotide database by using Basic Local Alignment Search Tool (BLAST) (1). Phylogenetic relationships were estimated using the Phylogenetic Inference Package (PHYLP version 3.57c) (7). Jukes-Cantor evolutionary distances were calculated using the DNADIST program and dendrograms depicting phylogenetic relationships were derived using the FITCH program. The strains were also conformed by FAME-GC analysis.

Crude Enzyme preparation

For enzyme preparation, the strains were grown at 28°C in colloidal chitin medium consisting of (g/l) : colloidal chitin, 10; peptone, 3; KNO_3 , 3; K_2HPO_4 , 0.7; MgSO_4 , 0.5; KCl, 1.0; and cultured in 50 ml medium in 250ml conical flasks with shaking at 180rpm for 3 days. The culture fluid was centrifuged at 8,000xg for 20 mins. The supernatant was subjected to precipitation with ammonium sulphate to 75% saturation, which was allowed to stand overnight and then collected by centrifugation at 10,000xg for 20 mins. The resultant precipitate was dissolved in a small amount of 20mmol/l citrate phosphate buffer (pH 5.8) containing 0.2 mol/l NaCl, and extensively dialysed against the same buffer (Tao Yong *et al.*). The resultant dialysate was chitinase crude extract that was subjected to further purification.

Measurement of Enzyme activity

The strains were preinoculated in TSA for 24 hrs. Chitinase activity was determined colorimetrically by detecting the amount of GlcNAc released from a colloidal chitin substrate (Thamthiankul *et al.*, 2001). The reaction mixture consisted of 0.3 ml of crude enzyme and 0.2 ml of colloidal chitin. The reaction was performed at 37°C for 30 min. The mixture was boiled for 10min, chilled and

The hydrolysis zones created by chitinase after dialysis were monitored by subjecting the dialysed samples to native PAGE and the gel was overlayed on 0.7% Agarose(in 200mM Sodium acetate buffer)-Colloidal chitin plate

[illegible]

containing 0.001 per cent dye each of Rhodamine-B and Rhuthidium red.

RESULTS AND DISCUSSION

The initial screening of chitin degrading bacteria provide 8 strains with Chitinoclastic activity. The identification of the strain according to Bergey's manual reveals all the 8 strains as

non-identical. The morphology by gram staining showsthem as gram negative isolates. The results were given in the form of Table 1.

The confirmation of the strains by 16s rDNA sequencing and FAME-GC analysis and purification is underway. The protein profile of all the strains and clearance zone as revealed by zymography is shown below :

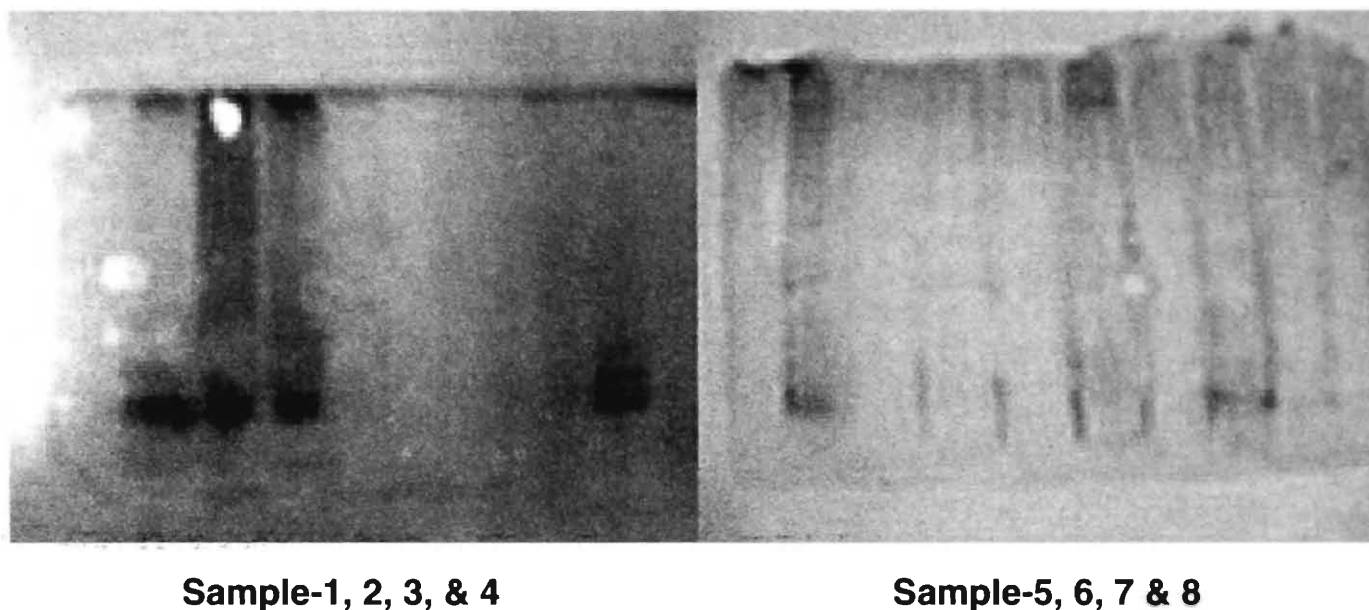


Fig. 1. SDS-PAGE

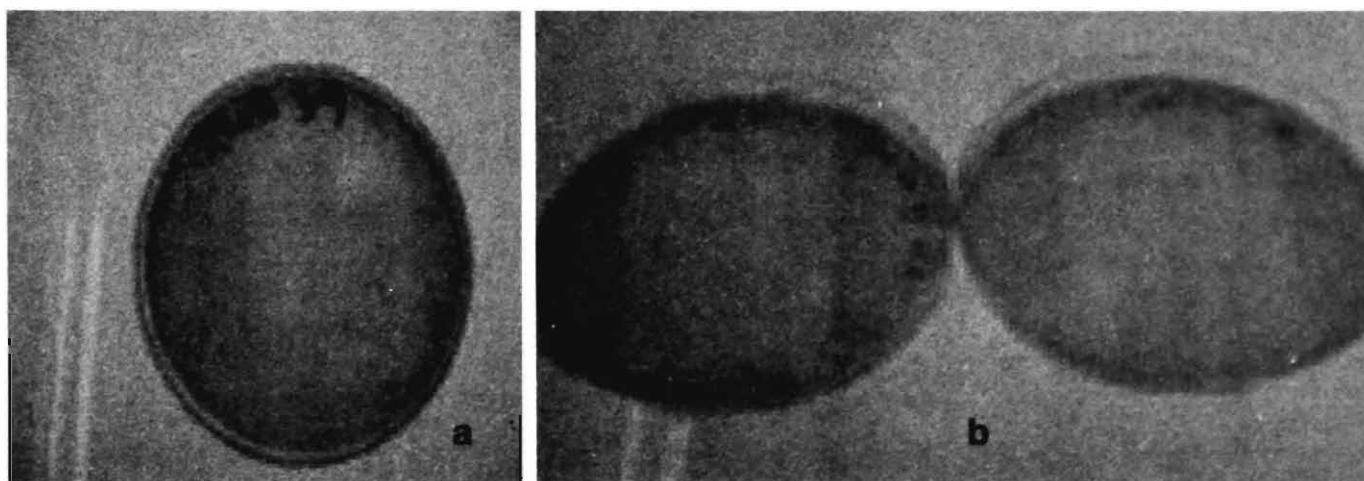


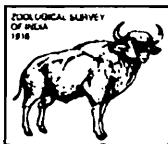
Fig. 2. ZYMOGRAPHY. (a) Clearance zone visualised in Agarose-Colloidal Chitin with Rhodamine-B dye; (b) Clearance zone visualised in Agarose-Colloidal Chitin with Rhuthidium red dye

After further Purification and characterization, the pure chitinase is tested for it's bioactivity as antifungal agents and

insecticidal activity to indicate its ability to be used as a new biopesticide.

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RELOCATION OF TIGERS IN SARISKA TIGER RESERVE

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INTRODUCTION

Sariska Tiger Reserve is a renowned Wildlife Sanctuary situated among the Aravalli hills in the Alwar district of Rajasthan state of India. Larger than Ranthambhore, it occupies an area of 881 km² in total, with a core area of approximately 500 km². Apart from the tiger, Sariska park is home to numerous wildlives like the leopard, sambhar, chital, nilgai, four-horned antelope, wild boar, wild dog, rhesus macaque, langur, hyena and jungle cats. The avian fauna includes Peafowl, Grey Partridge, Bush Quail, Sand Grouse, Tree Pie, Golden backed Wood Pecker, Crested Serpent Eagle and the Great Indian Horned Owl.

At present only 1,400 tigers are left in the country, according to a recent census conducted by the Wildlife Institute of India (WII), which has led to concern among wildlife activists as well as the government. Until 2004, Sariska had 18 tigers. A report produced by the Wildlife Institute of India in March 2005 confirmed that there was none left in Sariska tiger reserve.

Scant attention was paid in 2004 when a sudden drop in the tiger population was noticed. Ten tigers could have been saved if there were better security arrangements along the exit and entry points to check poaching. Some nakas, situated where maximum infiltration can take place, remain closed.

Sariska, once the preferred hunting grounds for Rajasthan nobility, was declared a sanctuary in 1958 and later tiger reserve in 1978. Although all the tigers have been felled by the end of 2004, Sariska still had some leopards, hyenas, jackals and deer species.

Rajasthan wildlife officials had drawn up a plan to revive Sariska by implanting tigers and shifting villages. However, the plan to shift villages was facing local opposition but the authorities played a positive role in rehabilitating the villages and this plan is now working up. In what is the first endeavour of its kind in India, two tigers from the Ranthambhore National Park have been relocated to a new habitat, Sariska, in 2008. If the experiment succeeds, it will be a major step towards saving the tiger, which has fallen victim to large scale poaching, loss of habitat and other apathies. Sariska has a rich prey base and will offer no difficulty for the tigers to establish their territory. Both the big cats have been fitted with radio collars to help experts monitor their movements and behaviour, considering that there are many 'risks' that the tigers may face in their new habitat.

In Sariska all the reasons responsible for disappearance of tigers completely is related to one single factor and that is the large number of villages inside the reserve, where no successful rehabilitation of villages has ever

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taken place. Therefore poachers could shelter in the villages of the area and kill tigers. Rehabilitation of villages is mutually beneficial to both the villagers and the wild life. The world is changing very fast. To join the mainstream of all round development it is important that the villages situated in inaccessible forest areas and in National Parks and Wildlife Sanctuaries are relocated to accessible locations. Tigers and people do not co-exist. Therefore no co-existence package is viable. Wherever villages exist the tigers in the vicinity have slowly perished.

There are around 12 thousand people residing inside the tiger reserve, with about 11-28 villages in the core area and about 170 villages situated along the reserve periphery. The beautiful balance that once existed between man and animal is no more. The priority of the forest officials now is to create an environment that is tiger-friendly. One of the priorities was to relocate the villages, before relocating the tigers. The Rajasthan Forest Department has identified 222 hectares of open space along the highway for relocating 125 households from two villages of Bhagani and Kankwadi. Last year, the Bhagani village was relocated about 100 kms away and now Kankwadi is being relocated. The other two village settlements will be dealt with in phased fashion. The major problem with the sustenance of new tigers will be keeping away the risks associated of have people so close by.

