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Status Survey of Endangered Species

Status Survey on *Trochus niloticus* (Linnaeus, 1767) in Andaman and Nicobar Islands

RAMAKRISHNA, C. RAGHUNATHAN and C. SIVAPERUMAN

ZOOLOGICAL SURVEY OF INDIA

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INTRODUCTION

Avant-Propos

The seas around Andaman and Nicobar Islands are a rich ground for a variety of commercially important molluscs. Among the seas shells, *Trochus* or Top shell and *Turbo* or Turban shell have unique position in commercial point of view. As early as 1927, the *Trochus* fishery was initiated in Andaman Islands, however the regular fishery on *Trochus* organised during October 1929 at these Islands. In the initial season, the fishery yielded not less than 500 tons of shells within the first three months, but the yield, however, began to steadily decline and although the period of fishing has since then been doubled the quantity of shells obtained was reached the low figure of 40 tonnes in one fishing season. The scarcity of full-sized specimens has also resulted in an indiscriminate fishing of shells of all sizes by both the licensed and unlicensed Japanese fishermen, so much so that, at the present day, the *Trochus* beds of Andaman and Nicobar waters were rapidly depleted. Subsequently, a consolidated scientific report was published in 1938 by Zoological Survey of India (ZSI, 1939) on the shell fisheries of these Islands during 1930-35 dealing with the history of Andaman shell fisheries, fishing methods, important beds of top and turban shells and the scientific work. Considering the importance of *Trochus* fisheries is threatened with almost complete extinction in its natural beds, the Government of India on the recommendations of ZSI initiated to control the *Trochus* fishery on scientific basis. The Andaman and Nicobar Administration after realising the importance of this fishery, started giving the fishing grounds on lease to merchants for fishing and collecting royalty from them (Appukuttan, 1979).

Fishing Zone

The Andaman and Nicobar Administration has identified nine *Trochus* fishing zones and leased out all these zones for fishing every year. There are seven licensed shell collectors in the island and each is permitted to raise up to 25 tonnes of *Trochus* and *Turbo* per year during the initial days of shell fisheries. The categorized nine important fishing zones and their port and latitude are given below :

1. Cape Price to Mayabunder, between Lat. 12° 56.5' and 13° 34.5'N. Port-Mayabunder
2. Cape Price to Austen Straight, between Lat. 12° 54' and 13° 34.5'N. Port-Mayabunder
3. Mayabunder to Long Island, between Lat. 12° 24' and 12° 55'N. Port-Long Island
4. Long Island to Shoal Bay, between Lat. 12° 0.5' and 12° 18'N. Port-Long Island
5. Shoal Bay to Chiriatapu, between Lat. 11° 29' and 11° 56.4'N. Port-Port Blair
6. Chiriatapu to Port Mouat, between Lat. 11° 29' and 11° 38'N. Port-Mouat

7. Ritchie's Archipelago, Island and Islets, between Lat. 10° 46.5' and 12° 19'N. Port-Port Blair
8. Nicobar Central group, between Lat.7° 52' and 8° 35'N. Port-Nancowrie
9. Nicobar Southern group between Lat. 6° 45'N and 7° 31'N, Port-Nancowrie

Method of Fishing

Traditionally, *Trochus* and *Turbo* were exploited from shallow and deeper waters. They were collected from the depth ranging from 6-13 fathoms by skin diving. The divers in the island know the rich shell beds in the coastal areas and collect the shell during low tide especially from the mangrove and coral areas. These shells always are seen underneath the rocks, corals stones, in the crevices of rocks or buried in the mud. Divers reach the shell beds by means of dinghy called *Sampen* or *Bonga dongi* and they dive without any diving gears. In each *Bonga dongi* 10 adults will be engaged. Such a unit will be able to collect about 100 shells a day. The main fishing season begins by January and lasts till July. Most productive areas for *Trochus* and *Turbo* zone 5 and 6 but the larger sized shells are being collected mainly form zone 8 and 9.

Fisheries and Statistics

Since prehistoric times, humans have exploited molluscan resources for multiple purposes. Shellfish have been traditionally used for such various purposes as currency (e.g., the *Trochus niloticus* and gold-ring cowry *Cypraea annulus*), *Trochus* shell has been harvested since the beginning of the 1900s. World production is currently estimated to be between 3000 and 6000 tons, making this species one of the most valuable gastropods in the world market both for shell and for meat. The search for food has constituted and still continues to form a major reason for shellfish exploitation. These are commonly collected or cultured nowadays to fulfill the high demand of the world market, as well as for local consumption by littoral dwellers. For many coastal populations of tropical areas, shellfish, as a substitute for fish, represents an important dietary component, especially for poor people. Other reasons for shellfish exploitation include the use of shells as a raw material for mother-of-pearl or for lime in pottery glazes, poultry food additives, or for personal adornment.

Trochus niloticus has been commercially exploited for several decades since from the establishment of a regular *Trochus* fishery in October 1929 at Andaman Islands. However, during the years 1939-45 commercial fishing was stopped and the beds were allowed to recover. A total of 400 tonnes of *Trochus* and 105 tonnes of *Turbo* were landed during 1976. A rough estimate of average shell landings of the islands is between 400-600 tonnes for *Trochus* and 100-150 tonnes for *Turbo* shells per year. As per the recent estimates the annual production of *Trochus* ranges from 400 to 500 tons fetching Rs.45,000/- per ton (Nayar and Appukuttan, 1983). *Trochus* is collected in a few kilograms, between 1994-95 and 1998-99 an average of 1825 kgs. of *Trochus* per year were collected, with the highest quantity of 4382 kg in 1996-97 and the lowest of 450 kg in 1995-96. At the current market prices raw *Trochus* shells can fetch Rs.60,000 to 65,000 per MT.

The cleaned *Turbo* shell may cost between Rs.20 and 50/- and *Trochus* shell between Rs. 5 and 15/-. The finished product viz. Necklace, carved out of bits of turbo shell costs Rs.35 to 60/-, ear rings Rs.15 to 25/- finger rings Rs.5 to 10/-, wrist let Rs. 25 to 50/-, buttons Rs. 7.50 per set, cufflinks Rs.8 to 15/- per pair, table lamp Rs.18 to 55/- and lockets Rs.5 to 15/-. The estimated profit is around 25% (Appukuttan, 1979).

Processing of shells

The raw shells brought by the divers are collected and dumped in godowns by the local merchants. The soft part of the shell is taken out either by boiling or by pit cutting. Once the soft body parts are removed completely, the shell is cleaned graded packed in gunny bags and marketed. It is understood that the local merchants 10-20% of the shells collected from various fishing zones of the islands is wormed. The boring organisms are mainly polychaetes and bivalves. The percentage of damaged is more in large sized shells. Fouling organisms like, barnacles are also seen in these shells. Encrustation of calacarious algae is a common phenomenon. Damaged shells were found more in *Trochus* landings than *Turbo*. By cleaning and mechanical grinding of the shell, the internal pearly lustre is revealed. After cleaning and processing these shells, they are highly attractive and versatile. *Trochus* shells also have the internal mother of pearl layer and by cleaning and polishing the outer layer, the pearly lustre is revealed. In Calcutta there are several handicrafts units and they manufacture number of shell articles. The process of manufacture of shell articles include curing in boiling water, removal of the upper skin by mechanical abrasion, bleaching, cutting, shaping, fitting, engraving, enamelling and final finishing. The finished products are sold widely in almost all the cities and tourist centres all over India. Of late some shell merchants of Calcutta and South India are exporting the finished products to different countries viz. France and USA. The ornaments and novelties made out of these shells have a good market in the USA. In France, buttons made of shells are utilized for latest fashion designs (Appukuttan, 1979).

Commercial value

The shells of *Trochus niloticus* are used as raw materials by the nacre button industry. The value of this natural material has increased steadily since the emergence of plastic materials. Artisanal jewellers put the shells to a variety of uses and designs such as inlaying and incrustation. Commercial demand for these products has been on the rise for more than 30 years (Lemouellic and Chauvet, 2008). The *Trochus* shells were exploited on a large scale in Andaman and Nicobar Islands and New Caledonia. The latter exported about 1900 tonnes of shells in 1978, which constituted more than 30 per cent of the world production. The *Trochus* meat is edible and is dried, cooked, or occasionally canned for local consumption. The aragonite shells, primary raw material for mother-of-pearl buttons, are exported to Asia and Europe. The annual world harvest is about 5,000 tons (Heslinga and Hillmann, 1981) with a dockside value of about $4 million (at $0.88/kg, Palau's 1982 price). The retail value of the finished product is many times higher, since an individual *Trochus* shell worth $0.15 ex-vessel will make 35 buttons worth about $0.30 each at retail (Udui and Van den Andel, 1981). Contrary to popular opinion, the widespread use of plastic

buttons and other fastening devices has not depressed the world *Trochus* market. Annual demand has been estimated at 6,000 tonnes worldwide (Bouchet and Bour, 1980), and the dockside price of *Trochus* shell has increased 500 percent during the last decade (Heslinga and Hillmann, 1981). The size limit and the seasonal restriction were originally implemented during the Japanese occupation. The Pacific Island *Trochus* industry remains a principal source of foreign exchange for artisanal fishermen particularly in remote areas.

Trochus niloticus are commercially important gastropods, distributed in the coral reefs of Andaman and Nicobar Islands and occurring upto 20m depth. *Trochus* fished for its meat and mother-of-pearl shell. *Trochus* shells were mainly polished and cut into various sizes and used in shell craft industry. *Trochus* shells are also used in the preparation of ornaments like earrings, pendants, necklaces and household articles such as table lamps, ashtrays, agarbatti stands, door hangings etc. (Plates 1-3). These are also used in the lime industry, poultry feed additives and the fine lime obtained from the shell is used in pottery glazes, toothpaste etc.

Systemic position

Trochus niloticus (Linnaeus, 1767) is a marine gastropod. It belongs to the Prosobranchia subclass, Archaeogastopoda order and Trochidae family. The *Trochus* or topshells are flat-based conical shells found in tropical and temperate waters. They have a horny operculum and a nacreous interior.

Trochus is a genus of medium-sized to very large sea snails. *Trochus niloticus*, for example, is a very large (up to 13 cm) Indo-Pacific top shell, which has a very thick inner layer of nacre. This species is commercially exploited to make mother of pearl buttons, mother of pearl beads, pendants and so on. In 2006, the sole commercial export of the Wallis and Futuna Islands was 19 tons of *Trochus* shells valued at US$122,000.

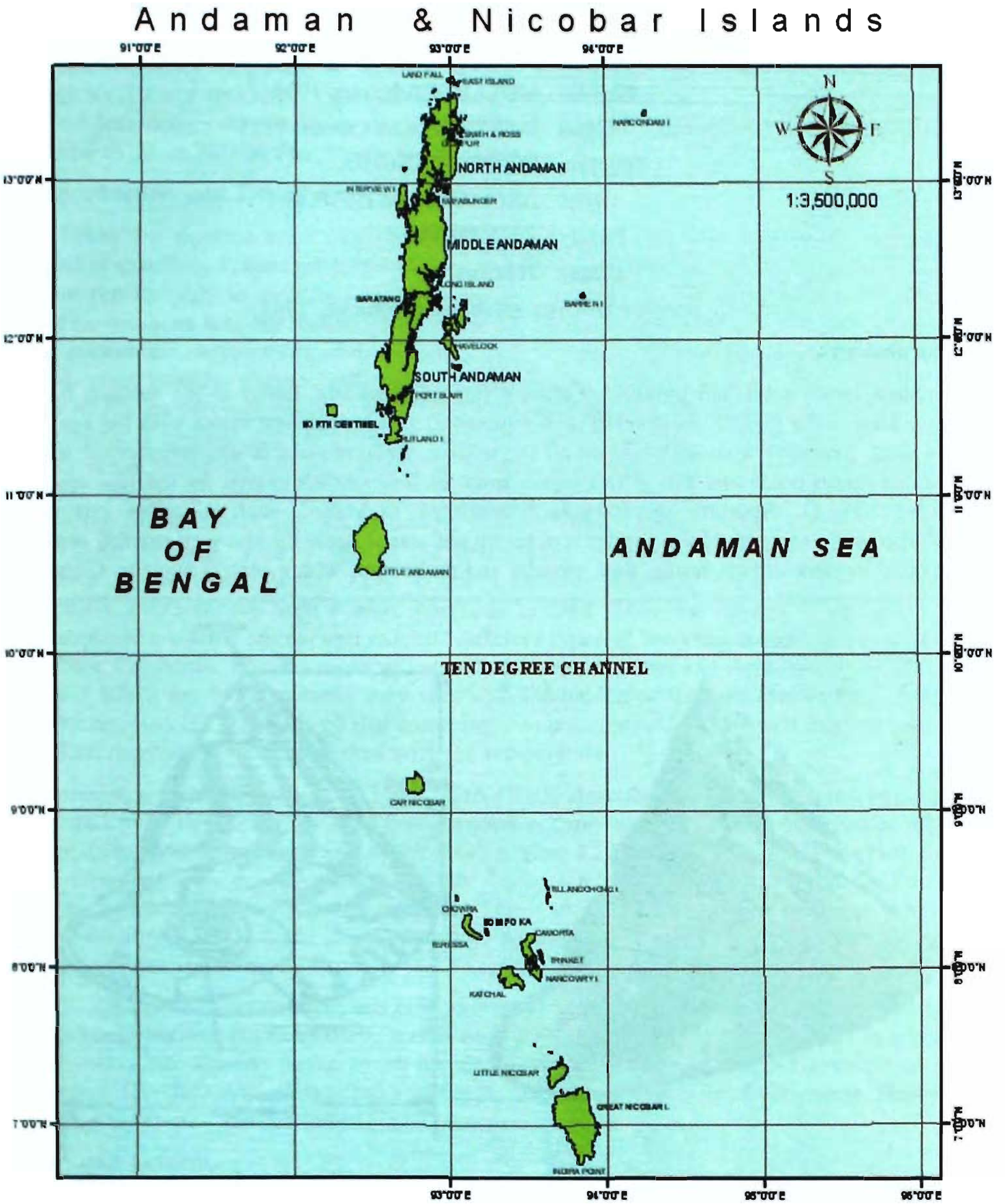
A total of 72 species within the genus *Trochus* have been reported worldwide. Among them 6 species viz. *Trochus niloticus* Linnaeus, 1767; *Trochus maculatus* Linnaues, 1758; *Trochus* (*Infundibulum*) *radiatus* Gmelin, 1791, *Trochus* (*Infundibulum*) *ochroleucus* Gmelin, 1791; *Trochus* (*Infundibulum*) *pustulosus*, Philippi, 1849 and *Trochus (Belangeria) scabrosus* Philippi, 1850 are fund in Indian waters. Except *Trochus (Infundibulum) pustulosus*, Philippi, 1849 and *Trochus (Belangeria) scabrosus* Philippi, 1850, remaining four species reported from India occurred in Andaman and Nicobar Islands (Subba Rao, 2003).