Problems faced by villagers residing inside

Crop depredation by wild animals is a very serious problem faced by villagers. Agricultural crops have become very good grazing grounds for the wild ungulates. Villagers are forced to spend nights guarding their agricultural fields. Cattle's lifting is another serious problem. Domestic cattle are easy prey for the tigers. Once used to eating these domestic cattle, these big cats can get addicted to this 'easy prey'. Because of the existing forest laws particularly the Wildlife (Protection) Act and the Forest (Conservation) Act, very few development activities can be taken up in villages situated inside. There are no proper connecting roads,

no electricity is available and very minimal health and other facilities are available. Because of remoteness very few teachers are willing to serve in the villages. The educational standards are therefore very poor. There is a growing social problem of marriage because of 'remoteness'. No outsider likes to marry in because of the inaccessibility of these villages.

Problems faced by wildlife and their managers

The sharing of biomass is an extremely serious threat to wild animals. The cattle belonging to these villages graze in areas meant for wildlife and compete with the wild ungulates for food. The area surrounding the villages is highly degraded because of anthropogenic pressures. There is constant threat of diseases spreading from domestic cattle to wild ungulates and the spread of weeds to the degraded areas is a common occurrence. Loss of habitat of wild animals occurs frequently and the disturbance to the movement of animals to the adjoining sanctuaries is common as corridor connectivity is broken. Revenge killing of tigers and leopards by villagers is common because of their predation on cattle creates stress. All in all because co-existence is not possible the relationship between man, forest and tiger is of extreme conflict and beneficial to neither. Therefore, the only way at is by relocating the villages.

Relocation of Tigers

In late 2007, three tigers were radio collared in Ranthambhore for monitoring purpose. When this was done, it was realized that the Forest Department was serious about shifting tigers to Sariska. One of these three tigers - a male that is slightly over 3 years old and is known as the Darra male or T 10-was the first tiger to be relocated to Sariska. The helicopter arrived in Ranthambhore on the evening of June 28, 2008. The idea was to relocate the first (of the five-2 males and 3 females) tiger on the morning of the 29th. It almost did not work out because it was raining heavily on the 29th morning. The tiger (Darra male) was located and the entire forest team was waiting for the

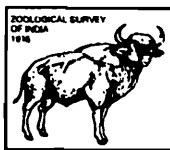
rains to stop. At 10.00 am the rain stopped, the tiger was tranquilized, put in the cage and airlifted. The tiger recovered from the tranquilizing dose in midair but was still too dazed to move around. They managed to land him in Sariska and move the cage to one of the enclosures constructed. The top official of Rajasthan Forest Department was in the helicopter with the tiger.

On July 4, 2008 a tigress, known as Bachhi (or, daughter-because she is the daughter of a Ranthambhore's most famous tigress-Machali -from the last litter) was similarly moved. This time the entire operation went like clockwork. What was interesting is that these two were territorial neighbors and had mated about a month ago. Both of them are still very young so the mating may not be fruitful but they would be surely recognizing each other's scent. A day after Bachhi reached Sariska, the Darra male was released from his enclosure. He was then free to establish his domain. The forest department has cleared the first big hurdle but there is still a big hill to climb. In the map pasted below Bachhi's territory is marked in

red, while the Darra male's territory is marked out in black. Hope they do well.

Two to four more Tigers to be relocated in a fortnight

Having received positive signals from the National Tiger Conservation Authority (NTCA) in Delhi, Rajasthan forest officials have relocated one tigress on February 25, 2009 and are hopeful of relocating three more tigers soon in the helicopters provided by Indian Air Force. NTCA had earlier put a rider on relocation of only 'transient tigers' and not tranquilizing those tigers that have earmarked their territory in Ranthambhore national park. The team of experts from Wildlife Institute of India, Dehradun has arrived at Sariska for monitoring the relocation. All relocated tigers are being fitted with a radio collar manufactured in Canada so as to keep a proper check on their movement once inside the reserve and prevent possibilities of any poaching. The relocation of Tigers is the first step towards propagating and conserving the extinct species and rehabilitating the area for the balance of the environment.



ROLE OF INDIAN COAST GUARD AS PROTECTORES OF MARINE ENVIRONMENT AND BIODIVERSITY

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INTRODUCTION

The longest coastline of India, covers the largest peninsular region of the continent of Asia. The geomorphology of the coast is complicated with sandy and rocky shores, large wide estuaries, mangrove forests and coral reefs. The governance and maintenance of this coast does deserve a special task force to handle hence the formation of Indian Coast Guard. The importance of protecting India was intensely felt and the Maritime Act was passed on 25th of August, 1976. As a follow up the Indian Coast Guard was established on 18th August, 1978.

THE INDIAN COAST GUARD

The Indian Coast Guard stands with a motto, "WE PROTECT" This motto of protection is covered by five major duty bound policies. They are,

1. To protect our ocean and offshore wealth including oil, fish and minerals.
2. To assist mariners in distress and safeguard life and property at sea.
3. To enforce maritime laws with respect to sea, shipping, poaching, smuggling and narcotics.
4. To preserve marine environment and ecology and protect rare species.

5. To collect scientific data and back-up the Navy during war.

Out of the five major duty bound policies four of them can be handled personally by the coast guard all by itself. But the duty "to preserve marine environment and ecology and to protect rare species" does require the coordinated effort of wild life department and marine scientists.

ACTION PLAN

Keeping in mind the requirement of integrated inter departmental effort, the Govt. of India has called for a high power committee to decide the *modes operandi* to protect our marine ecosystem and rare species. So, a high power committee chaired by Vice-Admiral S.N. Lakhkar sat over the issue on 11th January, 1991 with the Additional Inspector General of forests and arrived at the following decisions.

1. DGCG announced that CGHQ will issue instructions to CG formation for rendering all possible assistance to the local wildlife officials on being approached.
2. Additional IG, Forests has stated that action has been initiated to provide legal powers to local CG Stn. Commanders by designating them as honorary wildlife wardens.

3. The need for effective coordination between coast guard and the state forest departments in protection and conservation of marine wildlife has been emphasized.
4. Assistance of Coast Guard in conducting survey and research studies concerning endangered flora and fauna.
5. Coast Guard personnel who contribute significantly to the wildlife conservation should be rewarded suitably.

COMMENTS ON COMMITTEE DECISIONS

Committee decision 1 :

"The Director General of Coast Guard announced that Coast Guard Head Quarters will issue instructions to Coast Guard formations for rendering all possible assistance to the local Wildlife Officials on being approached"

Comments :

Unfortunately, this decision seem to throw the ball to the court of Wildlife Officials. The mandate of Coast Guard is to preserve marine environment and protection of rare species. But, rendering all possible assistance on being approached sounds more like that the Coast Guard is rendering a voluntary service to wildlife. But, it is the responsibility of both Coast Guard and Wildlife Dept. to implement a coordinated effort to undertake the responsibility. As such it is clear that by this time a coordination committee comprising of the Coast Guard, Wildlife department and the Marine Scientists should have been formed for each region wherever the Coast Guard formation is established.

This coordination committee should draft out a Plan of Action based on technically feasible discussion. Since the marine ecosystem is a sensitive zone, prone to damage due to any drastic change in the environmental parameters, the scientist should be asked to give his point of view. This will involve the prevention of possible causes that might damage the environment and the associated biodiversity. These scientists, who very often

form a part of a co-ordination committee are always known as Scientific Authority.

The Wildlife wardens and other forest officers form the Core management Committee. The management committee is solely responsible to initiate and implement the decision taken by the coordination committee.

The coast guard is expected to give complete support to the forest department to make things easier and effective. Any resistance met with may be handled by the Coast Guard at the sea front and the Forest Department from the shore front. Therefore, it emphasized that establishment of coordination committee is inevitable and should be done immediately.

Committee decision 2 :

"Additional Inspector General of forests has stated that action has been initiated to provide legal powers to local Coast Guard Commanders by designating them as honourary Wildlife Wardens"

Comments :

It should be noted that the power of "enforcing maritime laws with respect to sea, shipping, poaching, smuggling and narcotics" already exists with Coast Guard. The law to prevent poaching is part of the duty of CG to protect marine biodiversity, particularly rare animals. Assigning legal powers of Wildlife Warden by designating the local Coast Guard commanders as honourary wildlife wardens would surely keep the poachers on the run. This will help not only the officers of the forest departments but also the local stake holders to conduct their activities in peace.

Committee decision 3 :

"The need for effective co-ordination between the Coast Guard and the State Forest Department towards protection and conservation of marine wildlife has been emphasized"

Comments :

It is absolutely necessary to conduct periodic coordination committee meetings to monitor the progress on the action plan decided upon.

This will not only help to rectify the defects in implementing the action plan progress but also to keep a watch on the results of it.

Committee decision 4 :

"Assistance of coast guard in conducting survey and research studies concerning endangered marine flora and fauna"

Comments :

It is the involvement of Coast Guard that is essentially required than mere assistance. This involvement would also help the coast guard to understand the problems faced in marine ecosystem and its associated biodiversity.

Committee decision 5 :

"Coast Guard personnel who contribute significantly to wildlife conservation should be rewarded suitably"

Comments :

Significant contribution is always the result of sincere involvement of the personnel over the assignment undertaken. It deserves special award to the individual concerned.

Therefore, the above discussed five points undoubtedly make it clear that it is only a co-ordinated effort between the Coast Guard and the related departments would be able to preserve marine ecology and its biodiversity.

NETWORK OF CO-ORDINATION

It becomes mandatory for the Indian Coast Guard to be in touch with both the Central and State government organizations that are involved in marine research and management work. The central ministries which form the major components of marine research are the Ministry of Environment & Forests, Ministry of Agriculture and Ministry of Earth Sciences.

Ministry of Environment and Forests (MoEF)

The Botanical Survey and Zoological Survey of India function under the conservation & Survey Division of the MoEF. While a major contribution of BSI pertain to terrestrial flora, the contributions of ZSI, earlier to 1947, was more on marine biodiversity based on the

collections made on board RIMSS Investigator of the erstwhile British-Indian Navy. After 1947, with a lull period of two decades, the work on marine biodiversity was taken up intensively which resulted in the formation of Marine Biological Station at Chennai. Being assigned with responsibility of survey and conservation of marine biodiversity, the marine biological Station, periodically covers the entire coastline of India and its islands. The seed for the formation of declaring the Gulf of Mannar area was sown by MBS/ZSI. Therefore, it is relevant to have a network with MBS of ZSI under the MoEF. Also, the Regional Station of ZSI at Andhaman & Nicobar islands should form a part of the network in protecting the marine ecology and biodiversity of this island ecosystem. As far the marine flora is concerned, the BSI has some contribution but CMFRI of ICAR stands ahead of it. The Gulf of Mannar Biosphere Reserve Trust (GOMBRT), though established by Govt. of Tamil Nadu, is more affiliated with the MoEF of Govt. of India in its day to day activity. The Coast Guard formation at Mandapam and the GOMBRT should form a co-ordination network along with the Wildlife warden of GoMBR.

Ministry of Agriculture

There are many Institutes functioning either directly or through autonomous bodies of this Ministry. The Fishery Survey of India functions directly under the Ministry. It has a large fleet of trawlers operating mainly off the shore, particularly in the Exclusive Economic Zone. This Institute has a research wing to identify the fish species and to analyse its fishery potential. Interaction between the Coast and the Fishery Survey of India would certainly be beneficial to identify and conserve the biodiversity potential of our international waters and Exclusive Economic Zone.