List of species under the genus *Trochus*

1. *Trochus aemulans* A. Adams, 1855
2. *Trochus akoya* T. Kuroda, 1942
3. *Trochus calcaratus* Souverbie, 1875
4. *Trochus californicum* A. Adams, 1853
5. *Trochus camelophorus* Webster, 1906
6. *Trochus cariniferus* Reeve, 1842

7. *Trochus chloromphalus* A. Adams
8. *Trochus coerulescens* Lamarck, 1822
9. *Trochus conoidalis* Pease, 1867
10. *Trochus crassicosta* A. W. B. Powell, 1937
11. *Trochus creniferus* Kiener, 1880
12. *Trochus cumingi* A. Adams, 1853
13. *Trochus elegantulus* Wood, 1828
14. *Trochus erithreus* Brocchi, 1821
15. *Trochus fasciatus*
16. *Trochus fastigiatus* A. Adams, 1853
17. *Trochus ferreirai* Bozzetti, 1996
18. *Trochus firmus* Philippi, 1850
19. *Trochus flammulatus* J. B. Lamarck, 1822
20. *Trochus fultoni* Melvill, 1898
21. *Trochus granosus* J. B. Lamarck, 1822
22. *Trochus granularis* Röding, 1798
23. *Trochus hanleyanus* Reeve, 1842
24. *Trochus histrio* Reeve, 1848
25. *Trochus huttoni* E. A. Smith, 1876
26. *Trochus incrassatus* J. B. Lamarck, 1822
27. *Trochus intextus* Kiener, 1850
28. *Trochus kochi* Philippi, 1844
29. *Trochus laciniatus* Reeve
30. *Trochus lamprus* Watson, 1881
31. *Trochus lineatus* J. F. Gmelin, 1791
32. *Trochus maculatus* Linnaeus, 1758
33. *Trochus maculatus verrucosus* J. F. Gmelin, 1791
34. *Trochus murreus* L. A. Reeve, 1865
35. *Trochus nardinii* Selli, 1973
36. *Trochus neptuni* (A. Adams, 1855)
37. *Trochus nigropunctatus* Reeve, 1848
38. ***Trochus niloticus* (Linnaeus, 1767)**
39. *Trochus noduliferus* Lamarck, 1822

40. *Trochus obeliscus* J. F. Gmelin, 1791
41. *Trochus ochroleucus* J. F. Gmelin, 1791
42. *Trochus oppressa* F. W. Hutton, 1878
43. *Trochus optatus* Sowerby,
44. *Trochus pachychiles* Watson, 1879
45. *Trochus pallidulus* A. Adams, 1853
46. *Trochus pustulosus* Philippi, 1849
47. *Trochus radiatus* Gmelin, 1791
48. *Trochus radiatus fultoni* J. C. Melvill
49. *Trochus rota* R. W. Dunker, 1860
50. *Trochus rubicatus* R. A. Philippi, 1848
51. *Trochus sacellum* R. A. Philippi, 1854
52. *Trochus sacellum rota* R. W. Dunker, 1862
53. *Trochus sandwichensis* F. L. A. Souleyet, 1852
54. *Trochus satrapius* Maltzan
55. *Trochus scabrosus* R. A. Philippi
56. *Trochus schlueteri* Sowerby, 1894
57. *Trochus shinayaka* T. Habe, 1961
58. *Trochus smaragdus* L. A. Reeve, 1861
59. *Trochus squarrosa* J. B. Lamarck, 1822
60. *Trochus stellatus* Gmelin, 1791
61. *Trochus submorum* (Abrard, 1942)
62. *Trochus tentorium* Gmelin, 1791
63. *Trochus tiaratus* Quoy & Gaimard, 1834
64. *Trochus tomlini* Fulton
65. *Trochus transenna* Watson, 1879
66. *Trochus tricatenatus* Reeve, 1861
67. *Trochus tubiferus* Kiener, 1880
68. *Trochus venetus* L. A. Reeve, 1862
69. *Trochus verrucosus* J. F. Gmelin, 1791
70. *Trochus virgatus*
71. *Trochus viridis* Gmelin, 1791
72. *Trochus zhangii* Zhengzhi, 2002



Map of Andaman and Nicobar Islands

CLASSIFICATION OF *TROCHUS NILOTICUS* (LINNAEUS, 1767)

Kingdom ANIMALIA
Phylum MOLLUSCA Cuvier, 1795
Class GASTROPODA Cuvier, 1795
Subclass PROSOBRANCHIA
Order ARCHAEOGASTROPODA
Family TROCHIDAE
Genus ***Trochus***
Species ***Trochus niloticus*** (Linnaeus, 1767)

Morphology

Shell large, solid and pyramidal, with 8 flat-sided whorls, fluted at the sutures, base excavated in the middle. Sculptured with concentric striae, sculpture varies with the age of the shell; juveniles with sculpture on all the whorls, medium-sized adults ornamented with granose spiral cords and full-grown adults more or less smooth except for the few apical whorls (Fig.1). Aperture quadrangular, umbilicus excavated, with a callus coating, columellar lip separated by a gap from outer lip and meets basal lip in a well marked angle. Operculum dark brown, horny, thin, circular and multispiral with a central nucleus. Growth

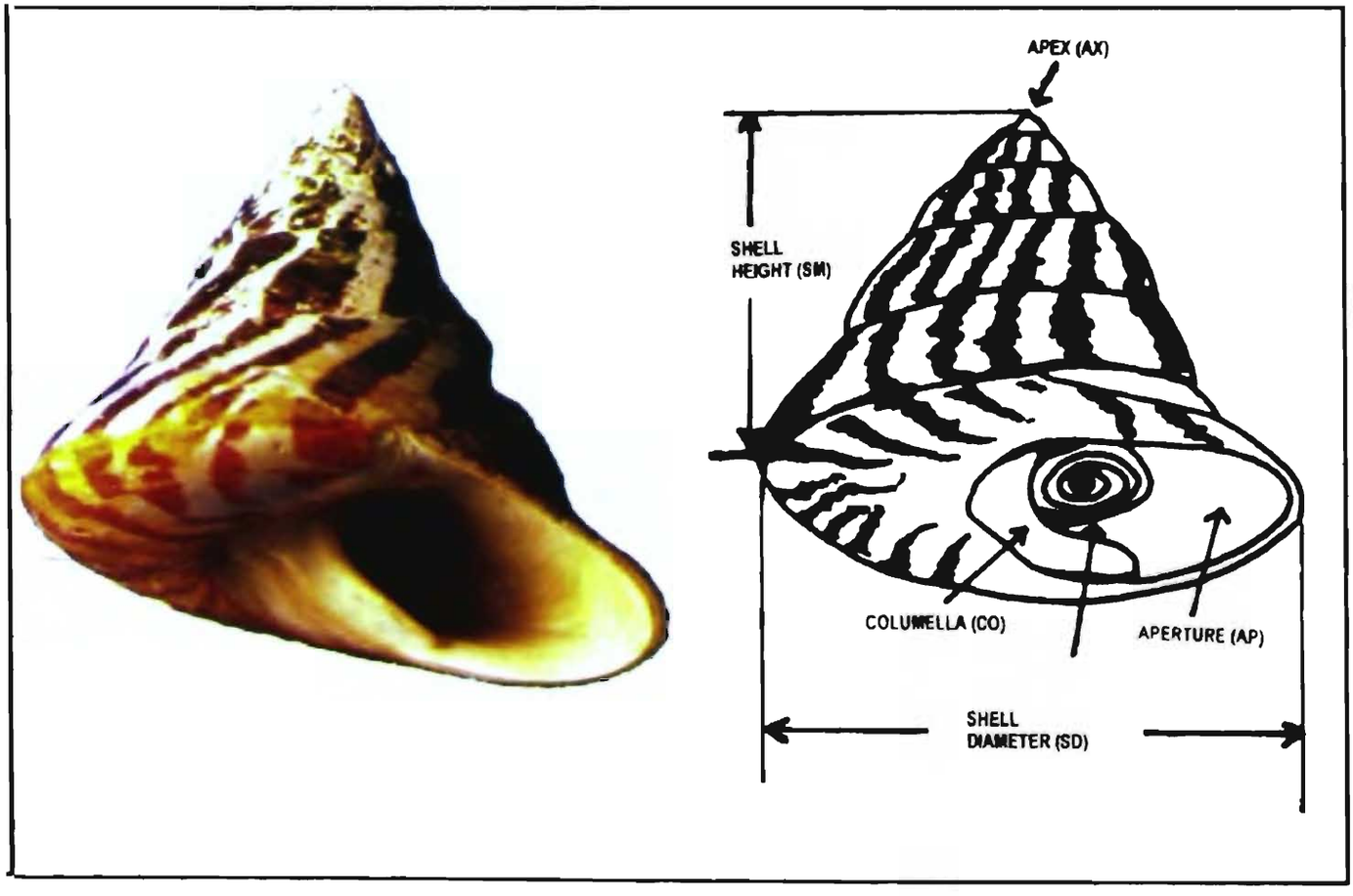


Fig. 1. Shell morphology of *Trochus niloticus*

of the *Trochus* is quite fast for the first 2-3 years (8cm base diameter). A ten year old attains the size of 12 cm. Commonly white with red brown or flame like stripes. Individuals live in shallow-water reef flats. In general, smaller individuals (<20 mm) are found in the shallowest water and larger ones (30-90 mm) seaward on the reef flat. Larger animals are found less commonly at depths as great as 7 m, and individuals have been reported at depths to 24 m (McGowan, 1956; Smith, 1987).

Reproduction and Larval Development

Sexes are separate but cannot be distinguished externally. Two sexes occur in about equal proportions. Mature adult specimens generally have maximum shell diameter of 7 cm. However, maturity in the males occurs when the shells attain 6-7 cm maximum diameter. Female becomes sexually mature when it is three years old and its shell height 9cm. *Trochus* are gonochoric, without any external sexual dimorphisms. Females and juneveile however, have green gonads, whereas males have white gonads (Amirthalingam, 1932a,b). Spring tide marks the breeding periods, with external fertilization and nocturnal spawning. Female spawning is induced by the presence of sperm (Amirthalingam, 1932c; Nash, 1985). In Micronesia, Australia and the Andaman Islands spawning occurs all year round (Rao, 1936). However, Amirthalingam (1937) inferred that in Andaman and Nicobar waters breeding is continuous and that spawning probably begins immediately after warm season i.e. April onwards. This is against the observation of Moorhouse (1932) on the same species in the Great Barrier Reef, where a definite spawning season of five months duration, commencing form March, has been noticed. Thus the species is an excellent example of a marine animal that exhibits different types of breeding in different localities. In New Caledonia, *Trochus niloticus* spawns between October and April (Bour, 1989). In age at which the snails maturity may vary with the habitat or location (Subba Rao, 2003). However, Rao (1937) observed that spawning was not confined to any well-marked season and no correlation was established with the temperature.

Heslinga and Hillmann (1981) and Nash (1985) described that the fertilized eggs are covered by a thick chorion. The first division occurs between 30 and 60 minutes after fertilization and the trochophore larvae hatches after 12 hours. At the end of the first day the larva becomes a veliger. Although the larva is teleplanic, its metamorphosis into a juvenile occurs classically during the third day of its life (Heslinga and Hillmann, 1981). Metamorphosis and settlement are stimulated by the presence of red algae or humic acids (Heslinga and Hillmann, 1981).

T. niloticus larvae, *Veliger* are now known to be of the short term lecithotropic type which, under favorable conditions, spends only a few days in the plankton. There is a high probability that *Trochus* larvae which recruit successfully to the benthic environment do so within a few days drift of their point of origin. After 2 to 3 years of development, *Trochus* reach market size and maturity (Fig. 2).

Age and Growth

Trochus grows fast during the first 2-3 years upto a size of 8-9 cm of base diameter and then it slows down. It may take about 10 years for the snail to attain a maximum shell

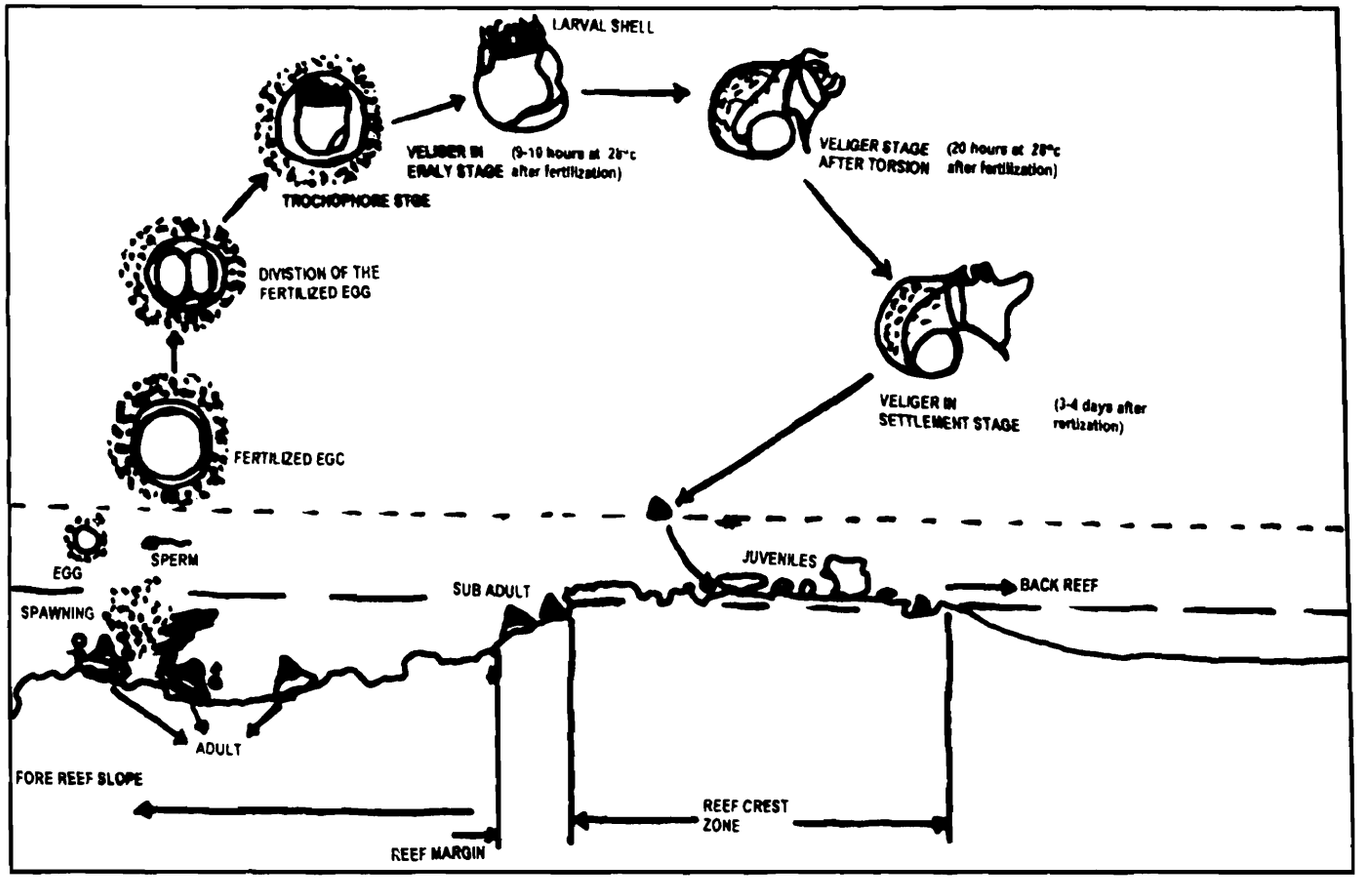


Fig. 2. Life Cycle of *Trochus niloticus*

diameter of 12 cm. The age of *Trochus* in the Andamans is shown to exceed ten years, and the incidence of morality due to disease or old age is indicated to be low. *T. niloticus* feeds fresh algae: *Caulerpa sertularoides* (Vahl) C. Agardh, *Ulva reticulata* Forsskal, *Padina australis* Hauck, and *Gracilaria salicornia* (C. Agardh) Dawson. Experimental studies conducted in Pacfic countries revealed that green macroalgae resulted in the best growth of *Trochus*. Brown macroalgae also contributed to an increase of shell size, but were inferior to green macroalgae. Studies on the growth rate of *Trochus* at different cultured densities in cages showed that the appropriate rearing density was 100 individuals/m^2 for animals 10-22 mm of shell diameter; Trochus size from 25-40 mm should be cultured at density less than 50 individuals/m^2; and *Trochus* size 40-50 mm should be cultured at density less than 20 individuals/m^2. *Trochus* larger than 50 mm shell diameter, should be reared at only 4-7 individuals/m^2. The growth however, is variable and depends on the availability of food and maintenance of optimum conditions in snail's habitat (Subba Rao, 2003).