Among the ICAR Institutes, the CMFRI has a record of its contribution for marine biodiversity in general and fishery biology in particular. The contribution of CMFRI on scomberoid and other fin fishes of fishery potential, the crustaceans, the mollusks, the

corals, the sponges, marine algae, sea grasses and very many phyto- and zooplankters is exemplary. Any coordinated effort to protect marine ecology and biodiversity without the participation of CMFRI will not be complete.

Research Institutes under CSIR :

The NIO (National Institute of Oceanography) is the nodal agency to carry out all marine research work including survey of Antarctica. The major contribution by NIO is on the ecological parameters like physical and chemical oceanography, marine geology and on submarine archaeological heritages. The NIOT (National Institute of Ocean Technology) concentrates its contribution more on the application aspects of marine science with particular reference to measuring oceanographic parameters, ocean meteorology and desalination plants etc.

Associated with NIOT is the ICMAM Project Directorate which focuses its activity on coastal management. The CSCMRI (Central Salt and Marine Chemical Research Institute) is another Research Institute under CSIR that concentrates more on taxonomy, biology and application aspect of marine algae and other associated flora. The INCOIS (Indian National Centre for Ocean Information Services) collects oceanographic and meteorological information and passes on to the stake holders particularly the fishing community. All these four Institutes would be able to provide required information and support to the Indian Coast Guard if a coordinated net work is established.

STATE GOVERNMENT ORGANISATIONS

The Forest Depts. of maritime states are duty bound to protect our marine and coastal ecology and its associated biodiversity hence should initiate a coordinated effort with the Indian Coast Guard. The wildlife wing of each maritime state is duty bound to protect the coral reefs, sea grass and marine algal beds, the sandy beaches which support as nurseries for marine turtle breeding, the mangrove forests and its associated biodiversity. To put in a nutshell the wildlife wing of forest departments of

maritime states are the Management Authorities. It is their duty to co-ordinate with Scientific Authorities and other associated Management Authorities like the Coast Guard towards protection of marine ecology and its biodiversity.

INFERENCE

It is now very clear that the Indian Coast Guard has a duty bound commitment to protect marine environment and marine biodiversity. But it is just 20% of its total commitment. The rest of the 80% commitment demands higher priority. Therefore, it is up to the coordinating agencies to collaborate with the coast guard and make proper use of their capacity. The relevant action plan pertaining to this responsibility is to be decided periodically by the co-ordination committee.

SPECIAL REQUEST TO INDIAN COAST GUARD

Coast guard personnel; while on board in offshore areas, can take up a pastime of watching whales, dolphins and turtles and swarm of sea snakes which would indirectly provide scientific data for future research.

Pods of whales and dolphins, breeding community of migrating turtles and sea snakes are a pleasure to watch in open seas. A proper guide book would help to identify the species of whales and dolphins. If the coast guard could provide the following details about these forms, it will help the scientist on shore who do not get such opportunity to go on board a research vessel as the coast guards do. A separate log book may be opened on board to record these following details.

1. Date and time of observation
2. Grid reference
3. Approximate number of animals in each observation
4. Direction of migration of observed population.

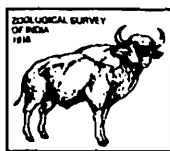
Thy above information would certainly be of immense use as GROUND TRUTH for

analysis for interpretation with the satellite imageries. This will also help to know the migratory corridors of whale, dolphins, turtles and sea snakes.

SUMMARY

The duty bound policies and the decisions taken by a high power committee on the possible role of Indian Coast Guard were discussed in detail. It has been emphasized that a coordination committee consisting of the

Forest departments, Scientists and the Indian Coast Guard should be formed immediately. This committee should decide the action plan to be adopted towards protection of marine ecology and the associated biodiversity. Since the coast guard has a priority mandate to participate towards defense of the country both physical and economical, it is suggested that other members of the coordination committee should take initiative to lessen their burden and involve the coast guard to implement the action plan processes.



PROJECT DUGONG : A CONSERVATION STRATEGY TO PREVENT EXTIRPATION OF THE SPECIES FROM INDIAN SEAS

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INTRODUCTION

Dugong dugon (Muller, 1776), the sea cow, is a herbivorous marine mammal. It is the only extant species of the family Dugongidae of the order Sirenia. Though not popular among every citizen, the dugong is well known to the members of the fishing community who fish within the range of its distribution. Represented by a relict population and separated by very long distances where its food of choosy sea grass grows as pastures, the dugongs' distribution in Indian Seas is restricted to isolated pockets like the Marine National Park of Gulf of Kutch, the Gulf of Mannar Biosphere Reserve, the Palk Bay and the Andaman & Nicobar Islands. The dugong is a Schedule I species under the Indian Wildlife (Protection) Act, 1972 which bans catching, killing, purchasing of dugong meat or possession of any part of its body. The IUCN has classified dugong as vulnerable to extinction and the CITES listed all dugong population, except the Australian, under Appendix I.

POPULATION STATUS

The population status of dugong in Indian seas is not sufficiently known since no

enumerative study was taken up. An attempt for a head count on the basis of sightings was conducted in the Gulf of Mannar Biosphere Reserve area as per the mandate of a project granted by the Ministry of Environment and Forest, Govt. of India to the Marine Biological Station, Zoological Survey of India. A consolidated report was submitted to the Ministry (Dhandapani, 1997). Even this enumeration is also not foolproof since it is based on sightings on different dates at different spots and there was always a chance for error since repeated sightings of the same animal or population could not be ruled out. Unfortunately, an attempt to conduct an aerial survey to have a synoptic view of dugong population of Gulf of Mannar area during this enumerative survey could not take off due to reasons beyond the control of the Investigator.

Reports on the presence of live dugongs in the Gulf of Kutch, Gulf of Mannar, Palk Bay and the Andaman & Nicobar Islands is based on the data made available by the fishermen through interview survey. In addition, news on the stranding of carcasses, hunted dugongs, or dugongs killed either by dynamite fishing practices or caught and drowned accidentally in bottom set gill nets is brought to the notice both by the media reports and through

published scientific reports. Evidently, it is clear that dugongs are hardly seen in the wild in Indian seas but are known to occur through reports of their death only.

PROJECT DUGONG : THE CONCEPT

In India, unlike the Tiger, the Elephant and the elusive Snow Leopard which have drawn the attention of public and the Government and enjoy the status to be protected under National Projects, the dugong is hardly known by its name even to the educated community. Public ignorance on the very existence of a rare marine mammal, which is vulnerable to extinction in the wild, is itself a matter of great concern. The categorisation of dugong by the IUCN Red List Data Book as VULNERABLE is based on the facts that the "dugongs are long-lived but with very low reproductive rate, long generation time and a high investment in each offspring. The dugong population is unlikely to increase at more than 5% per year. This makes the dugong more vulnerable to over-exploitation. Even a slight reduction in adult survivorship as a result of habitat loss, disease, hunting or incidental drowning in nets can cause a chronic decline" (Helene Marsh, 2001).

A review of literature on dugongs of Indian seas and the results of intense surveys conducted periodically reveals the fact that the population of dugong has depleted drastically (Jones, 1967b; Nair *et al.*, 1975; Silas and Fernando, 1985; Dhandapani, 1997; Das and Dey, 1999; Das, 2000; Helene Marsh, 2001; Badrudeen *et al.*, 2004; Dhandapani, 2008; and Elrika and Vardhan, 2009). The rate of depletion has been so alarming that the scientific community had a fear whether the dugong would go the way of Dodo (Silas and Fernando, 1985). Many scientific reports have warned the possible chances of dugong becoming extinct initially in Indian seas and later world over. "Dugongs appeared to have vanished or already extinct in some places. These include the waters of Mauritius, the Seychelles, western Sri Lanka, the Maldives, the parts of Japan, Hong Kong's Pearl river estuary, several islands in the Philippines, and parts of Cambodia and

Vietnam" says Helene Marsh (2001), the Action Plan Coordinator, IUCN/SSC Sirenia Specialist Group. Thus, "there is global concern for the protection of dugong, and in India the residential population of this species in the Gulf of Mannar and Palk Bay is the most vulnerable and facing extinction" (Badrudeen *et al.*, 2004). Fishermen in the Gulf of Kutch, during an interview survey, have reported of not having seen dugong for the past couple of years (per. comm.). As far the Andaman Seas, a recent report indicates the presence of dugong near the Havelock and Neil Islands (Elrika and Vardhan, 2009). But, the population of the Dugong Creek in the Little Andaman Is. has diminished so much that there is hardly any chance for Onge tribes to get a dugong for their community feeding (Das, 2000). The statement of estimated population of dugong in the entire Andaman Sea to be nearly one hundred by Das and Dey (1999) is not authentic and needs re-confirmation. Keeping this alarming status in view, this report emphasizes a National Level Programme to care for the conservation of this extant and relict species which faces extirpation hence the need for Project Dugong.

FACTORS CAUSING POPULATION DEPLETION

The survival of dugong population depends mainly on the suitability of its niche and its associated ecosystem. The food of dugong is consisted mainly of sea grass. An analysis of gut contents of dugongs captured in the Gulf of Mannar and Palk Bay were found to have the sea-grass species of *Cymodocea serrulata*, *Cymodocea isoetifolia*, *Halodule uninervis*, *Halophila ovalis* and *Enhalus acoroides*. Among these *Cymodocea serrulata* and *Halophila ovalis* were the major constituents (Nair *et al.*, 1975). The suitable niche of dugongs is the inshore waters, particularly the sandy and muddy sea floor of the continental shelf in the euphotic zone that supports a lush growth of sea grass.

Apart from diseases causing death of dugongs, destruction of sea grass beds due to natural disasters or otherwise caused by impact of human activity creates paucity of sea grass leading to starvation death of dugongs. Jones

(1967b) has stated that there has been reports of considerable fall on the dugong population in the Palk Bay after a cyclone in December, 1954, the storm water drain of which seem to have lowered the salinity very much in the inshore waters and caused the degradation of sea grass pastures leading to starvation death of dugongs.

Impact of human activity like trawl fishing over the pastures, picking of sea cucumbers and sea horses by uprooting the sea grass and discharge of raw industrial and domestic effluents into the sea contribute to the depletion of dugong population. Among the above mentioned four pockets of dugong domicile areas, the highest human activity takes place in the Palk Bay, Gulf of Mannar and the Gulf of Kutch. The fishing activity in the Palk Bay is more intense during the south-west monsoon period where the fishermen from Gulf of Mannar shift their activity along with the local fishermen. Here, the bottom set gill nets keep interfering with the feeding activity of dugongs resulting in accidental capture in these nets and cause death due to drowning. Fishing activity in the Gulf of Mannar area is intense throughout the year except during the south-west monsoon period. "Enacted laws specify that mechanized boats should not operate within 5km from the shore but mechanized boats churn the most important dugong feeding grounds causing hit injuries by propellers to juvenile dugongs which seem to be more curious than adults to watch the propellers. In addition, the trawling activity also causes uprooting and damaging of the sea grass" (Silas and Fernando, 1985). This fishing activity still continues in this area causing disturbance to the feeding dugongs particularly more during night. Intentional killing of dugongs is a major cause of concern, particularly in the Gulf of Mannar area. The meat of dugong is relished by fishermen of some villages who share it with the members of their community during special occasions. The use of dynamite for fishing is the main cause of intentional killing or extirpation since the operation of specially designed nets for dugong capture is no longer in use.

In recent years, on par with the fishing activity, numbers of fish processing centres and other industries have cropped up along the coastal zones of Gulf of Mannar Biosphere area. These industries release their factory wastes in the form of untreated effluents. Numbers of prawn farms established along this coast also contribute to this effluent discharge in to sea. The bad effects of these effluents depends on the quantum of dissolved organic matter and chemicals used which drive the dugongs away from the feeding grounds and later cause death and decomposition of sea grass.

Regarding Gulf of Kutch, the fishermen seem to have been consuming the meat of either accidentally caught dugongs or dead ones; but their oil extracted from fat was usually used for seasoning the outer surface of the boats. Apart from this, the recent establishments of oil refineries in the very National Marine Park area in the Gulf of Kutch seem to have shown its negative impact on the dugong population. According to the recent survey, the absence of dugongs in this area seem to be the result of frequently cruising in of super tankers and bulk carriers which keep churning the sea grass beds and prevent their growth.

The Andaman population of dugongs does not seem to be suffering the agony of dugongs of other parts of the country. The only area where it is being exploited for community feeding is in the Dugong Creek of Little Andaman Is. by the Onge tribe. Otherwise, the status of dugong population in Andaman group of islands seems to have better prospects.

NEEDED CONSERVATION MEASURES

Project Tiger, Project Elephant and Project Snow Leopard involve protection of these species from poachers and prevention of deforestation. Except for the elephant, the other two carnivores independently roam around their conservation area for food. But the elephant needs to look for its fodder in groups hence they need to follow their migratory corridors. The case of the dugong is different. The area of their pastures grows under specific environment and locations which need to be

protected lest the very feed of this species would be destroyed leading to extinction of the species. Secondly, the dugongs do not have any choice but to depend on the specific species of sea grass where they are forced to assemble for grazing. This makes it more difficult for the species to escape from poachers. Fortunately, the dugongs are nocturnal grazers and elude the human presence. Precisely, the conservation measures needed for dugong involves a dual responsibility of protecting not only the species but also its feeding stock. Does this mean that the dugong needs to be reclassified as "CRITICALLY ENDANGERED" to draw special attention? As this reclassification is a complicated issue with prolonged procedures and justification, it is recommended, under the existing conditions in Indian Seas, the dugong may be TREATED but not DECLARED as CRITICALLY ENDANGERED until it regains an appreciable population strength in its niche. Further, in order bring awareness about dugong among Indians, it becomes mandatory to declare dugong as National Marine Mammal (Dhandapani, 2008). This would add impetus to the process of protecting dugong from extinction.

It would be very much appreciated if Govt. of India takes up this proposal as top priority item; and it would be highly welcome if the concerned maritime states also take initiative in advance and follow the ACTION PLAN proposed as under.

PROJECT DUGONG : ACTION PLAN

A synopsis of all the above data put forward to present the case of dugong to launch a National Scheme of Project Dugong should naturally be considered and place dugong on top priority list for immediate implementation of the Project. Marine scientists are scared that lack of awareness and our negligence to launch 'Project Dugong' might lead to possible extinction of the species even before any one could actually realize it. Hoping that a possible action would be taken, an 'Action Plan' is proposed as follows :

1. As stated above, the dugong in India should be declared as the 'NATIONAL MARINE MAMMAL' to bring in awareness among public about the existence of such a marine mammal which, if not protected in time, would vanish from our waters.
2. Identify the extent of sea grass pastures in all these four pockets of dugong habitats in Indian seas with satellite imageries and demarcate the boundaries with buoys. Interconnect the buoys with laser or infra red rays to raise an alarm to warn off intruders to avoid damage to pastures.
3. Declare the demarcated pastures as 'DUGONG PROTECTION AREAS' as recommended by the United Nations Environment Programme.
4. Involve the stake holders, i.e. the members of the fishing community who depend on the marine resources around the Dugong Protection areas, as 'COMMUNITY AUTHORISED MANAGERS' to guard the Dugong Protection Areas along with the Coast Guard and the Wildlife Department.
5. Conduct aerial survey which is imminent to have a synoptic view of dugong population both of the grazing pastures and also of the off shore regions where the dugong occasionally migrate to elude human attention.
6. Radio Frequency Tags and Satellite Tracking Transmitters should be fixed with the help of local Stake Holders to keep in record of the identity and movement of dugongs.
7. Participation of Stake Holders in the tagging programme would hold them responsible for the numbered dugongs. On completion of tagging of every dugong, the Stake Holders should be encouraged with suitable rewards to be aware of their importance in this task of conservation of dugong population.
8. It is hoped that successful completion of the above Action Plan would Certainly

boost the dugong population to a sizeable number in all these four pockets. The Community Authorised Managers should maintain a periodic census record of dugongs.

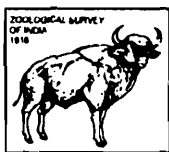
9. This enhanced dugong population would certainly become a tourist attraction and earn a fortune for the Stake Holders by conducting "DUGONG SAFARI" This fortune, which would include even foreign currency, would certainly benefit and encourage the local Stake Holders for all the sincere efforts they took to care for the dugongs.

SUMMARY

Public ignorance about the species, the relict distribution, the sole dependence on sea grass pastures for food, the possible extirpation of species for community feeding and very low reproductive rate leaves the dugong of Indian Seas at cross roads waiting for special attention for survival. A National Level Programme to the tune of Project Dugong is proposed and the required Action Plan is also suggested to recoup its population. The need to have the co-operation, participation and involvement of the stake holders who are expected to be the ultimate beneficiaries through this conservation programme of dugong is emphasized.

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TAMIL NADU BIODIVERSITY CONSERVATION STRATEGY AND ACTION PLAN

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INTRODUCTION

Sustainable Development

Sustainable development refers to the concept of meeting the requirements of the present generation without impairing the chances of the future generations from meeting their requirements. Our common future, 1987 report produced by the World Commission on Environment and Development, commonly known as Brundtland Commission report defines sustainable development as that which "Meets the needs of the present without compromising the ability of future generations to meet their own needs" Thus sustainable development is "development which does not compromise the future" It highlighted the need to integrate environmental and economic objectives to ensure sustainable development of Economical and Social systems.

The World Conservation Strategy International Union for Conservation of Natural and Natural Resources (IUCN, 1980) succinctly articulated the rationale for species conservation and absorbed it into the concept of conservation for development.

Living resource conservation for sustainable development was seen to have three specific objectives :

i) to maintain essential ecological processes

and life support systems (such as soil regeneration and protection, and the cleansing of waters), on which human survival and development depend;

ii) to preserve genetic diversity (the range of genetic material found in the world's organisms), on which depend the breeding programmes necessary for the protection and improvement of cultivated plants and domesticated animals, as well as much scientific advance, technical innovation, and the security of the many industries that use living resources;

iii) to ensure the sustainable utilization of species and ecosystems (notably fish and other wildlife, forests and grazing lands), which support millions of rural communities as well as major industries.

Biodiversity Conservation

"Biological Diversity" means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Convention on Biological Diversity).

Conservation is defined as management of human use of the biosphere so that it may yield sustainable benefit to the present generation

while maintaining its potential to meet the needs and aspirations of posterity. Thus conservation is positive, embracing, preservation, maintenance and sustainable utilization, restoration and enhancement of the natural environment (World Conservation Strategy (IUCN), 1980).

The term *conservation* has not been defined in Convention on Biological Diversity. In *Global Biodiversity Assessment published by UNEP (GBA, 1995)*, this term is used both in the narrower sense of preservation or maintenance of some or all of the components of biological diversity and in the broader sense to include also sustainable use of the components or their recovery or restoration or both. The concepts of preservation and sustainable use are intimately linked.

The objectives of Biodiversity Conservation are achieving Food Security, Health Security, Ecological Security, Evolutionary Security and Environmental Stability.

- **Food Security** depends on the conservation of traditional varieties of crop plants and traditional varieties of domestic animals. It also depends on the conservation of wild relatives of crop plants and wild relatives of domestic animals. These are the Gene banks for breeding of plants and animals and also raw materials for genetic engineering.
- **Health Security** depends on the conservation of medicinal plants.
- **Ecological Security** depends on the proper functioning of the ecosystem processes.
- **Environmental Stability** depends on the proper maintenance of ecological balance.
- **Evolutionary Security** depends on the process of speciation on the principles of survival of the fittest.

Sustainable Use of Biodiversity

- **Sustainable use** means the use of components of biological diversity in a way and at a rate that does not lead to

the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations (Convention on Biological Diversity) (Annamalai, 2004).

Wild Biodiversity of Tamil Nadu

Tamil Nadu

Tamil Nadu is situated at the South-Eastern extremity of the Indian Peninsula and it is the Southern most state of India. It is located between 8°05' and 13°34' North latitudes and 76°14' and 80°21' East longitudes. Andhra Pradesh in the North, Karnataka in the Northwest, Kerala on the West, Bay of Bengal in the East and Indian Ocean in the South bound it. With a coast line of 922 km and land boundary of 1200 km, the total area of the State is 1,30,19,000 ha., Chennai is the capital.

Forests

One sixth of landmass of Tamil Nadu is covered with forests. According to State of Forest Report, 2005 by the Forest Survey of India, the total forest cover of the State is 23,044 km² which constituting 17.72 per cent of geographic area. This includes 2,650 km² of very dense forest, 9,790 km² of moderately dense forest and 10,604 km² of open forest. Tamil Nadu ranks 11th among the Indian States and Union Territories with reference to total forest cover. The recorded forest area of the State is 22,877 km² constituting 17.59 per cent of the geographic area.

Protected Areas

The protected area of the country is 1,56,006 km² constituting 4.75 per cent of the geographic area and 20.03 per cent of the recorded forest area. The protected areas of Tamil Nadu extend to 3305 km² constituting 2.54 per cent of the geographic area and 15 per cent of the recorded forest area. Tamil Nadu ranks 14th among all the States and Union Territories of India in terms of protected area. There are 8 wildlife sanctuaries over 2,82,685.57 ha., and 12 bird sanctuaries over 17,074.59 ha. 5 National Parks over 30784.23 ha., 3 Tiger Reserves, 3 Elephant

Reserves and 3 Biosphere Reserves for insitu conservation of wild fauna and flora. There is one Conservation Reserve in Tamil Nadu. National Wildlife Action Plan 2002-16 (Page 10) states that "we should aim to bring 10 per cent of India's land mass under the PA network, of which at least half should inviolate habitats" Tamil Nadu Forest Department is striving to achieve this major objective (Sreedharan and Annamalai, 2006).

Algal diversity

Algae are both microscopic and macroscopic. They are present in both fresh and marine waters and in air and soil. They are also found growing on other plants (epiphytic), animals (epizoic), within the cavities of animals (endozoic), growing on rocks (epipellic, (on ice), floating planktonic attached (benthic). Algae range in form from unicellular through colonial, filamentous, siphonaceous to complex parenchymatous thalli of larger seaweeds.

The algal flora of Tamil Nadu is dominated by the members of the Chlorophyceae represented by 419 taxa, followed by the members of the Rhodophyceae (267), Cyanophyceae (235), Bacillariophyceae (233), Phaeophyceae (68) and Charophyceae. A total number of 1263 taxa belonging to 8 classes is reported to occur in Tamil Nadu, of these 1119 taxa are species of algae belonging to different groups and the rest are sub species (2), varieties (100) and forms (42). These algae are distributed under 432 genera belonging to 115 families under 38 orders. It is also reported that there are 668 taxa of fresh water algae and 625 taxa of marine algae were distributed in Tamil Nadu (Baluswami, 2006).