Food and Feeding

Trochus is herbivore with a selective deposit feeding. It feeds, mainly by scraping brown and green algae growing on rocks and coral masses. In Andaman and Nicobar Islands its commonest food is *Hypnea* sp. Soekendarsi *et al.* (1998) reported that, food items found in the stomach of *Trochus* include 42 taxa belonging to Chrysophyta, Chlorophyta, Rhodophyta, Cyanophyta, Foraminifera and suspended materials mixed with sand and

detritus. Under laboratory conditions *Trochus* fed *Isochrysis galbana* grew faster than did three other groups fed *Tetraselmis* sp., *Chaetoceros gracilis* and *Nannochloropsis* sp. (Latama, 1999). In the experiments by Soekendarsi *et al.* (1999) using individuals between 30 and 39.9mm in size, a diet of *Ulva reticulata* produced the highest recorded growth rate, while groups fed *Caulerpa sertularioides, Ulva reticulata, Padina australis, Gracilaria salicornia* and *Eucheuma denticulatum* exhibited a much lower growth rate. *Trochus* is extremely slow in its movements but covers a large area during its foraging activity in search of shelter. The younger snails are more active than the older ones. In Andaman and Nicobar Islands it occurs in scattered condition in the coral reefs and crevices and undersurfaces of rocks encrusted with brown and green algal growths in the littoral region upto 22m depths. The snails has the capacity to withstand unfavourbale conditions such as non-availability of food and desiccation. There are no natural enemies to *Trochus* and attacks by crabs, fish, molluscs etc. seems to be almost negligible (Subba Rao, 2003). There were no reports of any disease of significance. The mortality was mainly due to senility.

Animal Association

The animals associated with *Trochus* shells in the Andaman and Nicobar Islands have formed the subject of interest. Commercial value of shells is often reduced by certain molluscs and sponges, which either bore into the nacreous layer or create deep impressions in the periostracal and nacreous layers where they attach themselves. Prashad and Rao (1934) have described a new species of *Spiroglyphus* (Family Vermitidae) and two new limpet-like gastropods, *Saptadanta nasika* and *Patella tara*. Monod (1934) gives a full account of *Panaietes camerata* Stebb., a parasitic or commensal copepod almost invariably found in the living state in the buccal cavity or oesophagus of *Trochus niloticus*; and finally, Winckworth (1940) records *Acanthochitona penetrans* found living in the holes made on the shells by species of the bivalve *Lithophaga*. However, in Andaman and Nicobar Islands, Rao (1937) reported the following organisms found associated with *Trochus nilotiucus* and causing damage to the shell.

Boring bivalves : *Lithophaga (Lithophaga) nasuta* (Philippi), *Lithophaga (Lithophaga) lineata* (Quoy and Gaimard), *Parapholas quadrizonata* Spengler and *Rocellaria* sp.

Epifaunal gastropods : *Saptadanta nasika* Prashad and Rao (1934), *Patella (Patelloidea) tara* Prashad and Rao (1934), and *Vermetus (Spiroglyphus) andamanicus* Prashad and Rao (1934).

Sponge : *Cliona* sp.

Distribution

Trochus live chiefly on bottom deposits and fresh algal vegetation. It inhabits the intertidal and shallow subtidal zones. Its preferred habitat is the moderately exposed coral reef shore (Mc Growan, 1956; Gail, 1957; Smith, 1979). It is abundant on open coasts

exposed to rough weather but rare in protected areas. It is more abundant in Nicobar Islands at depths upto 13m and about 0.5 to 1.5 km from the shore. In Great Nicobar it was more abundant on the eastern side of the Galathea Bay. In Andamans large number of these shells is found on the inshore reefs. Shells from Nicobars are more flat based than those from Andamans.

Its natural distribution ranges from the Andaman Islands in the Indian Ocean to the Pacific Islands of Fiji and Wallis, including Palau, Yap, Papua New Guinea, the Solomon Islands, Vanuatu, and New Caledonia, and the north and north-eastern coasts of Australia (Bour, 1990). To the east, implanted populations of the Northern Mariana, Guam, Yap, Chuuk, Marshall and Phoenix Islands originated in Palau; the Society Islands population was implanted from Vanuatu and New Caledonia, whereas the Cook Islands population came from Fiji Islands (Fig. 3).

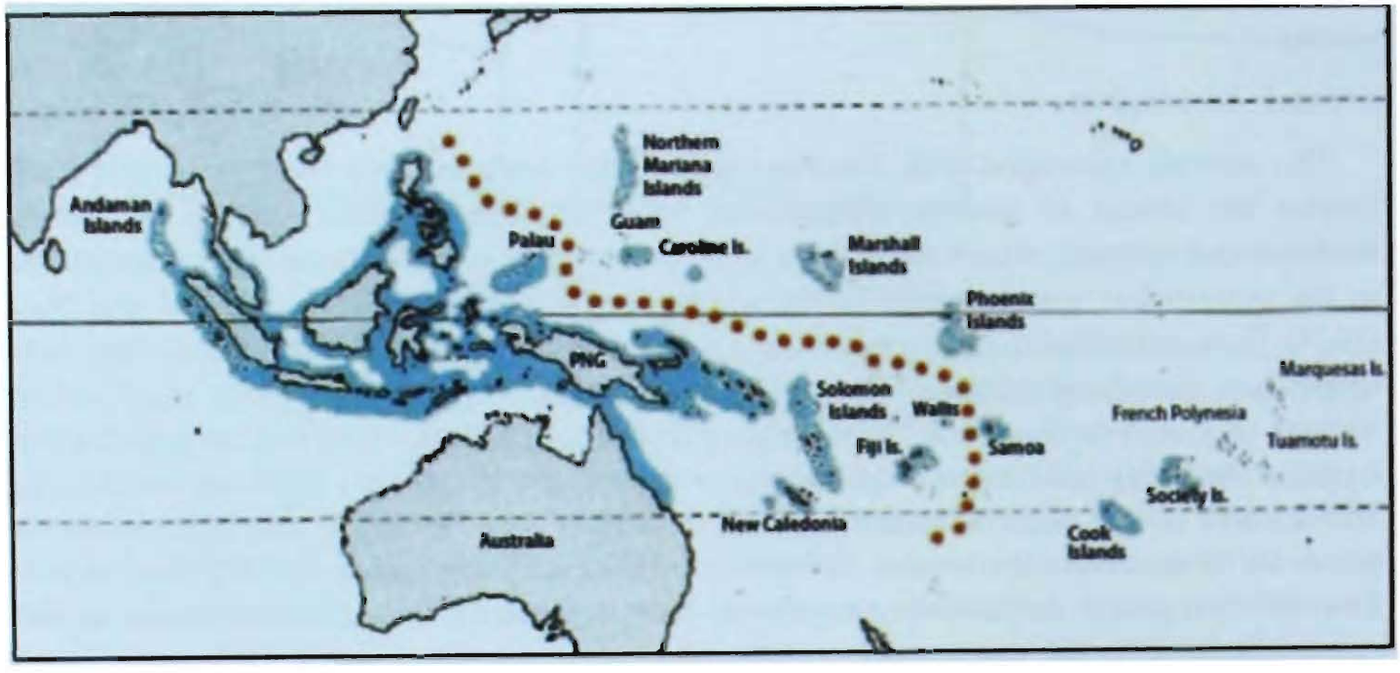


Fig. 3. Distribution of *Trochus niloticus* (Natural stocks occurs west of the dotted line and to the east implanted populations) – (*Source* : Lemouellic and Chauvet, 2008).

Legislation on *Trochus niloticus*

The Top shell, *Trochus niloticus* and Turbo shell, *Turbo marmoratus* are most important molluscs to artisanal fishers in the tropical and subtropical waters of the eastern Indian and western Pacific Oceans. Both species are collected in the Andaman for export (Silas *et al.*, 1985). These shells were collected and exported for button making and other mainly decorative uses, providing an important source of income for rural and outer island dwellers in the region. In recent years, the market value of Top and Turbo shells has increased markedly. As a result, the level of exploitation has also increased in many countries. There are fears in some locations that present levels of harvesting will not be sustainable and that

serious resource depletion will occur if management regimes are not developed and instituted.

India is also one among the country felt the serious of the resource depletion of these commercially important species due to over exploitation in Andaman and Nicobar Islands in the 1920s when the Japanese were given licenses to collect (Rao, 1937). In 1976, about 400 tons of *Trochus* and 105 tons of green snail, *Turbo* were landed in the Andaman (Appukuttan, 1977 & 1979). Nayar and Appukuttan (1983) calculated the annual production as 400-500 tons of *Trochus* and 100-150 tons of *Turbo.* Because of the increasing value and demand for this animals, over exploitation of *Trochus* and *Turbo* species from many of the islands around mainland and Andaman and Nicobar Islands is very much evident. Due to indiscriminate fishing of shells of all sizes by both the licensed and unlicensed fishermen, the present day, the *Trochus* beds of the Andaman waters are getting rapidly depleted. In consequence upon the depletion of population, the Government of India, Ministry of Environment and Forests vide notification dated 5th December 2001 brought these species under Schedule IV of the Wildlife (Protection) Act, 1972. Little Nicobar, Katchal and Kamorta Islands and their adjoining waters up to 500 m from shore could be declared reserves for *Trochus* and *Turbo*; leasing out operations for commercial exploitation should be terminated in these areas.

REVIEW OF LITERATURE

The *Trochus niloticus* and *Turbo marmoratus* are generally distributed throughout the Indo-Pacific region in the western Indian Ocean (Seychelles, Chagos, Andaman and Nicobar Islands), throughout South-east Asia (Malaysia, Indonesia, Thailand and the Philippines) to the South Pacific, as far east as Fiji. Both the species are considered to be one of the most valuable marine species present in Andaman and Nicobar Islands. The species have been commercially exploited for over a decade and a regular *Trochus* fishery was established in the Andaman in October 1929. In the initial season, the fishery yielded not less than 500 tons of shells within the first three months, but the yield, however began to steadily decline and although the period of fishing has since then been doubled the almost reached the low figure of 40 tonnes in one fishing season. It should be pointed out that the foregoing advice has been based on a limited amount of field work. In order to improve, refine, and generally monitor the effectiveness of this management strategy, it essential to continue their research/field work for the stock assessment. Based on information from the proposed survey it will be possible to reassess stock abundance estimates and thus amend the total allowable catch (TAC) quota for future harvests.

International Status

Although *Trochus niloticus* and *Turbo marmoratus* have been harvested since time immemorial for subsistence reasons (Hedley, 1917 and Yamaguchi, 1988), it is only since early this century that this tropical marine snails have been harvested commercially (Hedley, 917; McGowan, 1956; Bour *et al.*, 1982). These species found in the tropical and

subtropical waters of the eastern Indian and western Pacific Oceans. Its natural distribution extends from Sri Lanka in the west (Rao, 1936) to Wallis Island in the east (Gillett, 1986a). The northern limit of its range is the Ryukyu islands of southern Japan (Hedley, 1917), while its most southerly extent is New Caledonia (Bour *et al.*, 1982) and the Swain Reefs complex at the southern end of the Great Barrier Reef (GBR), Australia (Moorhouse, 1933). *T. niloticus* and *Turbo marmoratus* are generally inhabits the windward margin of coral reefs, although on some reefs it may also be found on the leeward side (McGowan, 1958; Nash, 1981; Heslinga *et al.*, 1984; Smith, 1987 and Yamaguchi, 1997). They lives in the intertidal and shallow subtidal zones, and feeds on the fine epilithic algal turf which grows on bare coral or coralline algal surfaces in this part of the reef (Moorhouse, 1932; Rao, 1937; Asano, 1944; McGowan, 1958). *Trochus* are generally found in depths less than about 7 m on the GBR (Nash, 1985), although they have been reported to depths of about 13 m (Rao, 1937), 19 m (Gail, 1958) and 24 m (McGowan, 1956). Asano (1963) reported that *Trochus* live at different depths on the different islands of Micronesia, and down to 8 fathoms (ca. 15 m) at Chuuk. Maximum depth at which *T. niloticus* has been reported is 14 fathoms (approximately 25 m) (Asano, 1963). The majority of the paper is concerned with *Turbo marmoratus*, the largest species of the family, which grows to more than 20 cm in shell diameter and 2.0 kg in weight. It is herbivorous and its nacreous shell is highly prized for inlay material of lacquer-ware, furniture and jewellery. It has been commercially exploited throughout its Indo-Pacific range for at least a century (Yamaguchi, 1997).

When the commercial fishing commenced, it became apparent that shell stocks are prone to overfishing (Rao, 1937; Gail, 1958; McGowan, 1956; 1958; 1959; Heslinga, 1981; Nash, 1985). This susceptibility to overfishing may be attributed to the act that these snails occupies a well-defined habitat (the intertidal and shallow subtidal zones on the seaward margin of coral reefs) and, despite their often cryptic behavior and inconspicuous alga-covered shells, are easily targeted by experienced fishermen. The Food and Agriculture Organization of the United Nations (FAO) cites the total world production in 1985 at 500 tonnes [based on Australian and Malaysian figures only]. This increased to 800 tonnes in 1986 and 1,000 tonnes in 1987 and 1988 (FAO, 1990). Rapid declines in abundance shortly after commencement of commercial fisheries suggest that *Trochus* and *Turbo* are highly susceptible to overfishing (Heslinga *et al.*, 1984; Nash, 1993 and Castell, 1997).

Reproduction and spawning behaviour has been described by Nash (1985), occurs throughout the year at low latitudes (Rao, 1937; McGowan, 1958; Heslinga and Hillmann, 1981; Nash, 1985) but only during the summer months at the southern limit of its range (Bour, 1989). Smith (1987) found *Trochus* size segregation by reef zone, with larger *Trochus* being found at deeper depths. Heslinga *et al.* (1984) found an inverse relationship of decreasing *Trochus* density with increasing depth. All three of these factors would tend to restrict both recreational and commercial harvesting to shallower areas.

National Status

In India, *Trochus niloticus* is the only species drawn the considerable attention of early Indian scientists. Studies pertaining to the distribution abundance ecology of topshell *T.*

niloticus were considerably available in early 19th century. A consolidated report on the shell-fisheries in the Andaman and Nicobar Islands during the years, 1930-1935 by the Zoological Survey of India enables to assess the value of the fishery research work. First and foremost attention was paid by Amirthalingam (1932a, b, and c) on taxonomy, ecology and biology of the species *T. niloticus* Linn. in the Andaman waters. Rao (1937) studied the reproductive biology and spawning period of *T. niloticus*. Rao and Raja (1936) found no seasonal differences in growth rate of *T. niloticus* in the Andaman Islands. Rao (1937) reported fragments of *T. niloticus* shell among the gut contents of "sharks, rays and gymnodontid fishes" There are a number of invertebrate animals, however, which damage the shell by boring into the nacre. These include vermetid gastropods (Prashad and Rao, 1933), limpets (Prashad and Rao, 1934), boring sponges (Rao, 1937) and boring bivalves (*Lithophaga* spp.) (Rao,1937). Shortly after commercial fishing commenced, it became apparent that *Trochus* stocks are prone to overfishing (Rao, 1937). In many regions reefs have been overfished and stocks are depleted. In the Indian Ocean, green snail is harvested in the Andaman and Nicobar Islands where 105 tonnes were harvested in 1976 (Appukuttan, 1977 & 1979). In the 1940s it was fished commercially in the Seychelles and Chagos Archipelago, fetching up to £ 400/ton of *Trochus niloticus*. Unsuccessful attempts were made to cultivate *Trochus* in the Andaman in the 1920s (Rao, 1937). *Turbo marmoratus,* the green snail collected in Andaman and Nicobar Islands (Appukuttan, 1977 and 1979); also found in Lakshadweep, however the status of these populations is unknown.

Studies on Key Areas

The Andaman and Nicobar Islands, especially, North Reef Island, Ritchie's Archipelago, Little Andaman, Kamorta Island, Katchal, Little Nicobar and Great Nicobar are consider to be the resource of *Trochus niloticus* and *Turbo marmoratus*. Studies on distribution and abundance of these species not get any attention from the scientific community in the recent past decades. Some of these islands were Little Nicobars, Katchal, Kamorta Islands and surrounding waters up to 500 m from shore declared reserves for *Trochus* and *Turbo*.