Bryophyte diversity

Bryophytes occupy an important place in the plant kingdom. They are the simplest and the most primitive of the land plants. They are the pioneers to colonies terrestrial habitat from aquatic environment. Their adaptation to a terrestrial mode of life is partial as water is indispensable in one stage or another in their life cycle. Hence, they are also known as the

amphibians of the plant kingdom. Bryophytes are useful to human beings as well as to other organisms. They are the secondary colonisers on barren rocks next to lichens in plant succession in xerosere. Thus they help in weathering of soil. They are extremely good soil binders as they form large mats on forest floors and roadside cuts, thus controls soil erosion.

In India, there are about 850 species of liverworts belonging to 140 genera and 52 families and 2000 species of mosses belonging to 342 genera and 54 families were reported. From the West Coast and the Western Ghats 121 species of liverworts with 10 endemic and 682 species of mosses with 190 endemic have been identified (Dulip Daniels, 2006).

Fungal diversity

Fungi are a group of organisms and micro-organisms that are classified within their own kingdom, the fungal kingdom, as they are neither plant nor animal. Fungi draw their nutrition from decaying organic matter, living plants and even animals. They do not photosynthesize as they totally lack the green pigment chlorophyll, present in green plants. Many play an important role in the natural cycle as decomposers and return nutrients to the soil. They are not at all destructive. Fungi are even used for medical purposes, such as species within the penicillium genus, which provide antibiotics.

In Tamil Nadu a total number of 1077 species in 370 genera have been recorded and it is widely distributed in Nilgiris, Palani hills and Annamalai hills. The first Indian fungus to be recorded was from Tranquebar, (Tarangambadi) in the erstwhile Madras State (Tamil Nadu). With the appointment of E. J. Butler as Cryptogamic Botanist to the Government of India, more systematic surveys of Indian fungal floras were initiated. However, large scale collections of fungi in Tamil Nadu were made only after the establishment of the Mycology section at the Agricultural college and Research Institute, Coimbatore (Natarajan, 2006)

Lichen diversity

Lichens are fungi that live in a symbiotic association with a green alga or a cyanobacterium or both to fulfill its nutritional requirements. In the lichen association the fungal partner is known as the mycobiont and the green alga or a cyanobacterium is known as the photosynthetic partner or the photobiont. In India, around 2000 to 2200 species are known to occur and in Tamil Nadu there are about 555 lichen species.

The algal or cyanobacterial partner (photobiont) has a different binomial. Lichen symbiosis is one of the most successful symbioses known in nature. This relationship enables lichens to colonize a vast spectrum of habitats and climates all over the world including extreme environments—from the Polar regions to the Equator and inter-tidal zones to mountain peaks. Lichens colonize natural substrata such as tree bark, wood, rock, soil, leaf surfaces, and shells/hard surfaces of living animals like carapaces, weevils and man-made substrates like walls, mortar, asbestos, glass, Iron poles, plastics etc. Lichens are part of vital components of ecosystem functions—in food web and food chains, nutrient cycling and are used by many animal groups as brooding/nest building spaces (Hariharan 2007)

Pteridophyte diversity

The Pteridophytes formed a dominant part of earth's vegetation. Pteridophytes lend a distinct charm to the landscape. The elegant tree ferns of the warm humid forest of eastern Himalayas, Pachmahri and Nilgiri hills, the epiphyteic ferns and the hanging club mosses of the tropical forests attract one's attention. The lithophytic and terrestrial forms that grow in comparatively larger numbers are also a source of great attraction because of their beautiful foliage. Some of them grow in water and form a luxuriant hydrophytic component of the lakes (Salvia), ponds and pools (Azolla, Marsilea). In India about 1300 species of Pteridophytes have been reported. Most ferns are leafy plants that grow in moist areas under forest canopy. They are "vascular plants" with

well-developed internal vein structures that promote the flow of water and nutrients. The ecological classification of Pteridophytes are given below (Manickam, 2007).

Ecological Classification of Pteridophytes of the Tamil Nadu

Sl. No.	Habitat	Number of species
1.	Terrestrial	90
2.	Lithophytes	67
3.	Epiphytes	42
4.	Aquatic	5
5.	Epiphytes/Lithophytes	44
6.	Epiphytes/Terrestrial	16
7.	Terrestrial/Lithophytes	15

Floral diversity

The Angiosperm diversity of India includes 17,672 species. With 5640 species, Tamil Nadu ranks 1st among all the States in the country. This includes 533 endemic species, 230 red-listed species, 1559 species of medicinal plants and 260 species of wild relatives of cultivated plant. The Gymnosperm diversity of the country is 64 species of which Tamil Nadu has 4 species of indigenous Gymnosperms and about 60 introduced species (Sreedharan and Annamalai, 2006).

Faunal diversity

The faunal diversity of Tamil Nadu includes 165 species of fresh water Pisces, 76 species of Amphibians, 177 species of reptiles, 454 species of birds and 187 species of mammals. According to the Conservation Assessment and Management Plan (CAMP) reports, the red-listed species include 126 species of Pisces, 56 species of Amphibians, 77 species of reptiles, 32 species birds and 40 species of mammals. The endemic fauna includes 36 species of Amphibians, 63 species of reptiles, 17 species of birds and 24 species of mammals. Schedule-I animals include 22 species of mammals, 42 species of birds and 9 species of reptiles. Schedule-II animals include 13 species of mammals. Schedule-III animals include 5 species of mammals. Schedule-IV animals

include 5 species of mammals, 367 species of birds, 109 species of reptiles and 23 species of Amphibians. Schedule-V animals include 13 species of mammals and 12 species of birds (Sreedharan and Annamalai, 2006).

Marine diversity

The Gulf of Mannar Marine National Park has the core area of about 560 km² from Rameswaram to Tutucorin lying within the Gulf of Mannar Biosphere Reserve covering an area of 10,500 km² on the south-east coast of India. It is one of the world's richest regions from marine biodiversity perspective and the first marine Biosphere Reserve in Southeast Asia. Among the Gulf's 3600 plant and animal species, there are the globally endangered species Sea Cow (*Dugong dugon*) and six mangrove species endemic to peninsular India.

Major ecosystem types available are Coral reefs, mudflats, beach, island, shallow water, and mangrove. Sea grass beds dominated by family like Hydrocharitaceae and Potamogetonaceae and species *Halodule uninervis*, *Cymodocea rotunds*, *C. Serulata*; Coral reefs; mangroves including *Rhizophora mucronata*, *Avicennia alba*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Lumnitzera racemosa* are also common in the stretch. The area has all the mangrove species available in India with *Pemphis acidula* being endemic and all the 11 sea-grasses of India occur here with *Enhalus acoroides* being endemic. The area supports 147 species of sea-weeds. Abundance of sea-weeds and sea-grasses in grazing ground attract Sea cow (*Dugong dugon*) the flagship species of the protected area. Other marine creatures like Dolphins, Sea-horse, Sea-cucumber, Sea-anemone are common here. 137 coral reef species form the basis of the ecosystem where 3600 species of plants and animals are associated. Peculiar animal like Balanoglosses living-fossil linking invertebrates and vertebrates is endemic here. Sandy shores of islands is feeding ground for five endangered marine turtles - Green turtle, Olive ridley turtle, Hawksbill turtle, Leatherback turtle and Loggerhead turtle and the first two breed here too. The islands form a good habitat and a stop

over between Chilka lake, Point Calimere and Sri Lanka for migratory birds. Nearly 180 birds are found here and waders and sea-birds being the most common (TNFD, 2008).

Threats to Biodiversity of Tamil Nadu in the past

Fire : Fire is one of the major causes of biodiversity loss in the past in the forests of Tamil Nadu and even to-day it continues to be the major threat to forest biodiversity.

Grazing : Grazing is a threat to forest biodiversity in the past and it continues to be a major threat to forest biodiversity even to-day.

Head loading : Head loading of firewood, fodder, small timber etc., was also a threat to forest biodiversity in the past and also in the present scenario.

Encroachment : Encroachment in the forest areas have taken a heavy toll of biodiversity in the past.

Development projects and diversion of forest lands : Majority of the dams and reservoirs in Tamil Nadu have been constructed in the forest areas and this is one of the most important reasons for loss of biodiversity in the past in Tamil Nadu.

Illicit arrack distillation : This used to be one of the threats for the biodiversity of Tamil Nadu in the past and it also continues to be a threat at present.

Clear felling and Tree planting programmer : In the past Cash Plantation divisions were adopting the method of clear felling of forests and raising mono culture plantations which resulted in loss of biodiversity.

Fuel coupes system : Most of the forests in Tamil Nadu have been worked under fuel coupe system which has resulted in destruction of most of the primary forests of Tamil Nadu.

Cardamom cultivation : As a revenue earning strategy, evergreen forest areas were leased for cardamom cultivation which was a major threat to the regeneration of evergreen forests in the Western Ghats of Tamil Nadu.

Illicit felling : Illicit felling of species like sandal and rosewood have almost completely eliminated the species in vast areas of Tamil Nadu forests.

Illicit collection of medicinal plants : This is one of the major causes for the complete disappearance of several medicinal plant species from the forest areas and even to-day this continues to be a major threat to loss of medicinal plants.

Destructive collection of Minor Forest Produce : Collection of bark, cutting of branches for collection of fruits of species like mango, nelli etc., and setting fire for collection of some of the minor forest produce was also a threat to biodiversity.

Ganja cultivation : Clearing of forest areas for ganja cultivation in inaccessible prime forest areas was also a form of threat for biodiversity.

Poaching : Poaching of wild animals in the past and hunting of wild animals prior to the enactment of Wildlife (Protection) Act, 1972 has taken a heavy toll of carnivores and herbivores in Tamil Nadu Forests.

Natural disasters : Natural causes of cyclone, flood and landslides have also taken their share of forest biodiversity in the past particularly riveraine forests and coastal forests.

Invasive alien species : Introduction of exotics and invasive alien species like Eucalyptus, wattle, pines etc., have also resulted in destruction of natural forests thereby leading to loss of biodiversity.

Plantation Corporations : Tamil Nadu Tea Plantation Corporation Ltd., (TANTEA), Arasu Rubber Corporation Ltd., (ARC) and Tamil Nadu Forest Plantation Corporation Ltd., (TAFORN) have been established after destroying beautiful evergreen forests in the Western Ghats and Eastern Ghats of Tamil Nadu.

Conservation efforts in the past

- Stopping of fuel coupe system from the year 1976 onwards has resulted in

recovery of forest growth in most of the areas.

- Discouraging planting of monoculture exotic plantations like eucalyptus.
- Protection of forests and law enforcement.
- Joint Forest Management and involvement of people in forest conservation
- Planting of mix of several species in Tamil Nadu Afforestation Project (TAP) and other plantation programmes instead of monoculture plantations.
- Stopping of clear felling for planting programmes and introduction of gap planting method in planting programmes.
- Eco-development and involvement of people in wildlife conservation in Kalakad Mundanthurai Tiger Reserve and in other protected areas.
- Tribal development programmes which has resulted in stopping of alienation of tribals from forests. Particular mention may be made here regarding benefit sharing of minor forest produce for the tribals.
- Stopping of cardamom lease in evergreen forest areas has resulted in recovery of evergreen forests.
- Supreme Court orders in Godavarman Thirumalpad case and other orders from Central Empowered Committee has also facilitated banning of felling of natural forests:
- Awareness creation on importance of forests linking, global warming has also resulted in favorable environment for forest conservation.
- Social Forestry programmes and Tree Planting in Private Lands for augmenting production of fuel wood and timber will go a long way in conservation of forests and biodiversity.

Tamil Nadu Biodiversity Strategy and Action Plan

As part of National Biodiversity Strategy and Action Plan (NBSAP), Tamil Nadu Biodiversity Strategy and Action Plan (TNBSAP) has been developed. TNBSAP has been prepared through a participatory planning process involving all major stakeholders like Forest Dwellers and Forest Fringe Dwellers, User Groups, Interest Groups, Government Departments, NGO's, Research Institutions, Colleges, Universities etc.

Aspects of Coverage

Conservation of biodiversity at ecosystemic, species, and genetic levels (through in situ, ex situ, in vitro, and other measures), and of the associated ecological functions, with a special focus on endemic, threatened, and otherwise critical elements.

Sustainable use of biological resources, implying their use in such a manner as will not imperil their long-term existence, or will not in other ways threaten biodiversity.

Social, economic, political and inter-generational equity, including in decision-making with regard to conservation and use, in sharing of benefits, in access to and protection of knowledge and information relevant to biodiversity, and so on.

Ethical, cultural, scientific, and economic dimensions, including:

- The right of species and ecosystems to survive.
- The primacy of survival and livelihoods based on biodiversity, and of creating a stake for people in conservation and sustainable use;
- The implications of research and use of human genetic diversity;
- Various cultural ways of relating to nature; and
- The role of biodiversity in economics and technology.

The scope of coverage and the aspect of coverage of TNBSAP are as per the NBSAP Guidelines.

The following books have been published by the Author as part of the Tamil Nadu Biodiversity Strategy and Action Plan and these books may be referred for complete details of the entire spectrum of the Biodiversity of Tamil Nadu:

- Tamil Nadu Forest Biodiversity Strategy and Action Plan
- Tamil Nadu Invertebrate Biodiversity Strategy and Action Plan
- Tamil Nadu Chordate Diversity Strategy and Action Plan
- Tamil Nadu Wild Plant Diversity Strategy and Action Plan
- Tamil Nadu Estuarine Biodiversity Strategy and Action Plan
- Tamil Nadu Aquatic Biodiversity Strategy and Action Plan
- Tamil Nadu Agro Biodiversity Strategy and Action Plan

Future strategies for biodiversity conservation in Tamil Nadu

Implement Forest Policy : Promote tree planting in wastelands to increase the tree cover to 1/3 geographical area of the State. The National Forest Policy, 1988 envisages that the area under forest and tree cover be enhanced to 33% by 2012. The geographical area of Tamil Nadu is 1,30,05,800 ha. As per the Forest Survey of India Report, 2003, the total forest and tree cover in Tamil Nadu is 27,63,400 ha.; that is 21.25 per cent. This 21.25 per cent is irrespective of the legally declared forest area, and includes all areas where tree cover is present whether inside or outside the forest area. In order to achieve the mandate of 33% tree cover by 2012, about 42,92,000 ha., has to be covered under tree cover. As the tree cover is already 27,63,400 ha. in Tamil Nadu as per Forest Survey of India (FSI) report, the balance area has to be brought under tree cover is 15,28,600 ha.

The mission can only be accomplished by undertaking massive tree planting programme in the farmlands adjunct with agriculture crops. The approach shall involve multi stakeholders; the farmers, the wood based industries, the financial institutions, the Government agencies, the Non-Governmental Organizations (NGO), the Media.

Implement National Forestry and Wildlife Action Plans

- Detailed strategies for conservation of biodiversity is given in National Forestry Action Plan and in National Wildlife Action Plan
- They have to be implemented in the State
- Disseminate these information to all the officers of the Forest Department

Increase the Protected Area for in situ Conservation

- Strengthen the ongoing initiatives of declaring more areas as sanctuaries
- Create new protected areas like community conservation area and conservation reserve
- Speed up the process of declaring Mudumalali and Anamalai as Tiger Reserve
- Speed up the process of declaring Agasthiarmalai Biosphere Reserve of Tamil Nadu part.
- 8 Wildlife sanctuaries (2,82,685.57), 12 Birds sanctuaries (17,074.59), 5 National parks, (30,784.23), 3 Tiger Reserves, 3 Biosphere Reserves

Restore Degraded Forests

- Restore degraded forest and open forest by gap filling to create dense forest in the non-protected areas.
- Carefully assess the need for replanting the degraded areas and open forests in the protected areas taking the habitat requirements of wild animals in to consideration.

Preserve all the existing grasslands

- In the past grasslands have been converted to plantations and it is a ecological disaster.
- Preserve all the existing grasslands as such.
- Do not convert any of the existing grasslands in the forest areas.

Maintain the existing positive trend in Forest Cover

- Maintain the present positive trend in the forest cover change by strict protection and restoration

Consolidate the Joint Forest Management

- Consolidate the gains of the JFM in about 1000 Village Forest Committees (VFC)
- Facilitate sustainability of the Village Forest Committees (VFC) to sustain JFM
- Extend JFM to all the 3072 Forest Fringe hamlets under Tamil Nadu Afforestation Project (TAP)/FDA/Other Schemes
- Provide corpus fund of Rs.5.00 lakhs for attaining financial sustainability through micro credit and revolving fund for reducing forest dependency (Adopt KMTR model)
- Promote Self Help Groups (SHG) in all VFCs by Forest Department, NGOs, Womens Development Corporation, Banks etc to reduce poverty which is the basic reason for forest dependency
- Please refer 2 books on JFM by the author namely JFM concepts, policies and Guidelines and JFM Status Report 2003 for Tamil Nadu for details.

Expand Eco Development

- Consolidate the gains of Eco Development in Kalakad Mundanthurai Tiger Reserve (KMTR) and further strengthen the ongoing initiatives (For details please refer Eco Development in KMTR, Status Report 2004 by the Author)

- Extend KMTR model of Eco Development to all the Protected Areas (PAs)
- Provide corpus fund of Rs.5.00 lakhs for attaining financial sustainability through micro credit and revolving fund for reducing forest dependency
- Promote SHGs in all VFCs by Forest Department, NGOs, Womens Development Corporation, Banks etc to reduce poverty which is the basic reason for forest dependency

Promote Agro Forestry

- Promote Agro forestry as a Alternative Production Strategy for meeting the fuel, fodder, small timber, timber and green leaf manure needs of the farmers
- Utilize the ongoing Wasteland and Watershed Development Programmes for increasing Agro forestry
- Promote tree seedlings nurseries by Private Agencies, NGOs, Agriculture Department, Horticulture Department, and Forest Department

Promote Social Forestry

- Promote social forestry as a alternative production system for meeting the wood based requirements of rural population and industries
- Consolidate all the gains of social forestry and retain all the social forestry plantations as such
- Replant felled/failed tank bed areas
- Expand Strip plantation along the railway lines, road sides, canal sides, river sides, etc.
- Notify the hillock and revenue poramboke plantations under sec.26 of Tamil Nadu Forest Act for effective protection

Adopt Watershed Management as a Core Strategy

- Focus on water conservation to conserve biodiversity

- Consolidate the ongoing watershed based development under TAP / Western Ghat Development Programme/Hill Area Development Programme etc.
- Continue the ongoing watershed based development in forest areas
- Extend the watershed based development and management to all the forest and protected areas to reduce soil erosion, and to augment water resources
- Tie up with the District Watershed Development Agency and Wasteland Development Programmes

Awareness Creation and Sensitization

- Create awareness regarding the importance of the biodiversity conservation among the public
- Use the occasions of World Forestry day, World Water day, Wildlife Week Celebration, VFC day, Vana Mahotsava and periodical VFC meetings for awareness creation

Strengthen symbiotic relationship between tribals and forests

- Recognize the cultural dependency of the tribals on forest biodiversity
- Continue the existing free access to MFP for the tribals
- Convert the tribals as Friends of Forests
- Evolve acceptable relocation packages for the tribals living in the enclaves inside the Protected Areas

Acquire Private Forest enclaves in Protected Areas

- Acquire the Private forest enclaves in the protected areas
- Implement Private Forest Act strictly in private forest areas
- Regulate felling in plantation areas without affecting watershed

Minimize the pressure from other enclaves

- People residing inside the enclaves like EB Colonies and other villages exert pressure daily on the biodiversity of the nearby forest/protected areas particularly for fuel wood, grazing and for shelter needs.
- Evolve effective strategies for reducing the population in the enclaves by settling them outside.
- Evolve relocation packages for settling them outside the PAs/forest areas

Minimize diversion of forest lands

- Diversion of forestlands in the past has resulted in extreme loss of biodiversity. How many species and how much of genetic diversity have been lost is not known
- Implement Forest Conservation Act effectively
- Prevent further diversion of forest lands

Prevent and manage Fire

- Fire causes serious losses to biodiversity
- Millions of invertebrates and thousands of vertebrates perish in fire
- Evolve fire management plan for each forest division involving fire line clearance, engaging fire watcher and by controlling fire
- Provide cell phone and modern gadgets for communication and for fire control

Reduce Head loading

- Create sustainable alternative livelihood options for headloaders by adopting micro credit and micro financing (adopt KMTR model)
- Supply fuelwood on cost basis to the pilgrims inside the forest areas
- Supply energy saving devices and provide loans for acquiring LPG etc
- Promote Agro forestry in all the forest fringe villages

- Please refer the book on Eco Development in KMTR – Status Report 2004 by the Author for details

Reduce Grazing

- Prevent grazing in PAs
- Create sustainable livelihood options for forest dependent graziers by adopting micro credit and micro financing (adopt KMTR model)
- Promote stall fed milch cattle by arranging loans
- Create fodder resources outside the Forest areas
- Promote Agro forestry and silvipasture for meeting fodder needs

Prevent destructive methods of MFP collection

- Sustain the benefit sharing in all the JFM areas in an equitable manner
- Prevent destructive methods of MFP collection
- Prevent MFP collection from Protected Areas by creating alternative livelihood options through micro credit for the dependents (adopt KMTR model)

Minimize Trade pressure on Sandalwood

- Genetic diversity of sandal has been completely eroded due to smuggling
- Strengthen law enforcement against the sandalwood smugglers
- Trade pressure caused by sandal wood based industries is the root cause for sandal smuggling
- Promote sandal plantations by farmers and private agencies
- Establish *ex-situ* conservation centers in Research Gardens for conserving the genetic diversity of the sandal

Reduce Trade pressure on Medicinal Plants

- Over 95 per cent of medicinal plants used in industry comes from wild sources.

- Export on medicinal plants also heavily depends on wild sources.
- These pressures will destroy wild medicinal plant resources from forests.
- Promote cultivation of medicinal plants to meet the industrial and export demand.

Prevent destructive methods of wild plant collection

- Over 70 per cent of wild medicinal plants collection involves destructive harvesting because of use of plant parts like roots, bark, wood, stem and the whole part of the herb.
- Promote cultivation of all such plants and meet the demand from cultivated sources only.