OBJECTIVES OF THE STUDY

Rationale

The Directorate of Industries, Andaman and Nicobar Administration, Port Blair has approached the Zoological Survey of India, Port Blair on dated 20th April 2009 to undertake a detailed survey on the potential availability of *Trochus niloticus* and *Turbo marmoratus* in Andaman and Nicobar Islands in order to assess the present status of these organisms. Besides, the present study was also initiated by the Deputy Inspector General (WL), Government of India, Ministry of Environment and Forests vide letter No.1-11/2009WL dated 23rd March 2009 with a request to the Director, Zoological Survey of India, Ministry of Environment and Forests, to undertake the status survey on *Trochus niloticus* in Andaman and Nicobar Islands, in response to the request received from the Andaman and Nicobar Islands Sea Shell Artisans Welfare Association for the relaxation of ban on *Trochus*

niloticus. Accordingly the Director, ZSI, requested its Regional Centre at Port Blair by vide letter F. No.232-1(2)/2006/Tech/4299 dated 30th March 2009 to carry out the status survey and hence the present study.

Period of study

The present status survey on *Trochus niloticus* was carried out during August 2009 to March 2010.

AIM

The commercial exploitation of marine invertebrates including *Trochus niloticus* increased attention during past decades and progress has been made in the knowledge of stock dynamics and fisheries management. Although, marine invertebrates yield lower landing in quantity in comparison with fin-fishes, their economic value compensate for this difference by accounting importance of the molluscs, they are a vital component in the food chain at various trophic levels and play an important role through grazing, predation and structure and function of marine communities.

The prime objectives of the study is as follows :

1. To assess and quantify the distribution, abundance of *Trochus niloticus* and *Turbo marmoratus* resources in selected places of Andaman and Nicobar islands.
2. To monitor the status of the *Trochus niloticus* and *Turbo marmoratus* beds
3. To assess the physicochemical features of ambient environment.
4. To investigate the status of key biological parameters such as phytoplankton and zooplankton productivities.

STUDY AREA

The Andaman and Nicobar Islands are situated in the Bay of Bengal within 6^0 and 14^0N latitude, 92^0 and 94^0 E longitudes. They are also called the Bay Islands. There are 572 islands in the Andaman and Nicobar archipelago with a total land area of 8293 sq km. 38 of these islands are populated. The Andaman and Nicobar are separated by the Ten Degree Channel, which is about 90 miles (150 km) wide and 400 fathoms deep. The Andaman group consists of more than 324 islands with an area of 1953 sq km and Nicobar group comprises 24 islands with the land mass of 1841 sq km. The Andaman and Nicobar islands have a continental shelf of 35,000 sq km with an EEZ of 8149 of sq km, includes the ecologically enriched faunal and floral diversities. The entire coastline of these islands is wavy with many long, narrow creeks, lagoons and bays supporting sandy, rocky, muddy beaches and mangroves. There are 106 protected areas in these islands, 96 designated as wildlife sanctuaries, 9 national parks and one biosphere reserve. There are about 6540 species of fauna, 2500 species of flora reported from these islands. About 4% of marine species are endemic.

Andaman and Nicobar Islands with one fourth of the total coastline of India and about 80 percent of the total Exclusive Economic Zone (EEZ) has significant potential in fisheries. However, this potential is yet to be tapped. The substantial loss to the fishery sector amounting to about 2331.92 corers caused by the high intensity earth quake of December 26, 2004 followed by a powerful tsunami has further affected fisheries in Andaman and Nicobar Islands. The present level of marine fish production in Andaman and Nicobar Islands is 30,000 tonnes which is about 12 percent of the estimated potential. Most of the produce is consumed locally. The exports are insignificant and have declined between 1996 and 2000. Marine fish production in Andaman and Nicobar Islands is faced with a complete lack of strategy to promote this activity.

The molluscs *Trochus niloticus* and *Turbo marmoratus* were important export value commodity from early 19th century in Andaman. Wild populations of *T. niloticus* occur between longitudes 90° W (Andaman Islands, India) and 180° W, and latitudes 20° N and 25° S. Both the species inhabits the intertidal and shallow subtidal zones. However, despite its relative scarcity, compared to many other South Pacific marine resources, increasing demand for pearl shell, and the relative value of green snail compared with other pearl shell species for inlay work, has resulted in premium prices being paid for green snail. As a result, it has made significant contributions to the total value of exports of marine products from Andaman and Nicobar islands. With a rapid increase in the value led an increase in fishing pressure on stocks of shells has resulted. In many areas, this has probably led to a substantial reduction in shells populations throughout its distribution.

Status survey on the gastropod *Trochus niloticus* was conducted at 79 stations covering entire Andaman and Nicobar archipelago (Fig. 4, Table 1, Plates 4-9).

Table 1. Area surveyed for *Trochus niloticus* in Andaman & Nicobar Islands

Sl. No.	Area surveyed	GPS Coordinates	Date of Survey
SOUTH ANDAMAN			
1.	Off Burmanella	Lat. 11° 33. 468'N, Long. 92° 43.873'E	July 8, 2009
2.	Off Rangachang	Lat. 11° 34. 350'N, Long. 92° 44.133'E	July 9, 2009
3.	Chidyatapu	Lat. 11° 29. 460'N, Long. 92° 42.530'E	July 10, 2009
4.	Pongibalu	Lat. 11° 31. 030'N, Long 92° 39.159'E	August 17, 2009
Rutland Island			
5.	Chain Nalah	Lat. 12° 08. 522'N, Long. 93° 06.551'E	July 24, 2009
6.	Padauk Dikri	Lat. 12° 29. 288'N, Long. 92° 40.141'E	July 24, 2009
7.	Surumai Dikri	Lat. 11° 25. 504'N, Long. 92° 40.301'E	July 26, 2009
8.	Komeo	Lat. 11° 24. 314'N, Long. 92° 39.780'E	January 9, 2010
9.	Mitta Nalah	Lat. 11° 28. 541'N, Long. 92° 40.371'E	October 2, 2009
10.	Arom Point	Lat. 11° 30. 541'N, Long. 92° 38.769'E	October 11, 2009

Sl. No.	Area surveyed	GPS Coordinates	Date of Survey
11.	Aam Dera	Lat. 11° 24. 664'N, Long. 92° 37.456'E	January 10, 2010
12.	North Wandoor	Lat. 11° 37. 270'N, Long. 92° 37.035'E	
13.	Grub Island	Lat. 11° 35. 391'N, Long. 92° 35.637'E	January 12, 2010
14.	Jolly Buoy Island	Lat. 11° 30. 251'N, Long. 92° 32.591'E	March 12, 2010
15.	Tarmugli Island	Lat. 11° 33. 261'N, Long. 92° 36.809'E	December 16, 2009
16.	North Bay	Lat. 11° 42. 068'N, Long. 92° 45.116'E	February 4, 2010
17.	Off Collinpur	Lat. 11° 41. 598'N, Long. 92° 37.035'E	June 4, 2009
18.	Off Kurmadera	Lat. 11° 39. 933'N, Long. 92° 35.903'E	June 5, 2009
Ritchie's Archipelago			
19.	Havelock Island	Lat. 12° 00. 005'N, Long. 92° 56.808'E	October 10, 2009 & March 20, 2010
20.	Inglis Island	Lat. 12° 08. 639'N, Long. 93° 06.786'E	October 19, 2009 & March 21, 2010
21.	Henry Lawrence Island	Lat. 12° 05. 000'N, Long. 93° 06.312'E	October 20, 2009
22.	John Lawrence Island	Lat. 12° 04. 075'N, Long. 93° 00.398'E	November 21, 2009
23.	Outram Island	Lat. 12° 00. 574'N, Long. 92° 56.808'E	October 17, 2009
24.	Peel Island	Lat. 12° 03. 315'N, Long. 92° 59.929'E	October 21, 2010
25.	Wall & Nicolson Island		
26.	South Button Island	Lat. 12° 13. 467'N, Long. 92° 01.334'E	March 10, 2010
27.	North Button Island	Lat. 12° 18. 974'N, Long. 92° 03.826'E	March 11, 2010
28.	Middle Button Island	Lat. 12° 16. 473'N, Long. 93° 01.334'E	March 12. 2010
29.	Wilson Island	Lat. 12° 13. 061'N, Long. 93° 15.207'E	October 19, 2009
Neill Island			
30.	Lakshmanpur	Lat. 11° 50. 826'N, Long. 93° 00.554'E	January 21, 2010
31.	Hawrah Bridge	Lat. 11° 49. 727'N, Long. 93° 00.818'E	January 21, 2010
32.	Middle Point	Lat. 11° 50. 857'N, Long. 93° 00.554'E	January 22, 2010
33.	Ramangar	Lat. 11° 48. 400'N, Long. 93° 01.440'E	January 23, 2010
34.	Sunset point	Lat. 11° 51. 941'N, Long. 93° 00.667'E	January 23, 2010
35.	Little Neil Island	Lat. 11° 47. 063'N, Long. 93° 04.616'E	January 24, 2010
36.	Pearl Park Beach	Lat. 11° 50. 766'N, Long. 93° 00.795'E	January 24, 2010
Little Andaman Island			
37.	Butler Bay	Lat. 10° 40. 232'N, Long. 92° 56.808'E	October 10, 2009

Sl. No.	Area surveyed	GPS Coordinates	Date of Survey
38.	Kala Pathar	Lat. 10° 39. 558'N, Long. 92° 34.109'E	October 10, 2009
39.	Haminder Bay	Lat. 10° 32. 975'N, Long. 92° 32.651'E	October 11, 2009
40.	Off Ramkrishnapur	Lat. 10° 42. 630'N, Long. 92° 33.066'E	October 12, 2009
41.	Sister Island	Lat. 10° 55. 830'N, Long. 92° 07.023'E	October 13, 2009
42.	Hut Bay	Lat. 10° 35. 419'N, Long. 92° 33.066'E	October 11, 2009
43.	Dugong Creek	Lat. 10° 48. 385'N, Long. 92° 64.000'E	October 13, 2009
44.	Off Light House	Lat. 10° 30. 734'N, Long. 92° 30.264'E	October 14, 2009
MIDDLE ANDAMAN			
45.	North Reef Island	Lat. 12° 56. 084'N, Long. 92° 57.345'E	December 19, 2009
46.	Interview Island	Lat. 12° 59. 125'N, Long. 92° 42.981'E	December 20, 2009
47.	Mayabunder		December 27, 2009
48.	Avis Island	Lat. 12° 56. 210'N, Long. 92° 33.066'E	December 28, 2009
49.	Sound Island	Lat. 12° 56. 084'N, Long. 92° 57.345'E	December 29, 2009
50.	Rail Island	Lat. 12° 56. 860'N, Long. 92° 54.620'E	December 30, 2009
51.	Karlo Island	Lat. 12° 56. 084'N, Long. 92° 53.378'E	December 26, 2009
52.	Karmatang	Lat. 12° 51. 322'N, Long. 92° 56.050'E	December 27, 2009
NORTH ANDAMAN			
53.	Ross Island	Lat. 13° 18. 167'N, Long. 93° 04.261'E	August 18, 2009
54.	Smith Island	Lat. 13° 18. 406'N, Long. 93° 04.207'E	August 19, 2009
55.	Ariel Bay	Lat. 13° 16. 093'N, Long. 93° 02.433'E	August 20, 2009
56.	Lamia Bay	Lat. 02° 24. 879'N, Long. 97° 05.516'E	August 21, 2009
NICOBAR ISLANDS			
Car Nicobar Island			
57.	Malacca	Lat. 09° 10. 490'N, Long. 92° 49.714'E	November 15, 2009
58.	Kakaana	Lat. 09° 07. 750'N, Long. 92° 48.678'E	November 16, 2009
59.	Tamoloo	Lat. 09° 11. 350'N, Long. 92° 49.498'E	November 17, 2009
60.	Kimos	Lat. 09° 07. 587'N, Long. 92° 46.316'E	November 18, 2009
61.	Perka	Lat. 09° 11. 203'N, Long. 92° 49.877'E	November 19, 2009
62.	Lapati	Lat. 09° 13. 978'N, Long. 92° 48.002'E	November 20, 2009
Nancowry Islands			
63.	Kamorta Island Bada Enaka	Lat. 12° 51. 322'N, Long. 92° 56.050'E	February 23, 2010

Sl. No.	Area surveyed	GPS Coordinates	Date of Survey
64.	Champin Island	Lat. 08° 01. 670'N, Long. 93° 33.123'E	February 24, 2010
65.	Trinket Island	Lat. 08° 02. 806'N, Long. 93° 34.556'E	February 25, 2010
66.	Kamorta Island – Kardip	Lat. 08° 02. 151'N, Long. 93° 33.182'E	February 26, 2010
67.	Kamorta Island – Kakkana	Lat. 08° 07. 170'N, Long. 93° 31.606'E	February 28, 2010
68.	Munak Island	Lat. 07° 59. 813'N, Long. 93° 30.534'E	March 1, 2010
69.	Katchal Island	Lat. 07° 58.952'N, Long. 93°24.351'E	August 2, 2009
70.	Teressa Island	Lat. 08° 13.686'N, Long. 93°10.913'E	August 5, 2009
71.	Kundol Island	Lat. 07° 10. 023'N, Long. 93° 42.949'E	August 9, 2009
Great Nicobar Island			
72.	Campbell Bay	Lat. 06° 59. 749'N, Long. 93° 56.718'E	February 24, 2010
73.	Off Laxman Beach	Lat. 07° 01. 482'N, Long. 92° 37.456'E	February 25, 2010
74.	Off Gandhi Nagar	Lat. 06° 50. 496'N, Long. 93° 53.680'E	February 21, 2010
75.	Johinder Nagar	Lat. 06° 57. 226'N, Long. 93° 55.495'E	February 22, 2010
76.	Singam Basti	Lat. 06° 58. 307'N, Long. 93° 55.748'E	February 20, 2010
77.	Navy Dera	Lat. 07° 07. 571'N, Long. 93° 53.133'E	February 19, 2010
78.	Indira Point	Lat. 06° 45. 428'N, Long. 93° 49.541'E	February 27, 2010
79.	Kopen Heat	Lat. 06° 50. 923'N, Long. 93° 47.983'E	February 26, 2010

MATERIAL AND METHODS

Physico-chemical Parameters

The surface seawater samples were collected from all the stations of study for the estimation of following parameters.

Temperature : Surface seawater temperature was measured using standard mercury thermometer.

Salinity : The seawater salinity data was collected at all the places of study by using hand held Refractometer, Model ERMA, Japan

pH : The seawater pH was measured soon after collection of water sample using Portable Water Quality Analyser, Model SYSTRONICS Water Analyser 371

Transparency : The transparency of seawater column was measured by using Secchi disc from surface of sea to assess the depth of light penetration

Turbidity : The seawater turbidity was measured by Turbidity Meter Model EUTECH Instruments ECTN100IR, Singapore.