Prevent further Encroachment

- Encroachers dependence on forest biodiversity for every day needs is a matter of serious concern
- Evict existing encroachments
- Relocate encroachers outside the PAs and forests
- Prevent further encroachments by Periodical monitoring of the vulnerable areas and all the encroachment enclaves

Speed up Settlement process

- Delay in settlement leads to encroachment and loss of biodiversity
- Speed up the process of settlement
- Review each case of settlement and fix a time limit for concluding each case

Review Mining Policy

- Review the existing mining in the forest areas
- Prevent further fresh mining from the forest areas
- Constantly monitor the illegally mined areas in the past and prevent fresh illegal mining

Reduce Exotic Plantations

- Review the existing policy on retention of exotic plantations
- Convert exotic plantations to indigenous trees after analyzing the location specific demand for fuel wood for domestic consumption and for tea industries
- Restore sholas in the exotic plantation areas wherever possible
- Explore the possibilities of sustainable management of existing exotic plantations wherever needed

Prevent Poaching

- Take proactive steps against poaching
- Track the elephant movement regularly by the anti-poaching watchers
- Conduct permanent anti-poaching camps in all protected areas
- Prosecute the poaching cases effectively

Minimize accidental death of wild animals including Electrocution

- Reduction in population of some of the wild animals like elephant is caused due to accidental death including electrocution
- Accidental deaths occurs due to passing vehicles inside the Sanctuary
- Preventive steps to be taken to minimize death due to accidents

Rescue and Release of Wild Animals

- Wild animals do not respect the forest boundary. They stray outside and this leads to poaching
- Keep a team for rescuing the wild animals straying outside the forest areas and protected areas
- And release the rescued animals back in to the forests and not in the Zoos.

Minimize Man - Animal Conflict

- Forest fringe dwellers take a negative attitude towards wild animals because

of crop raiding and due to death caused to human beings and cattle lifting by wild animals

- Compensation has to be paid at the earliest in all such cases

Prevent Pollution

- Many herbivores die due to intake of polythene pollutants
- Ban entry of plastic and polythene pollutants inside the Forest and Protected areas
- Periodically Collect and dispose of the polythene pollutants by using VFC volunteers, NGO, Students etc

Prevent Spread of Invasive Alien Species

- Clearing or tree felling inside the forest areas creates gap which invites invasive alien species (like Lantana, Eupatorium, Prosopis, Parthenium etc) to occupy and colonize the area thereby displacing the native biodiversity
- Prevent felling and creation of gaps
- Fill the gap with native biodiversity
- Remove the invasive alien species from all the protected areas
- Remove the invasive alien species from the Mangrove areas
- Remove the invasive alien species from other forest areas wherever possible.

Reduce Pilgrims and Tourists Pressure

- Evolve location specific strategies for preventing negative impacts on biodiversity by the pilgrims and tourists
- Pollution in tourism zone of PAs is a serious issue affecting biodiversity
- Pilgrims and tourists also set unintentional fire

Prevent Habitat Fragmentation

- Ensure safe passage for elephants in the corridor

- Prevent intentional death by electrocution in the corridor
- Strive for people's participation for the safety of the elephants in the corridor region
- Ban further constructions in the corridor region

Evolve Species Specific Conservation Plans

- Species specific conservation plans are to be evolved for each location particularly for
- Species specific/location specific strategies are needed for effective conservation

Integrate Biodiversity Conservation in Forest Planning

- Prepare protected area management plans clearly focusing on total biodiversity conservation
- Include a chapter in Forest Working Plan regarding biodiversity conservation
- Prepare biodiversity status report for each division indicating the checklist of fauna and flora (refer a book on the Biodiversity of KMTR by the Author)
- Continuously update the information regarding the checklist

Training and Capacity Building

- Train all categories of forest officials on biodiversity conservation
- Establish a system for periodical updating of knowledge on biodiversity.

Promote Research on Survey of Biodiversity

- Survey of flora and fauna has to be carried out in each forest division for proper documentation and for evolving location specific conservation packages.

Evolve Monitoring Strategies for Red Listed and Other Important Species

- List out the flora and fauna that are to be

continuously or periodically monitor in each forest division

- These species may include red listed over exploited, endemic are those that are less than 100 in number in any division.

Evolve Recovery Strategies for Red Listed Species

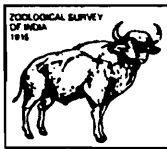
- Increase the number of individuals/ population of each red listed species to a safe level in each location for recover

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BIODIVERSITY CONSERVATION-THE NEED OF THE ERA

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INTRODUCTION

Biodiversity keeps the planet habitable and ecosystems functional. The wealth of life on earth today is the product of hundreds of millions of years of evolutionary history. Over the course of time, human cultures have emerged and adapted to the local environment, discovering, using and altering local biotic resources. Many areas that now seem "natural" bear the marks of millennia of human habitation, crop cultivation and resource harvesting. The domestication and breeding of local varieties of crops and livestock have further shaped biodiversity. Biodiversity is the basis for nutritional adequacy and food security and hence it should be preserved and managed for a sustainable economic development and progress. Development has to be both people centered and conservation based. Unless we protect the structure, functions and diversity of the world's natural system, development will undermine itself and fail. The strategy for biodiversity conservation is fundamental to the success of the developmental process. Biodiversity strategy explains, conserving biodiversity, is not just a matter of protecting wildlife in nature reserves. It is also about protecting the natural systems of the earth that are our life support system; purifying waters; recycling oxygen carbon and other essential

elements; maintaining the fertility of the soil; providing food from the land, freshwater and seas; yielding medicines, and genetic richness on which we depend on the ceaseless struggle to improve our crops and live stocks. In the light of above information, the authors have made an attempt to examine the threats to biodiversity and suggest the strategies for biodiversity conservation

THREATS TO BIODIVERSITY

1. Habitat fragmentation, degradation and loss, and shrinking genetic diversity

Habitat destruction is identified as the main threat to biodiversity. The pressing needs of rural and urban people for food, fibre, shelter, fuel and fodder combined with compelling need for economic development exert enormous pressure on natural resources. The loss and fragmentation of natural habitats affect all animal and plant species. Various species of plants and animals are on the decline due to habitat fragmentation and overexploitation, e.g. habitats of Great Indian Bustard in Madhya Pradesh, Gujarat and Rajasthan, and of the Lion-tailed Macaque in Western Ghats. Habitat fragmentation is also one of the primary reasons leading to cases of man animal conflict. Common property resources like pastures and village forests, which served as a buffer

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between wildlife habitat and agriculture, have been gradually encroached upon and converted into agricultural fields and habitation. Due to this, the villagers are brought into a direct conflict with wild animals. The usual cases regarding man-animals conflicts relate to leopards, elephants, tigers, monkeys, blue-bulls, wild boars and certain birds. Loss of habitats has led to depletion of genetic diversity of several wild animals and cultivated plants. Shrinking genetic diversity leads to more vulnerability to diseases and pests and lesser adaptability to environmental changes.

2. Declining natural resource base and overexploitation of resources

Forests face threats on account of diversion of forest land for agriculture, industry, human settlements, and other developmental projects. Construction of roads and canals, quarrying, shifting cultivation and encroachments are other threats. Degradation of forests results from illicit felling, excess removal of forest products, fodder, fuel wood, forest floor litter, overgrazing and forest fires. As a result, some of the floristic and faunal components, including many keystone and endemic forest species are now left with a narrow eroding population which needs to be urgently conserved. The forestry is the second largest land use in India after agriculture, covering approximately 23.57 percent (recorded forest area) of the total geographical area. An estimated 41 percent of the country's forest cover has been degraded to some degree. As much as 78 percent of forest area is subject to heavy grazing and about 50 percent of the forest area is at risk from forest fires. Domestic demand for timber and fuel wood is well above the sustainable level. Unsustainable exploitation of biodiversity resources, particularly by developed countries, has serious adverse impacts, both local and global.

3. Invasive Alien Species

Among the major threats faced by native plant and animal species, the one posed by the invasive alien species is truly scaring since it is considered second only to that of the habitat

loss. The major plant Forest Invasive Species (FIS) include *Lantana camara*, *Eupatorium glandulosum*, *Parthenium* species, *Mimosa* species, *Eichhornia crassipes*, *Mikania micrantha*, *Ulex europaeus*, *Prosopis juliflora*, *Cytisus scoparius*, *Euphorbia royleana* etc.

4. Climate Change and Desertification

Climate change, on account of a buildup of greenhouse gases in the atmosphere leading to global warming, poses another significant threat to biodiversity, ecosystems, and the goods and services they provide. There are indications that the projected changes in temperature and CO₂ concentration may alter growth, reproduction and host-pathogen relationships in both plants and animals.

5. Impact of Development Projects

India, with its large population, is poised for rapid economic growth. Large infrastructural and industrial projects, including highways, rural road network, and the special economic zones (SEZs), are coming up. With cities and townships expanding, often at the cost of agriculture, and agriculture expanding at the cost of tree cover, fresh threats to biodiversity are emerging. In addition, changing lifestyles of the people, with rising incomes, in both rural and urban areas, are placing increasing demands on biodiversity.

6. Pollution

Biodiversity in India is facing threat from various sources of pollution. The major threats are from improper disposal of municipal solid waste, sewage, excessive use of chemical pesticides and continuous use of hazardous chemicals even where non-hazardous alternatives are available.

7. Biodiversity Information base

So far, almost 70 per cent of the country's land area has been surveyed and around 46,000 species of plants and 89,000 species of animals have been described. It is estimated that about 400,000 more species may exist in India which need to be recorded and described. The baseline data on species and genetic diversity, and their

macro-and micro-habitats, is inadequate. Further, although, a number of organizations/agencies are working on various aspects of biodiversity, the information on the subject is scattered and not yet integrated into a national database. Some of the databases being developed are not upto the standard, primarily because of lack of infrastructure, skilled manpower and coordination among experts in different fields.

8. New and emerging biotechnologies

Development and introduction of transgenic or genetically modified organisms, through the use of r-DNA technology, are already in the process of revolutionising all facets of human life, be it agriculture, industry or health care. About 20 recombinant therapeutics and a transgenic crop i.e. *Bt* cotton have already been approved for commercial use in the country. The area under *Bt* cotton cultivation has increased substantially in the last four years. Further, 11 transgenic crops are under various stages of field trials. Among various biosafety issues, there are concerns with respect to impact on biodiversity. However, the long-term impact of introduction of transgenics on biodiversity, particularly on genetic diversity of domesticated animals and crops, is far from clear. The sheer magnitudes of potential benefits of transgenics, and the perceived fears of their possible harmful consequences, call for urgent steps to review the existing mechanisms and protocols for biosafety assessment of transgenic organisms on a continuous basis.

9. Human threats to Biodiversity

One reason for the growing interest in biodiversity is the threat that human activities may pose for plant and animal species. As humans take over more land for agriculture, cities, highways, and other uses, natural habitats are seriously disrupted. As human populations grow, the threat to biodiversity will continue to grow with it. And as more people place greater stress on the natural environment, greater will be the loss of resources plant and animal communities need to survive. Some people argue that all species, as they exist, have

a right to continue to exist in their own natural habitats, untouched by human development. Moreover, in many cases existing reserves are relatively small and are threatened by man by means of illegal poaching of animals and plants, and tourism.