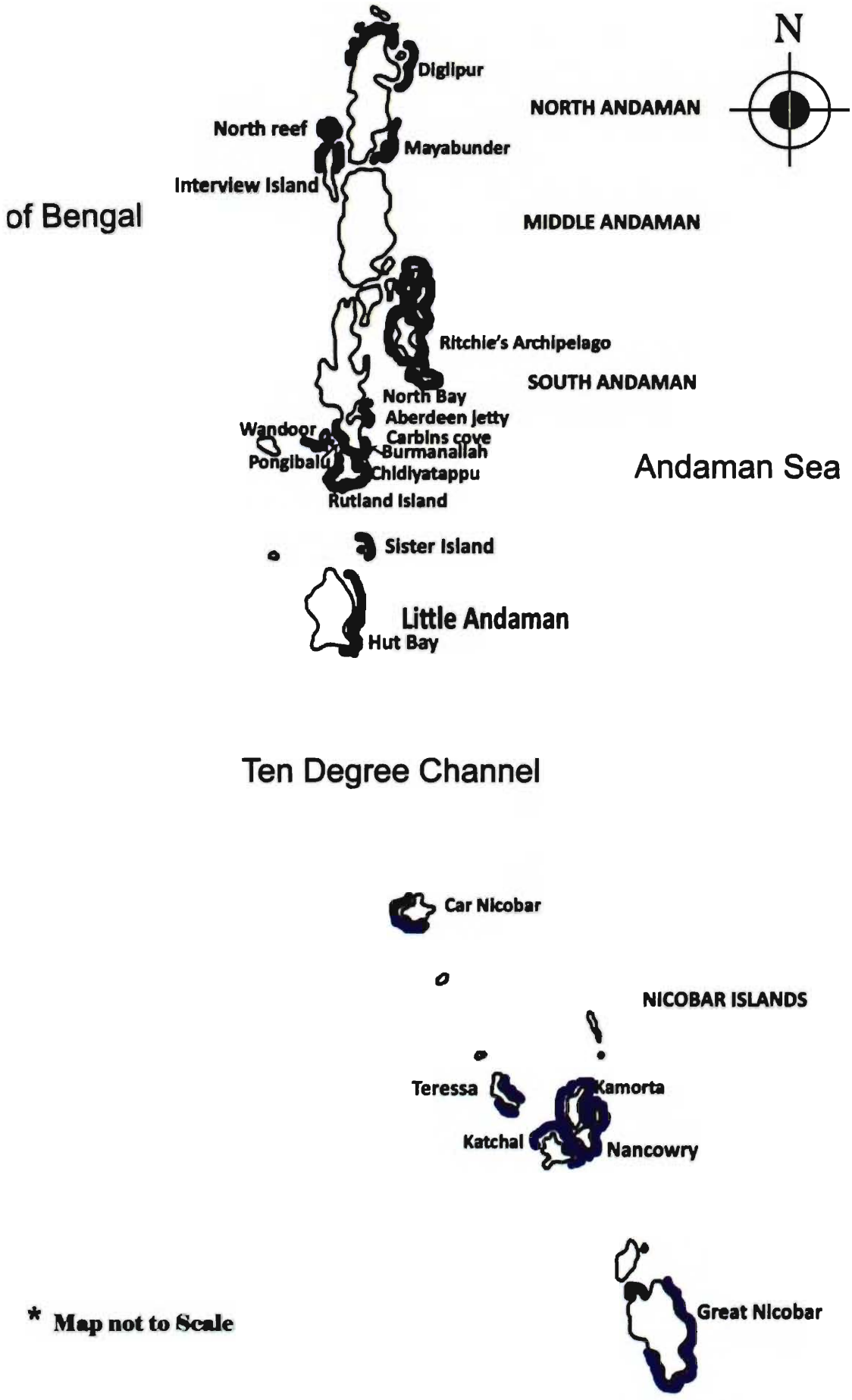


Fig. 4. Map showing the area surveyed for *Trochus niloticus*

Coordinates : The data on the coordinates of the survey area were collected by using Global Positioning System, Model GARMIN 12 Channel GPS.

Biological Parameters

Phytoplankton : Phytoplankton samples were collected from the surface seawater at all the stations. Fifty litres of seawater samples were concentrated to 250 ml by filtering through 20 μ mesh sized plankton net. The concentrated samples were immediately preserved by adding 5 ml of 40% formalin and 2 ml of Lugol's iodine. In the laboratory the samples were concentrated in to the volume of 25 ml and preserved in 4% formalin prepared in seawater. These samples were subjected to qualitative and quantitative evaluation of phytoplankton. For the quantitative estimation a Sedgewick Rafter Counting Cell was used. Phytoplankton samples were identified upto species level under binocular microscope following standard monographs (Husted, 1930; Pergallo, 1965).

Zooplankton : Zooplankton samples were collected by surface haul using Heron-Tranter Plankton net having 0.7 m dia mouth 3 m long with a mesh size of 200 μ for 10 minutes at 2 knot speed. The amount of water passed through was calculated by using flow meter while hauling the net. The collected plankton samples were preserved in 4% formalin. The wet weight of the zooplankton was determined after washing with distilled water thereafter filtering through filter paper. The dry weight was determined by drying the filtered samples in a hot air oven at 70°C till constant weight. The results were calculated as mg/100m^3 of seawater. Zooplankton volume was measured by displacement method. In this method samples were filtered and blotted with filter paper and the mass was transferred to measuring cylinder having known volume of 4% formalin prepared in seawater. The rise in level of seawater in measuring cylinder was recorded. The distance between final and initial reading gives volume of zooplankton. The results were expressed as ml/100m^3 of seawater. The numerical density of zooplankton was calculated by using Sedgewick Rafter Counting Cell. The species were identified upto species level under binocular microscope by referring standard manuals and monographs.

Estimation of *Trochus niloticus* standing stock

The efficiency of surveys for *Trochus* is greatly assisted by the restricted habitat preference of the animals. *Trochus* are almost exclusively found on hard substratum in shallow water that has a high current flow. This type of habitat is dominated by characteristic species of stony corals and crustose coralline algae, which create a complex topography providing both feeding and sheltering areas for the snails.

Reef Walks : Intertidal areas of reef areas have been surveyed by reef walks wherever possible the data were collected quantitatively by employing quadrat (100x100 cm) at every 10m interval perpendicular to shore of the islands.

Subtidal surveys : The undersea survey has been conducted by SCUBA diving to estimate the status and density of *Trochus niloticus* to the maximum depth of 20 m in the selected regions of Andaman and Nicobar Islands where the distribution of these snails frequently reported.

Assessment : The assessment *Trochus* on the subtidal region has been performed by Line Intercept Transect (LIT) method (English *et al.*, 1994) with the help of SCUBA diving and underwater videographic monitoring (Plate 10). The transect area has been standardized depending upon the availability of *Trochus* beds on the reefs. *Trochus* were quantified by employing 100×100 cm quadrant at every 10m interval along the transect line on the reef area. The numerical density and abundance of these gastropods have also been estimated. The data has been calculated for number of *Trochus* recorded per $100m^2$ area.

Species diversity : The species diversity of phytoplankton and zooplankton was calculated according o the Shannon-Weiner formula.

H' = Ó Pi long e Pi

Where Pi = proportion of the *i*th species in the collection and H'= Diversity of a theoretically infinite population.

Personal interaction

Besides field surveys, the personal interaction with fishermen, traders and skin divers were made at all the places of study to gather information about the present status of the availability of *Trochus*. Apart from that discussions were made with the officials of Forests Department and research institutions to update the information about the past and present status on *Trochus* in Andaman and Nicobar waters. And also information pertaining to poaching and illegal fishing of *Trochus* was collected wherever possible, despite the ban on fishing of these gastropods as they included in Schedule-IV category of Wildlife Protection Act (1972) by the Government of India, Ministry of Environment and Forests.

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 the all the places of present study are depicted in Table 2-5. The mean surface sweater temperature ranged from 27.6 to 28.04°C at Nicobar Islands and Little Andaman Island respectively. No much variation in the mean salinity of the seawater was observed among the stations. However it varied from 33.75 ppt at North & Middle Andaman to 34.11 ppt in Ritchie's archipelago. The difference of salinity 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 South and Little Andaman to 7.3 in Ritchie's Archipelago and Middle & North Andaman. The transparency in terms of penetration of light in the seawater column was also measured at both the

places and it ranged from 7.4m in Middle and North Andaman to 8.4 m in Ritchie's Archipelago. 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 found minimum (577.08) at Middle & North Andaman and maximum (679.44) at South Andaman. The intertidal mean exposure during low tide at the surveyed area ranged from 24.60 to 107.5 m at Nicobar Islands and North & Middle Andaman respectively. The lower tidal exposure in intertidal region of Nicobar Islands and higher exposure in North and Middle Andaman is mainly due to the impact of December 2004 earthquake cum tsunami struck in these islands causing the uplift of landmass of North Andaman and submergence of Nicobar Islands by 1m respectively.

Biological parameters

Phytoplankton : Phytoplankton are the primary producers of the marine trophic level and play a vital role while assessing the health of the marine environment. The results of phytoplankton samples collected from surface seawater of all the stations along the study area in Andaman and Nicobar Islands are presented in tables 6-10. A total of 77 species of phytoplankton belonging to 55 genera were recorded from the study area. Among them the maximum of 54 species obtained from Nicobar Islands while the minimum of 45 species recorded from Ritchie's Archipelago. The total mean cell count of phytoplankton was encountered as high, $97.17\times10^{2}L^{-1}$ at Little Andaman and as low $71.30\times10^{2}L^{-1}$ at Ritchie's Archipelago. Although most of the species are distributed throughout the study area, it is fascinating to note that, *Bellerochea malleus, Synedra formosa, Tetraedron trigonum* and *Westella botryoides* found only in South and Little Andaman while *Coelosphaericum kuetzingianum* reported only at Ritchie's archipelago. The low phytoplankton productivity in few stations 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 (2.81) at North & Middle Andaman waters and minima (2.33) at both Ritchie's Archipelago and Nicobar Islands were noticed.

Zooplankton : The zooplanktons are the secondary producers or primary consumers and their productivity is highly responsible for the fishery potential including shell fishes. 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 11-15. Altogether, 96 species of zooplankton belonging to 19 groups were recorded from the study area. However, total number species observed at South and Little Andaman, Ritchie's Archipelago, Middle and North Andaman and Nicobar Islands were 65,

65, 80 and 67 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 (Fig. 5). 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 2223.47 mg/100m^3, 589.74mg/100m^3 and 4.9 ml/100m^3 at Nicobar Islands and maximum of 2975.83 mg/100m^3 fresh weight in Middle & North Andaman, 790.63 mg/100m^3 dry weight and 7.2 ml/100m^3 volume in South Andaman respectively. The numerical density of zooplankton varied from 19195 to 23105 no./100m^3 for Ritchie's Archipelago and Little Andaman respectively. The species diversity of zooplankton was also calculated at all the stations and it showed high index of 2.40 at South Andaman and low of 1.68 at Little Andaman (Fig. 6).

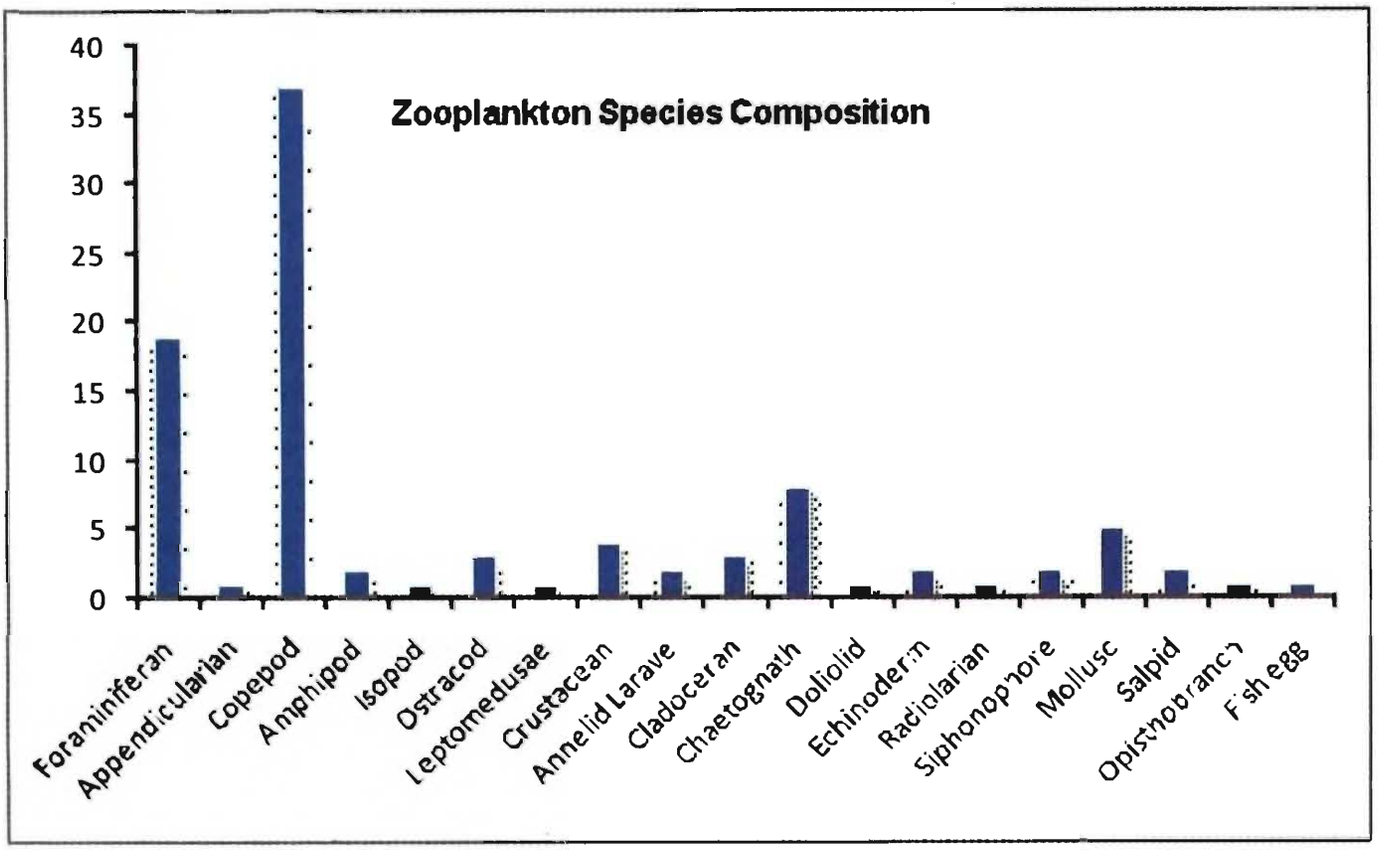


Fig. 5. Species composition of zooplankton under different groups in study area

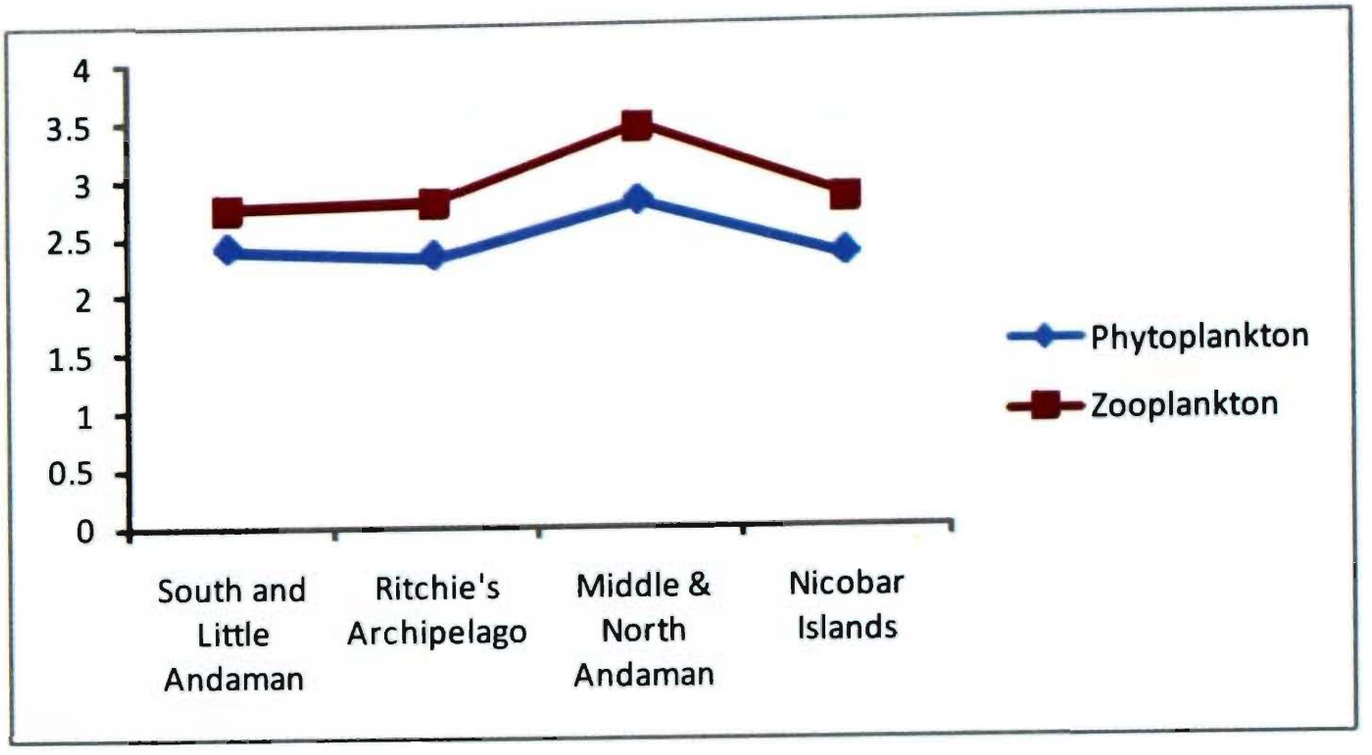


Fig. 6. Species diversity (H') of phyto and zooplankton in study area

The density, biomass and distribution of zooplankton obtained from the present study is significantly correlated with the phytoplankton productivity in quite a number of the stations 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 some stations 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.