Approach and strategies for Biodiversity Conservation

Successful action to conserve biodiversity must address the full range causes of its current threats and embrace the opportunities that genes, species and ecosystem provide for sustainable development. The major goals of biodiversity conservation are :

- Preparing a National land and water use plan, mapping the areas of the country that are essential for ecological and livelihood security, and declaring them off-limits to large-scale commercial developmental purposes
- Re-orienting development-related policies, laws, and schemes, to ensure that biodiversity and people's livelihoods are secured
- Promoting tree planting in waste lands to increase the tree cover to 1/3 geographical area of the region
- Prevention of grazing in protected areas
- Minimization of trade pressure on medicinal plants
- Increasing agro forestry and social forestry
- Strengthening symbiotic relationship between tribals and forests
- Prevention and minimization of forest fire
- Conserving of rare, endangered, endemic and insufficiently known floristic and faunal components of natural habitats, through appropriate institutionalization and human resource capacity building.
- Minimization of man-animal conflicts.
- Controlling of poaching and illegal trade in wild animals and plant species.
- Minimization of accidental death of wild animals including electrocution

- Developing an appropriate Early Warning and Awareness System in response to first new sightings of invasive alien species
- Initiation of research on impacts of climate change on forest types, eco-sensitive zones, crop yields and biodiversity
- Estimating the full economic and social values of biodiversity, especially its role in ensuring water and climatic stability, soil productivity, and people's livelihoods
- Strengthening, monitoring and enforcement of emission standards for both point and non-point sources of pollution
- Treatment of industrial effluents to minimize adverse impacts on terrestrial and aquatic biological resources
- Conducting regular surveys to monitor changes in populations of target species (wild and domesticated), using remote sensing and other updated tools and techniques
- Updating the database on sacred groves and sacred ponds documenting bioresources and associated knowledge conserved at these sites
- Introduction of DNA fingerprinting, other molecular analytical techniques and studies on genetic diversity of critically endangered species to develop appropriate conservation strategies
- Integrating biodiversity concerns through inter-sectoral and inter-departmental coordination at local, district, state, and national levels
- Respecting, protecting, and building on traditional knowledge of biodiversity, including through community-led development of biodiversity knowledge
- Promoting both formal and non-formal means for environment education and biodiversity conservation through audio, visual and print media
- Designing and implementation of awareness programmes, particularly for rural women and incorporating modules on conservation and sustainable utilization of biodiversity in foundational and professional training
- Strengthening education, training, awareness and extension programmes on biodiversity issues for various stakeholders including all levels of students, professionals (such as Engineers, Doctors, Lawyers, CAs), Elected representatives (such as representatives of Panchayati Raj Institutions, MLAs, MPs, Mayors), Judiciary, NGOs, those in public and private sectors, defence and para military forces, customs, police, media, cultural, spiritual and religious institutions/individuals
- Promoting ecologically and socially sensitive tourism and pilgrimage activities with emphasis on regulated and low impact tourism
- Increasing funding for conservation measures, including through innovative financial mechanisms such as a tax on industries that use biological resources, an urban tax on rich citizens that benefit from 'free' services provided by natural ecosystems
- Promoting traditional and new technologies that reduce the negative impact of current human activities and use ecologically sustainable alternative materials, such as organic farming, non-conventional energy, environmentally friendly architecture

CONCLUSION

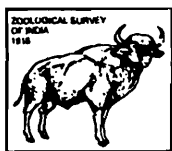
In order to achieve sustainable development and biodiversity conservation, effective conservation efforts should begin in the fields, forests, watersheds, grass lands, coastal zones and settlements, where people live and work. In this context, there must be new partnerships and contracts within the communities, involving biologists and resource economists together with social scientists, political leaders, businessmen, religious leaders, farmers, journalists, teachers and lawyers. Biodiversity

conservation planning exercise must include systematic attention to implementations and the mechanisms for monitoring implementation must be built into the planning process. Finally, we as human beings should change our life style through Gandhian mechanism of simple living, high thinking and integrating

environment consciousness with biodiversity conservation in order to achieve the sustainable development for the sake of future generations. We must act guardian of the environment and use natural resources but has no power to control and dominate over nature and its elements.

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DIGITALIZED (CD-ROMs) ANIMAL ALTERNATIVES IN LEARNING OF PRACTICES : AN APPROACH TO CONSERVATION OF ANIMALS USED IN ZOOLOGY/ LIFE SCIENCES/ANIMAL SCIENCES PRACTICALS

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INTRODUCTION

The Zoology/Life Science/Animal Science educators must know that the concept of animal dissections in Zoology curriculum was incorporated from the Western countries and these countries have banned animal dissection in the recent past. Dr. M.A. Akbarsha, Professor of Animal Sciences, Bharathidasan University, Tiruchirapalli, Tamil Nadu reported that the animal dissections are the major component of the practical curriculum for B.Sc. and M.Sc. Zoology courses which resulted in the depletion of green frog and garden lizard populations, animals that are indiscriminately killed for purpose of dissections in the laboratories. It is estimated that over six million animals are killed for the dissection industry each year. The teachers also realized the practical difficulties in getting the animals such as frogs and calotes for dissection. Further the students are also suffering to learn the dissection due to non-availability and difficulty in handling the animals especially girl students. A ban on dissection of frog and garden lizard for laboratory purposes appears desirable since the suppliers to Schools and Colleges collect them

invariably in the field with serious impact on the ecological balance. The Fresh water Frogs [*Rana* sp.] is included under Schedule IV Wildlife (Protection) Act, 1972. Vide Notification No.FL-28/78 FRY (WL) dated 9th September, 1980, published in the Gazette of India, Ext., pt II,S.3 (i), p.431 dated 2nd October,1980. When we talk about biodiversity conservation, it is our duty to safeguard the existing populations of the animals.

As a Zoologist every one of us must ask a pertinent question, whether animal dissection is a process of learning or skill-development. Most of the Zoologists accept that from the skill development point of view also, dissection is no more relevant. The teachers realize the practical difficulties in getting the animals such as frog and garden lizard for dissection. As Zoology teachers and Biodiversity conservationists, why not we change our attitude? What prevents us from changing? Now things have changed.

The curricular transformation is not only a challenge to an educator but it is of great opportunity for reaping benefits of every kind-Scientific, economic and humanitarians. The

curriculum planners and decision makers need to drive change, taking on new, collaborative roles and using innovative thinking to integrate the emerging "science of learning" into the educational systems. The students should have the opportunity to attend dynamic, high-quality curriculum designed to meet the challenges of the Digital Age.

The teachers have the right and academic freedom to change the Zoology practical curriculum to replace the dissections, which involves killing of animals, with the available alternatives. It is high time for the Zoology/Animal science teachers to take up decision regarding minimizing or total replacement of animals with flesh and blood for B.Sc. and M.Sc. practicals to acquire skill. It is also necessary to change the practical syllabi so as to enable to minimize or totally replace of the use of animals for the purpose of dissections.

Computer aided services have started coming up and students can be trained in animal anatomy using computers, and even online. Is the Zoology/Animal Science Teachers/Pharmacologists/Educators/Scientists/Researchers/Biodiversity Conservationists/Environmentalists aware of the digital technology and animal alternatives? In view of the growing awareness of the need to improve animal welfare and conservation, animal alternatives (CDROMs) are developed. These softwares (simulators) are developed to provide alternatives to animal use for Zoology/Animal Science/Physiology/Pharmacology practicals. These non invasive alternatives not only reduce animal use but also enhance the teaching quality and attract the experts of education for their use in teaching. A digital society requires teachers who are both digitally literate and liberally sensitive. Teachers must be multi-skilled in order to manage the multi-skill demands of a curriculum.

*You must do today's job with today's tools
If you do today's job with yesterday's tools
Tomorrow you will be out of business.*

The concept of Educational Technology has taken many "Avatars" from Programmed

Learning to Virtual Learning, grown more complex and its scope has grown wider with the focus and thrust on the integration of Information and Communication/technology (ICT) into Teaching and Learning in this digital age. How well are teachers able to go beyond chalk and talk to utilize these technologies? What challenges and opportunities are on the anvil in the digital age? Is the new digital age the answer to the prayers of teachers? Digitization refers to creating a digital object (i.e., one existing inside a computer) from a physical object.

Rajasekaran Pillai observed that the Orientation/Refresher Course conducted by the Academic Staff College could help them to become conversant with the modern Technologies in teaching. Further, he said the training of college/university Teachers would convert the traditional classrooms into multimedia ones. It is high time the teaching community got trained to be content creators to quench a thirst for e-Learning by making use of the UGC-Academic Staff Colleges in India.

The curricula for digital era and emerging technologies can be powerful allies to improve teaching and learning. The attitude of teachers is changed/changing and they have come forward and proposed substituting the use of computer simulations and multimedia presentations in place of the conventional dissections. From virtual dissections and experiments in laboratories, the students can perform on-screen, to full virtual reality simulations and very high degree of interactivity. The present digital age keyboard, mouse and interactive multimedia software packages on CD-ROMs in Animal Sciences not only supplement black board but also play a significant role in the conservation of animals. These alternatives, besides being non-invasive, prevent indiscriminate killing of animals from the wild, which can cause serious disturbance to the natural ecosystems that are already under threat due to environmental contamination. The soft-wares offer the facility to highlight or incrementally dissolve away specific organs or

organ systems by controlling their opacity within a composite image; present physiological processes such as digestion or the activation of muscles through the technique of 'morphing'; spin organs and skeletal systems and present animations and fly through any part of the body. These opportunities, absent in the real lab but available on demand at high speed in simulation, can provide a very rich and sensitive experience which allows a much fuller appreciation of structure and function relationships. The teacher can make use of the assessment methods viz., quiz, tag, labeling and testing, available in the CD-ROM such as *Dissection Works* and *Frog Pro Dissector*.

As an Educator, a clear distinction has to be known between Education, which aims to contribute to the development of proper attitudes towards the use of animals and alternatives and training, and to ensuring that the experiments are of the highest quality. The aim of the seminars is to train teachers in using a range of important alternatives to harmful animal use in higher education, and in the new Concepts in Animal Welfare Curriculum from World Society for the Protection of Animals (WSPA). The international organizations such as International Network for Humane Education (InterNICHE), World Society for the Protection of Animals (WSPA), International Centre for Alternatives in Research and Education (ICARE) and in India People for Animals (PFA) playing a major role in conducting/sponsoring workshops to train the teachers. Dr. M.C. Sathyanarayana, Department of Zoology and Wildlife Biology, A.V.C.

College, Mayiladuturai, Tamil Nadu and Dr. M.A. Akbarsha, Professor of Animal Sciences, Bharathidasan University, Tiruchirapalli, Tamil Nadu are campaigning to reduce animal dissection in the Zoology/Animal Science curriculum of several Universities and Colleges taking advantage of their nomination in Boards of Studies and also by organizing hands-on training workshops for Zoology/Animal Science teaching community.

The trained teachers will then be able to introduce alternatives and animal welfare in general more easily into the educational system.

The objective of the each demonstration is

To give an overview and a detailed presentation of each alternative

To show exactly how each alternative can be used to optimize its pedagogical impact

To illustrate the potential of each alternative to replace harmful animal use

To answer questions from participants about the alternative

The Inter NICHE, UK invited the author (Dr. MCS) as Trainer to train the college/university teachers and researchers during the Workshop on Alternatives, Animal Welfare and the Curriculum organized by International Network for Humane Education (Inter NICHE) and the World Society for the Protection of Animals (WSPA) held across India in different cities from 23rd August to 1st September 2004. There was a good response from the teacher for the alternatives.

**ANIMAL DIGITAL CD-ROM IS NOT ONLY BEYOND CHALK AND TALK
BUT ALSO BEYOND BLOODSHED**