Status of *Trochus niloticus*

Extensive undersea and intertidal surveys were conducted in 79 stations covering entire Andaman and Nicobar waters to assess the present status and density of *Trochus niloticus* and *Turbo marmoratus*. Among the area surveyed, 18 stations falls under South Andaman, 8 stations in Little Andaman, 18 stations in Ritchie's Archipelago, 12 stations in Middle and North Andaman and 23 stations in Nicobar Islands. The assessments made from the intertidal area to the maximum subtidal region of 20 m deep with an interval of 5m depth.

The area from the shoreline to the maximum of 3 km inshore regions was surveyed during the study at the places. Although the availability of *Trochus niloticus* was found in all the station of study, not even a single specimen of *Turbo marmoratus* could be observed during the period of investigation.

Density : Results of the survey conducted in intertidal regions i.e. zero meter depth found *Trochus niloticus* in few places at South Andaman (Burmanella, Rangachang Collinpur and Kurmadera), Dugong creek in Little Andaman, 7 places in Ritchie's Archipelago, all the stations of Middle & North Andaman and Campbell Bay, Laxman beach, Indira Point and Kopen heat of Great Nicobar in Nicobar Islands. As far as subtidal region is concerned, these snails were distributed in all the stations of present study upto the range of 20 m deep. The mean numerical density of *Trochus niloticus* varied from 6 shells/100 m^2 in the coastal waters of South Andaman to 15 shells/100 m^2 in Nancowry Islands (Tables 16-19, Fig. 7 & 8, Plates 11 & 12). The density of these species increased from intertidal region to the subtidal region. The high number of animals found in the depth range between 10 and 20 m. All the islands in Nancowry group the density of *Trochus* is high and to the maximum of 20 shells/100 m^2. Apart from that moderately high number of this gastropod was also found in Car Nicobar as well as Great Nicobar in Nicobar group of Islands and in North & Middle Andaman. It is to note that, North & Middle Andaman is the only region where *Trochus* distributed from intertidal region to subtidal region at all depths of study. However, in Middle Button and Wilson Islands of Ritchie's archipelago the distribution of these species found only in 5-15 m depth.

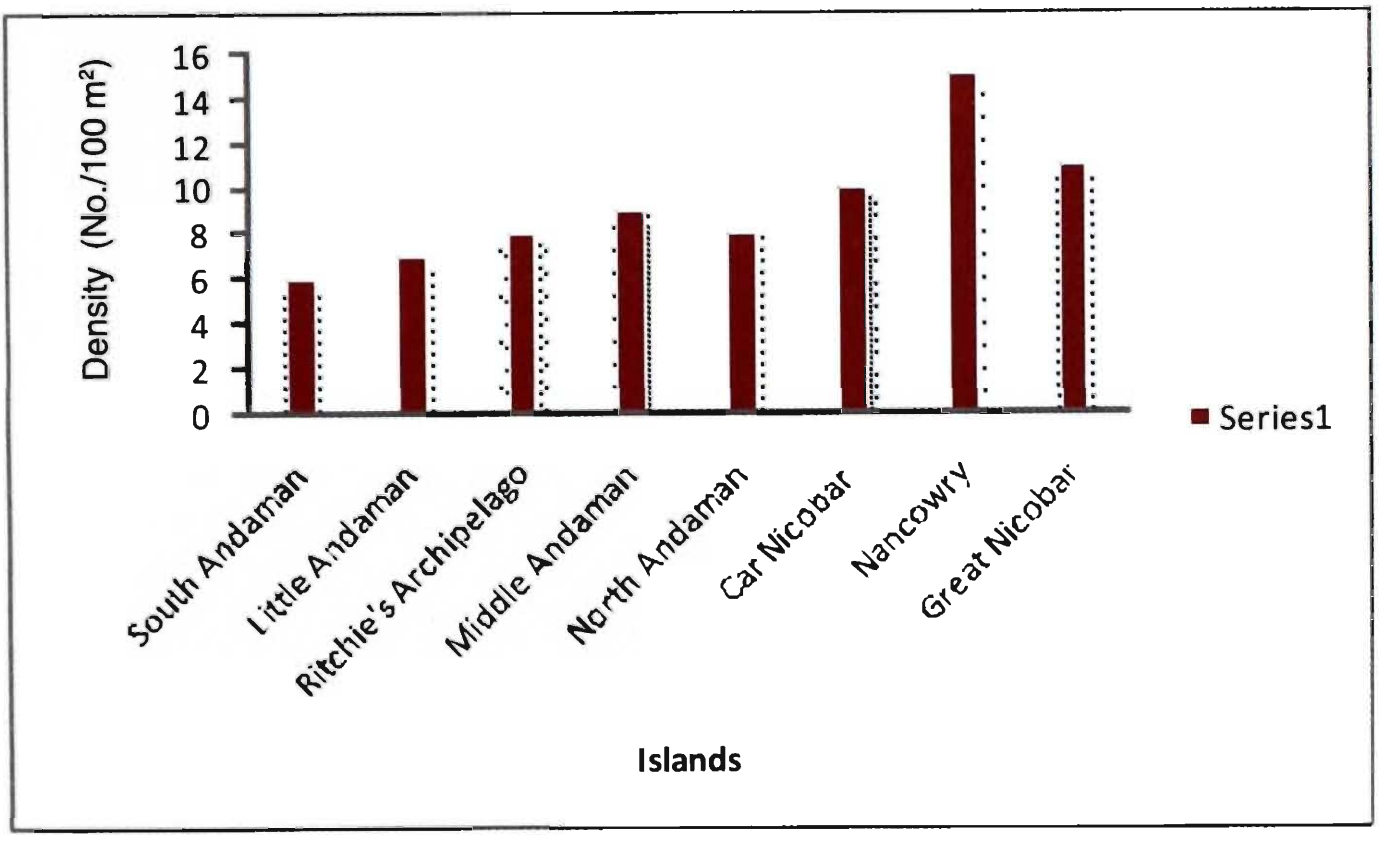


Fig.7. Numerical Density of *Trochus niloticus* in A & N Islands

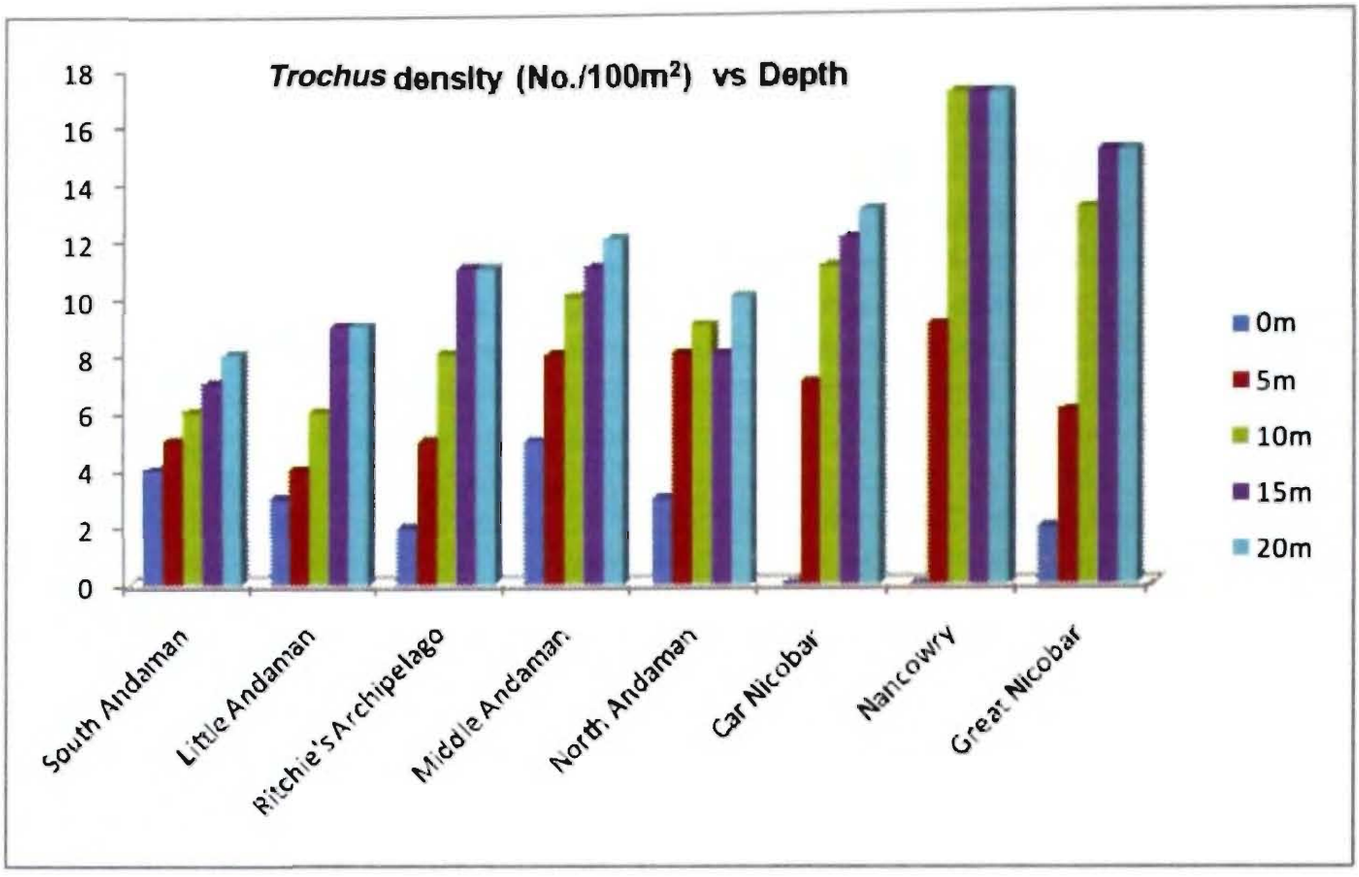


Fig. 8. Numerical Density of *Trochus niloticus* in different depths in A & N Islands

Size **:** In the present study, the basal part of the shell diameter has been measured as the size of the *Trochus niloticus* at all the stations and the mean values are presented in tables 16-19 and figs. 9 & 10. The specimens observed from the intertidal region i.e. zero meter depth are always smaller in size when compared to the subtidal one. The mean size of the specimens at intertidal regions varied from 5.33 to 5.68 cm in the places where it occurred. However, in most of the places, increment in the size of *Trochus* corresponding to greater depths has been observed. Among the study area, the minimum mean size of *Trcohus* i.e. 9.31cm was recorded at North Andaman while maximum mean size (12.73 cm) encountered at Nancowry Islands. Like numerical density, all the islands of Nancowry group shown larger specimen upto the maximum size of 13.62 cm. Besides, *Trochus* reported from Car Nicobar and Great Nicobar Islands and Middle & North Andaman also recorded comparatively quite larger animals than the shells of South Andaman and Ritchie's Archipelago. The mean maximum size of the specimen reported from Nancowry Islands is comparable with the *Trochus* of Japan (13.19 cm), New Caledonia (12.37 cm), Australia (14.71 cm), Vanuatu (14.30 cm) and Wallis (12.81) as reported by Lemouellic and Chauvet (2008)

The epitome of the status survey revealed that the density and size of the *Trochus niloticus* is comparatively higher in the Nicobar group of Islands than Andaman group. Apart from that in Middle and North Andaman were shown moderately high density of animals. The top shell, *Trochus niloticus* has been severely depleted throughout the reefs

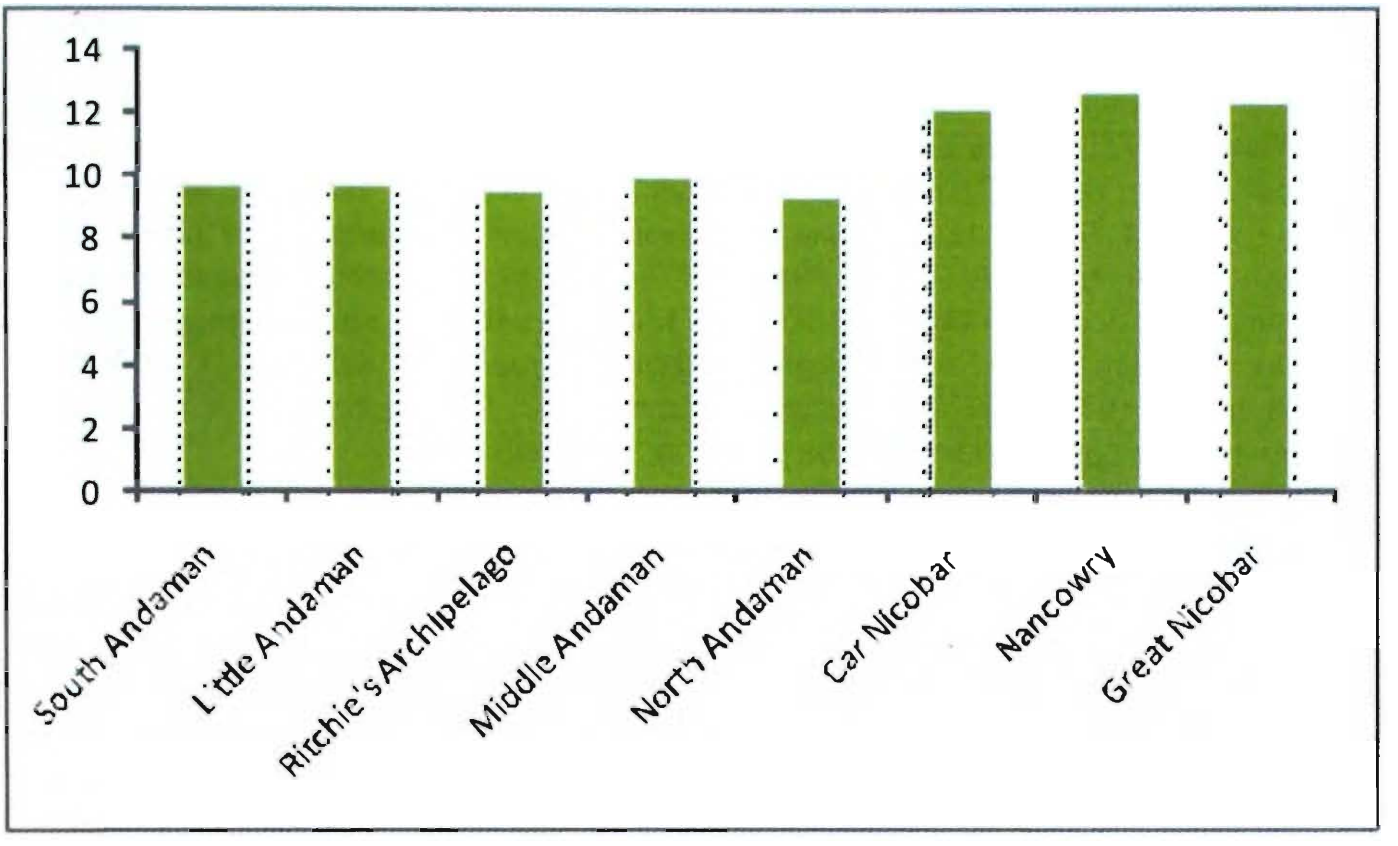


Fig. 9. Mean size of *Trochus niloticus* in A&N Islands

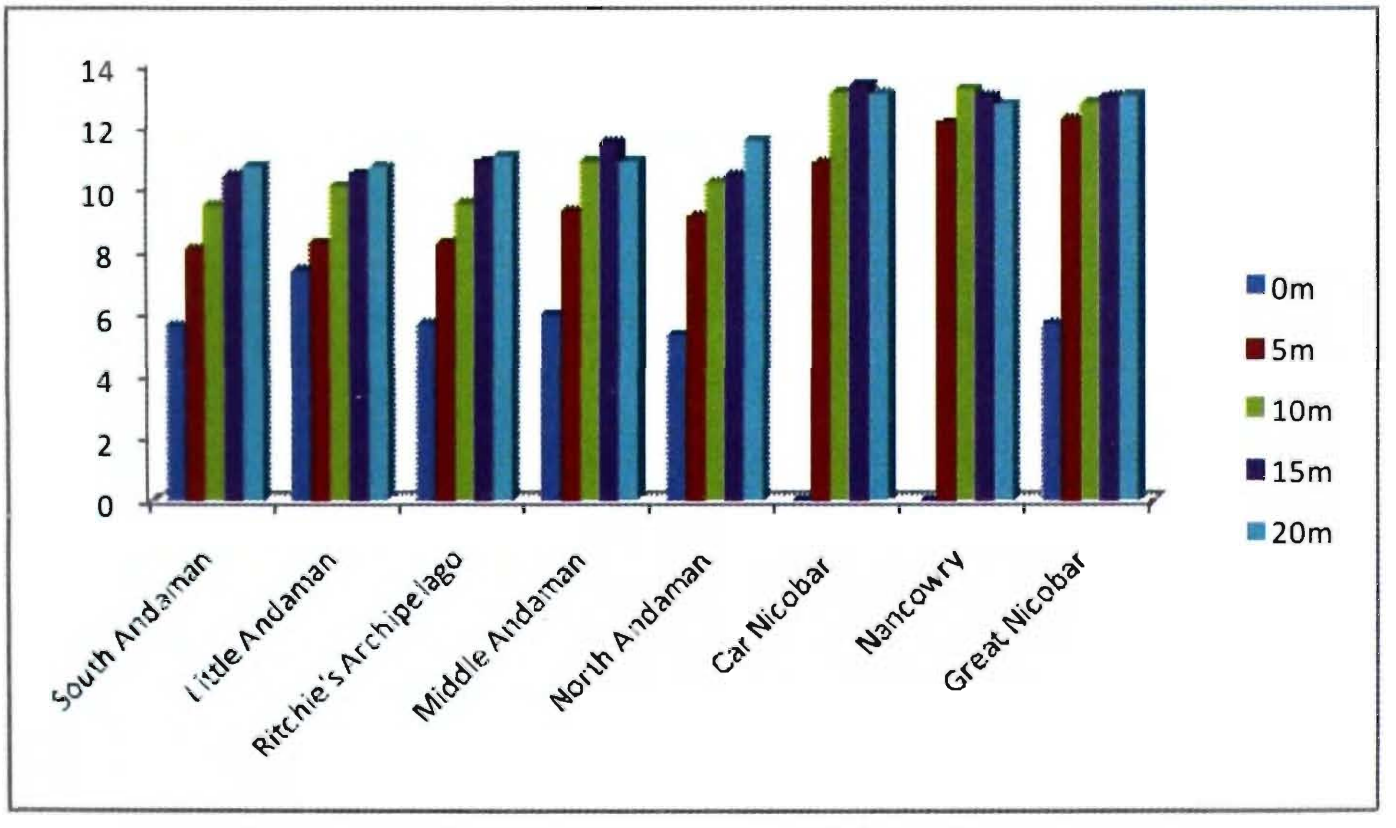


Fig. 10. Size (shell diameter) of *Trochus niloticus* in different depths in A & N Islands

(Skewes *et al.*, 1999). The ease of collecting *Trochus* has made it particularly vulnerable to unsustainable exploitation. Studies on *Trochus* stock densities on the Great Barrier Reef of Australia have found that 500 or more individuals per hectare to be common (Long *et al.*, 1993, Castell, 1997). Smith *et al.* (2000) reported 6.4 individuals of *Trochus* per hectare in Ashmore Reef in the northwest Kimberley coastline of Australia. However, the results on standing stock of *Trochus* in Andaman and Nicobar waters estimated in the present study was quite significant as the natural stock of *Trochus* in these archipelago is marginally higher than their density in Great Barrier Reef. It indicates that the ban on fishing of *Trochus niloticus* in Indian waters and inclusion of these gastropods in Schedule-IV of Wildlife Protection Act (1972) since 2001 made a greater impact for the recovery of their natural population in an optimal size over the period of 10 years.

Habitat : Present survey observed that *Trochus* live in coral reefs especially on dead corals where the growth of fresh algal vegetation is abundant. It is also found in the crevices of reefs and boulders. Their shells are infested by the spat of molluscs, polycheates, sponges as well as algal growth. It inhabits intertidal and shallow subtidal zones moderately exposed coral reef shore. They are abundant on open coasts exposed to rough weather than the protected areas and embayment. The smaller specimens of *Trochus* are extremely cryptic and live inside the crevices of coral reefs.

Table 2. Physico-chemical Parameters in seawater of South and Little Andaman.

Sl. No.	Area	Temp. (°C)	Salinity (PPT)	pH	Trans-parency (m)	Turbidity (NTU)	Intertidal exposure (m)
South Andaman							
1.	Off Burmanella	28.30	33.87	7.4	6.5	750	130
2.	Off Rangachang	28.40	33.52	7.4	5.8	786	150
3.	Chidyatapu	28.00	34.00	7.2	6.0	745	50
4.	Pongibalu	28.00	34.12	7.3	9.7	582	30
Rutland Island							
5.	Chain Nalah	28.00	33.17	7.1	10.0	561	40
6.	Padauk Dikri	27.50	34.18	7.3	10.0	572	35
7.	Surumai Dikri	27.60	34.15	7.3	9.3	582	35
8.	Komeo	27.00	34.57	7.4	9.0	590	30
9.	Mitta Nalah	28.10	32.10	7.2	8.5	627	30
10.	Arom Point	27.10	33.50	7.2	10.7	533	35
11.	Aam Dera	28.50	34.12	7.5	7.5	720	35
12.	North Wandoor	28.50	35.00	7.3	6.0	783	30
13.	Grub Island	27.50	34.21	7.4	8.0	720	20
14.	Jolly Buoy Island	27.40	34.74	7.5	8.0	680	25
15.	Tarmugli Island	27.00	34.20	7.0	7.5	685	25
16.	North Bay	28.00	33.78	7.1	6.2	753	20
17.	Off Collinpur	27.00	32.73	7.2	6.0	780	60
18.	Off Kurmadera	27.00	32.81	7.1	6.0	781	40
	Mean value	**27.72**	**33.89**	**7.2**	**7.82**	**679.44**	**45.55**
Little Andaman Island							
19.	Butler Bay	28.10	33.41	7.0	7.2	625	30
20.	Kala Pathar	28.00	33.84	7.2	7.0	622	35
21.	Haminder Bay	28.20	34.17	7.4	8.1	701	30
22.	Off Ramkrishnapur	28.30	35.18	7.2	7.0	602	25
23.	Sister Island	28.50	33.21	7.3	9.5	530	20
24.	Hut Bay	27.90	33.10	7.0	7.0	740	20
25.	Dugong Creek	27.80	34.00	7.2	8.0	637	25
26.	Off Light House	27.50	34.28	7.5	9.0	570	30
	Mean value	**28.04**	**33.89**	**7.2**	**7.9**	**628.37**	**26.87**

Table 3. Physico-chemical Parameters in seawater of Ritchie's Archipelago.

Sl. No.	Area	Temp. (°C)	Salinity (PPT)	pH	Trans-parency (m)	Turbidity (NTU)	Intertidal exposure (m)
1.	Havelock Island	27.3	32.31	7.2	8.5	602 30	
2.	Inglis Island	28.1	33.52	7.3	8.3	621	32
3.	Henry Lawrence Island	29.2	33.87	7.4	7.5	720	35
4.	John Lawrence Island	28.0	33.27	7.2	7.7	715	30
5.	Outram Island	27.5	33.51	7.4	8.5	720	50
6.	Peel Island	28.2	33.70	7.5	8.3	710	55
7.	Wall & Nicolson Island	28.3	34.20	7.6	8.4	702	55
8.	South Button Island	28.0	33.89	7.2	7.3	673	40
9.	North Button Island	28.0	34.90	7.7	9.1	515	20
10.	Middle Button Island	27.3	35.00	7.2	7.2	630	25
11.	Wilson Island	27.9	34.87	7.5	7.0	622	30
Neil Island							
12.	Lakshmanpur	27.5	34.12	7.0	7.1	618	35
13.	Hawrah Bridge	28.0	34.87	7.1	6.5	752	40
14.	Middle Point	28.0	34.30	7.4	9.3	621	45
15.	Ramangar	28.2	34.27	7.2	9.0	630	40
16.	Sunset point	28.3	34.17	7.3	10.2	512	40
17.	Little Neil Island	28.4	34.15	7.3	10.4	518	45
18.	Pearl Park Beach	28.1	35.00	7.5	10.5	520	50
	Mean value	**28.0**	**34.11**	**7.3**	**8.4**	**633.39**	**38.72**

Table 4. Physico-chemical Parameters in seawater of Middle and North Andaman.

Sl. No.	Area	Temp. (°C)	Salinity (PPT)	pH	Trans-parency (m)	Turbidity (NTU)	Intertidal exposure (m)
Middle Andaman							
1.	North Reef Island	27.5	33.21	7.1	12.00	437	120
2.	Interview Island	27.2	34.51	7.0	11.0	452	200
3.	Mayabunder	27.1	32.28	7.5	6.0	512	65
4.	Avis Island	27.5	34.12	7.6	6.7	560	50
5.	Sound Island	28.0	34.00	7.4	7.0	602	55
6.	Rail Island	28.1	34.02	7.2	7.5	652	50
7.	Karlo Island	28.7	34.12	7.3	6.0	608	60
8.	Karmatang	28.3	34.71	7.4	5.5	552	205
North Andaman							
9.	Ross Island	28.2	33.2	7.3	6.2	600	105
10.	Smith Island	28.0	33.81	7.1	6.5	612	150
11.	Ariel Bay	28.1	33.51	7.2	7.0	670	110
12.	Lamia Bay	28.0	33.45	7.0	7.2	668	120
	Mean value	**27.9**	**33.75**	**7.3**	**7.4**	**577.08**	**107.5**

Table 5. Physico-chemical Parameters in seawater of Nicobar Islands

Sl. No.	Area	Temp. (°C)	Salinity (PPT)	pH	Trans-parency (m)	Turbidity (NTU)	Intertidal exposure (m)
Car Nicobar Island							
1.	Malacca	26.5	33.12	7.3	8.1	557	22
2.	Kakaana	27.0	34.10	7.1	9.2	512	20
3.	Tamoloo	26.8	34.81	7.2	13.7	318	18
4.	Kimos	27.3	34.21	7.3	12.1	415	15
5.	Perka	27.2	33.15	7.4	12.7	428	20
6.	Lapati	27.4	33.50	7.5	12.8	420	21
Nancowry Islands							
7.	Kamorta Island Bada Enaka	27.0	33.28	7.0	8.7	560	21
8.	Champin Island	28.0	34.00	7.2	6.7	627	20
9.	Trinket Island	27.5	34.02	7.1	9.2	512	22
10.	Kamorta Island – Kardip	27.3	34.12	7.2	5.5	812	35
11.	Kamorta Island – Kakkana	28.0	34.15	7.3	6.5	756	35
12.	Munak Island	28.2	33.21	7.2	7.8	628	30
13.	Katchal Island	28.5	33.10	7.5	7.0	677	30
14.	Teressa Island	28.3	32.50	7.3	7.5	640	22
15.	Kundol Island	28.4	33.12	7.6	8.0	602	25
Great Nicobar Island							
16.	Campbell Bay	26.1	33.51	7.1	5.1	922	20
17.	Off Laxman Beach	27.3	34.25	7.2	6.7	712	22
18.	Off Gandhi Nagar	27.2	34.51	7.2	5.8	910	20
19.	Johinder Nagar	27.1	34.18	7.7	6.2	810	28
20.	Singam Basti	27.8	34.20	7.0	5.8	833	25
21.	Navy Dera	28.1	34.15	7.1	7.0	752	30
22.	Indira Point	28.7	34.10	7.2	8.0	760	35
23.	Kopen Heat	28.5	34.21	7.3	7.5	720	30
	Mean value	**27.6**	**33.80**	**7.3**	**8.2**	**647.1**	**24.60**

Table 6. Phytoplankton productivity and diversity in South and Little Andaman

Sl. No.	Area	Tide	Cell count (No. × 10^2L^{-1})	Species Diversity (H')
South Andaman				
1.	Off Burmanella	LT	92.45	2.18
2.	Off Rangachang	LT	97.58	2.20
3.	Chidyatapu	LT	87.65	2.10
4.	Pongibalu	LT	47.51	1.11
Rutland Island				
5.	Chain Nalah	LT	78.00	2.14
6.	Padauk Dikri	BHL	67.43	1.98
7.	Surumai Dikri	BHL	118.27	2.80
8.	Komeo	LT	125.07	2.98
9.	Mitta Nalah	LT	132.94	3.08
10.	Arom Point	LT	98.10	2.70
11.	Aam Dera	LT	85.72	2.40
12.	North Wandoor	BHL	97.30	2.60
13.	Grub Island	BHL	70.28	2.10
14.	Jolly Buoy Island	BHL	58.52	2.02
15.	Tarmugli Island	BHL	60.21	2.07
16.	North Bay	LT	97.83	2.67
17.	Off Collinpur	LT	143.21	3.31
18.	Off Kurmadera	LT	93.18	2.90
	Mean value		**91.74**	**2.41**
Little Andaman Island				
19.	Butler Bay	LT	97.10	2.91
20.	Kala Pathar	BHL	90.15	2.85
21.	Haminder Bay	LT	137.81	2.91
22.	Off Ramkrishnapur	LT	98.70	2.58
23.	Sister Island	LT	121.80	2.78
24.	Hut Bay	BHL	68.21	2.51
25.	Dugong Creek	LT	98.70	2.58
26.	Off Light House	LT	64.86	2.11
	Mean value		**97.17**	**2.65**

Table 7. Phytoplankton productivity and diversity in Ritchie's Archipelago

Sl. No.	Area	Tide	Cell count ($No.\times10^2L^{-1}$)	Species Diversity (H')
1.	Havelock Island	LT	102.31	2.91
2.	Inglis Island	LT	90.50	2.53
3.	Henry Lawrence Island	BHL	85.17	2.40
4.	John Lawrence Island	LT	93.10	2.71
5.	Outram Island	LT	66.15	2.30
6.	Peel Island	LT	68.20	2.41
7.	Wall & Nicolson Island	BHL	70.23	2.87
8.	South Button Island	LT	67.50	2.31
9.	North Button Island	LT	66.18	2.40
10.	Middle Button Island	LT	68.00	2.51
11.	Wilson Island	LT	53.18	1.89
Neil Island		LT	92.10	2.59
12.	Lakshmanpur	BHL	63.00	2.10
13.	Hawrah Bridge	BHL	75.19	2.57
14.	Middle Point	BHL	55.21	1.82
15.	Ramangar	BHL	40.25	1.70
16.	Sunset point	LT	53.12	1.80
17.	Little Neil Island	LT	70.00	2.15
18.	Pearl Park Beach	LT	75.35	2.21
	Mean value		**71.30**	**2.33**

Table 8. Phytoplankton productivity and diversity in Middle and North Andaman

Sl. No.	Area	Tide	Cell count (No.×10^2L^{-1})	Species Diversity (H')
Middle Andaman				
1.	North Reef Island	LT	70.31	2.72
2.	Interview Island	LT	80.51	2.81
3.	Mayabunder	LT	133.21	3.10
4.	Avis Island	LT	102.38	3.00
5.	Sound Island	LT	91.56	2.89
6.	Rail Island	LT	80.31	2.73
7.	Karlo Island	LT	75.21	2.60
8.	Karmatang	LT	120.15	3.01
North Andaman				
9.	Ross Island	LT	112.10	2.98
10.	Smith Island	LT	83.12	2.74
11.	Ariel Bay	LT	70.58	2.53
12.	Lamia Bay	LT	72.31	2.60
	Mean value		**90.98**	**2.81**

Table 9. Phytoplankton productivity and diversity in Nicobar Islands

Sl. No.	Area	Tide	Cell count (No.×10^2L^{-1})	Species Diversity (H')
Car Nicobar Island				
1.	Malacca	BHL	73.15	2.31
2.	Kakaana	LT	52.50	1.61
3.	Tamoloo	LT	62.38	1.70
4.	Kimos	LT	72.51	1.92
5.	Perka	LT	76.32	2.35
6.	Lapati	LT	70.30	1.98
Nancowry Islands				
7.	Kamorta Island Bada Enaka	LT	122.10	
8.	Champin Island	BHL	91.38	2.74
9.	Trinket Island	BHL	75.19	1.93
10.	Kamorta Island – Kardip	LT	117.27	3.01
11.	Kamorta Island – Kakkana	LT	128.10	3.12
12.	Munak Island	LT	73.19	1.92
13.	Katchal Island	LT	81.50	2.38
14.	Teressa Island	LT	82.00	2.54
15.	Kundol Island	LT	71.00	2.31
Great Nicobar Island				
16.	Campbell Bay	LT	130.25	3.18
17.	Off Laxman Beach	LT	115.03	2.97
18.	Off Gandhi Nagar	LT	83.10	2.87
19.	Johinder Nagar	LT	80.71	2.60
20.	Singam Basti	LT	101.31	2.93
21.	Navy Dera	LT	58.17	1.57
22.	Indira Point	LT	62.31	1.68
23.	Kopen Heat	LT	60.21	1.62
	Mean value		**84.35**	**2.33**

Table 10. Distribution of phytoplankton in South, Little, North and Middle Andaman, Ritchie's Archipelago and Nicobar Islands.

Sl. No.	Species	South and Little Andaman	Ritchie's Archipelago	Middle and North Andaman	Nicobar Islands
1	*Actinastrum hantzchii*	P			P
2	*Actinotychus undulates*		P	P	
3	*Amphora lineolata*	P	P	P	P
4	*Amphora ostreoria*	P	P	P	P
5	*Asteronella japonica*	P	P	P	P
6	*Auladiscus orbiculatus*	P		P	
7	*Auliscus sculptus*	P		P	
8	*Bacillaria paradoxa*			P	
9	*Bellerochea malleus*	P			
10	*Biddulphia heteroceros*	P	P	P	P
11	*Campylodiscus iyengarii*	P	P	P	P
12	*Ceratium axiale*		P	P	P
13	*Ceratium azoricum*	P	P		P
14	*Ceratium furca*	P	P		P
15	*Ceratium trichoceras*	P	P	P	P
16	*Chaetoceros coaractatus*		P		P
17	*Chaetoceros lorenzianus*		P	P	P
18	*Climacosphenia moniligera*		P		P
19	*Closterium* sp.			P	P
20	*Coelosphaericum kuetzingianum*		P		
21	*Corethron hystrix*	P			
22	*Coscinodiscus eccentricus*	P	P	P	P
23	*Coscinodiscus jonesianus*	P	P	P	P
24	*Coscinodisucs oculus iridis*	P	P	P	P
25	*Coscinodiscus* sp.	P	P	P	P
26	*Cyclotella meneghiniana*			P	P
27	*Cyclotella stelligera*		P	P	P

Sl. No.	Species	South and Little Andaman	Ritchie's Archipelago	Middle and North Andaman	Nicobar Islands
28	*Cymbella marina*	P			
29	*Diatoma anceps*	P			
30	*Diploneis smithi*	P			
31	*Diploneis weissylogii*	P			
32	*Fragillaria crotonensis*	P	P	P	P
33	*Fragillaria oceanica*	P	P	P	P
34	*Gloeotrichia echinulata*	P		P	P
35	*Goniaulax birostris*	P		P	P
36	*Gossleriella tropica*	P	P		P
37	*Grammatophora mirificum*	P	P		P
38	*Gyrosigma balticum*	P	P	P	P
39	*Hemiculus hauckii*	P	P		
40	*Lauderia annulata*		P	P	
41	*Lauderia borealis*				P
42	*Leptocylindrus donicus*			P	P
43	*Lyngbya confervoides*	P	P	P	P
44	*Melosira* sp.	P	P	P	P
45	*Merismopedia* sp.				P
46	*Nitzschia seriata*	P	P	P	P
47	*Nitzschia sigma*	P	P	P	P
48	*Ornithocerus steinii*		P		
49	*Oscillatoria limosa*		P		
50	*Pediastrum simplex*		P		
51	*Phyrophacus harologicum*		P		
52	*Pleurosigma angulatum*	P	P	P	P
53	*Pleurosigma elongatum*	P	P	P	P
54	*Pleurosigma galapagense*	P		-	P
55	*Pleurosigma normanii*	P		P	
56	*Prorocentrum maximum*	P	P	P	P

Sl. No.	Species	South and Little Andaman	Ritchie's Archipelago	Middle and North Andaman	Nicobar Islands
57	*Prorocentrum micans*	P	P	P	P
58	*Protoperidinium depressum*		P	P	
59	*Protoperidinium oceanicum*	P	P	P	P
60	*Rhaphoneis discoides*		P		P
61	*Rhizosolenia cylindricus*		P	P	P
62	*Rhizosolenia stolterfothii*	P			P
63	*Schroederella delicatula*	P			P
64	*Stephaenodiscus* sp.				P
65	*Striatella delicatula*		P	P	
66	*Surirella flaminensis*	P	P	P	P
67	*Surirella maximum*	P	P	P	P
68	*Synedra formosa*	P			
69	*Tetraedron trigonum*	P			
70	*Thalassiothrix frauenfeldii*			P	P
71	*Thalassiothrix longissima*	P	P	P	P
72	*Thalassiothrix nitzschioides*	P	P	P	P
73	*Trachyneis aspera*	P		P	P
74	*Treubaria varia*				P
75	*Triceratium favus*				P
76	*Umbilicosphaera mirabilis*	P			P
77	*Westella botryoides*	P			
	Total no. of species	**51**	**47**	**45**	**54**

P – present

Table 11. Quantitative estimation of zooplankton in South and Little Andaman.

Sl. No.	Area	Numerical Density (No./100m³)	Fresh Weight (mg./100m³)	Dry Weight mg./100m³)	Volume (ml./100m³)	Species diversity(H')
	South Andaman					
1.	Off Burmanella	28320	3620	912	10.2	3.31
2.	Off Rangachang	27420	3210	817	9.7	3.02
3.	Chidyatapu	21480	2860	728	7.2	2.12
4.	Pongibalu	20320	2720	712	7.1	2.00
	Rutland Island	18450	2420	689	7.0	2.01
5.	Chain Nalah	17210	2330	662	6.2	1.81
6.	Padauk Dikri	17200	2310	668	6.3	1.80
7.	Surumai Dikri	17250	2280	635	6.2	1.81
8.	Komeo	16320	1830	512	5.2	2.20
9.	Mitta Nalah	20520	2810	625	6.2	2.50
10.	Arom Point	22330	2030	683	6.3	2.61
11.	Aam Dera	26400	3210	818	7.0	2.70
12.	North Wandoor	26520	3320	827	7.2	2.70
13.	Grub Island	27320	3450	935	7.9	2.71
14.	Jolly Buoy Island	21420	3120	912	8.0	2.81
15.	Tarmugli Island	16350	2180	810	8.1	2.41
16.	North Bay	21450	2890	822	7.3	2.30
17.	Off Collinpur	22350	2910	781	7.4	2.14
18.	Off Kurmadera	23450	3470	820	7.2	2.70
	Mean value	**21688**	**2787.89**	**756.21**	**7.24**	**2.40**
	Little Andaman Island					
19.	Butler Bay	21420	2030	628	6.5	1.51
20.	Kala Pathar	21610	2010	637	6.6	1.60
21.	Haminder Bay	23500	2318	748	6.7	1.72
22.	Off Ramkrishnapur	24210	2450	673	6.0	1.62
23.	Sister Island	26120	3610	928	6.2	1.52
24.	Hut Bay	28100	4210	1120	6.3	1.40
25.	Dugong Creek	21500	2820	915	8.0	2.01
26.	Off Light House	18370	2280	676	7.5	2.07
	Mean value	**23105**	**2716**	**790.63**	**6.7**	**1.68**

Table 12. Quantitative estimation of zooplankton in Ritchie's Archipelago.

Sl. No.	Area	Numerical Density (No./100m³)	Fresh Weight (mg./100m³)	Dry Weight mg./100m³)	Volume (ml./100m³)	Species diversity(H')
1.	Havelock Island	17380	2230	630	4.1	1.57
2.	Inglis Island	16930	1940	427	5.0	1.43
3.	Henry Lawrence Island	20150	2320	791	5.5	2.12
4.	John Lawrence Island	22980	3210	818	5.8	2.35
5.	Outram Island	21370	3170	798	6.0	2.89
6.	Peel Island	24210	3350	825	5.8	3.12
7.	Wall & Nicolson Island	25230	3410	830	6.5	3.15
8.	South Button Island	18370	2470	720	5.7	3.62
9.	North Button Island	17680	2180	767	4.2	2.17
10.	Middle Button Island	1770	2160	712	4.0	2.10
11.	Wilson Island	20120	2480	780	5.6	1.90
	Neil Island	22210	2920	782	5.9	1.87
12.	Lakshmanpur	22340	2980	790	6.0	2.27
13.	Hawrah Bridge	21430	2720	728	5.7	2.08
14.	Middle Point	16420	1980	417	5.2	1.57
15.	Ramangar	17610	2100	520	3.1	1.27
16.	Sunset point	18380	2310	588	3.5	1.80
17.	Little Neil Island	19920	2450	620	3.9	1.77
18.	Pearl Park Beach	20210	5580	655	4.0	2.10
	Mean value	**19195**	**2734.74**	**694.63**	**5.0**	**2.16**

Table 13. Quantitative estimation of zooplankton in Middle and North Andaman.

Sl. No.	Area	Numerical Density (No./100m³)	Fresh Weight (mg./100m³)	Dry Weight mg./100m³)	Volume (ml./100m³)	Species diversity(H')
	Middle Andaman					
1.	North Reef Island	18350	2460	567	5.3	1.18
2.	Interview Island	19410	2690	590	5.6	1.74
3.	Mayabunder	28150	3980	978	8.1	2.38
4.	Avis Island	27620	3710	935	7.8	2.17
5.	Sound Island	26180	3420	882	7.1	2.16
6.	Rail Island	24620	2980	768	6.2	2.07
7.	Karlo Island	25150	3110	818	6.7	3.15
8.	Karmatang	22410	2890	617	5.4	2.10
	North Andaman					
9.	Ross Island	25510	3020	727	6.8	3.05
10.	Smith Island	2020	2410	528	5.8	1.88
11.	Ariel Bay	21660	2620	612	6.0	1.92
12.	Lamia Bay	21390	2420	627	6.2	1.89
	Mean value	**21872**	**2975.83**	**720.75**	**6.4**	**2.14**

Table 14. Quantitative estimation of zooplankton in Nicobar Islands.

Sl. No.	Area	Numerical Density (No./100m³)	Fresh Weight (mg./100m³)	Dry Weight mg./100m³)	Volume (ml./100m³)	Species diversity(H')
	Car Nicobar Island					
1.	Malacca	28300	3790	822	6.7	2.91
2.	Kakaana	21410	2120	617	4.2	1.83
3.	Tamoloo	17340	1980	572	3.7	1.45
4.	Kimos	18200	1990	581	3.9	2.00
5.	Perka	19410	2010	620	4.0	2.15
6.	Lapati	20210	2230	647	4.7	2.17
	Nancowry Islands					
7.	Kamorta Island – Bada Enaka	27640	3650	783	6.6	2.65
8.	Champin Island	23470	2450	541	5.7	2.40
9.	Trinket Island	21650	2160	527	5.4	2.18
10.	Kamorta Island – Kardip	21720	2190	528	5.2	2.12
11.	Kamorta Island – Kakkana	20420	2210	621	5.8	2.40
12.	Munak Island	17240	1980	528	5.2	1.89
13.	Katchal Island	17430	1970	540	5.3	1.90
14.	Teressa Island	16220	1920	527	4.9	1.75
15.	Kundol Island	25470	2820	617	5.5	1.82
	Great Nicobar Island					
16.	Campbell Bay	26400	3440	847	5.8	1.83
17.	Off Laxman Beach	25350	2740	628	5.8	1.97
18.	Off Gandhi Nagar	17640	1940	564	5.2	2.00
19.	Johinder Nagar	17200	1920	528	4.2	1.17
20.	Singam Basti	15300	1210	415	3.2	1.06
21.	Navy Dera	15420	1320	475	3.4	1.12
22.	Indira Point	17210	1480	488	3.7	1.14
23.	Kopen Heat	18220	1620	548	4.2	1.76
	Mean value	**20385**	**2223.47**	**589.74**	**4.9**	**1.89**

Table 15. Distribution of zooplankton in study area.

Sl. No.	Species	South and Little Andaman	Ritchie's Archipelago	Middle and North Andaman	Nicobar Island
	(1) Foraminiferans				
1.	*Amhistegina lessoni* d'Orbigny	+	+	+	+
2.	*Amphisorus hemprichii* Ehrenberg		+	+	+
3.	*Cibicides lobatulus* d'Orbigny		+	+	+
4.	*Calcarina calcar* d'Orbigny	+	+	+	+
5.	*Elphidium crispum* (Linne)		-		+
6.	*Globigerina tricolunoides*		+	+	
7.	*Globigerina sacculifer* (Brady)	+	+	+	-
8.	*Loxostomum limbatum* var *costulatum* (Cushman)	+	+		+
9.	*Loxostomum rostrum* (Brady)	+	+	+	+
10.	*Loxostomum truncatum* Phleger and Parker			+	+
11.	*Planobulina mediterranensis* d' Orbigny	+	+	+	+
12.	*Quinqueloculina seminulum* (Linne)		+	+	+
13.	*Quinqueloculina subcuneata* Cushman		+	+	
14.	*Rosalina floridana* (Cushman)		+	+	
15.	*Rosalina globularis* d'Orbigny	+	+		+
16.	*Rosalnia bradyi* (Cushman)	+		+	+
17.	*Siphonia reticulata* (Czjzek)				+
18.	*Spirillina lateseptata*		+		+
19.	*Triloculina oblonga* (Montagu)		+	+	
	(2) Appendicularians				
20.	*Oikopleura dioica*	+	+	+	+
	(3) Copepods				
21.	*Acartia erythracea*	+		+	+
22.	*Acartia southwelli* Sewell	+	+	+	+
23.	*Acrocalanus gracilils* Giesbrecht	+	+		+
24.	*Copilia mirabilis* Dana	+		+	

Sl. No.	Species	South and Little Andaman	Ritchie's Archipelago	Middle and North Andaman	Nicobar Island
25.	*Corycaeus catus* F. Dahl	+	+	+	+
26.	*Corycaeus danae* Giesbrecht	+	+		+
27.	*Corycaeus speciosus* Dana	+	+	+	+
28.	*Centropages dorsispinatus*		+	+	+
29.	*Euchaeta concinna*		+	+	+
30.	*Eucalanus attenuatus* (Dana)	+	+	+	+
31.	*Euterpina acutifrons* (Dana)	+	+	+	
32.	*Isias tropica* Sewell	+	+	+	+
33.	*Labidocera acuta* (Dana)	+		+	
34.	*Longipedia coronata* Claus	+	+	+	+
35.	*Longipedia weberi* A. Scott	+	+	+	
36.	*Lucicutia flavicornis* (Claus)	+	+	+	+
37.	*Macrocypris mima*	+	+	+	+
38.	*Macrosetella gracilis* (Dana)	+	+	+	+
39.	*Metacalanus aurivilli* Cleve	+	+	+	+
40.	*Metis jausseamei* (Richard)	+	+	+	+
41.	*Microsetella norvegica* (Boeck)	+	+	+	+
42.	*Microsetella rosea* (Dana)			+	
43.	*Miracia efferata Dana*	+		+	+
44.	*Nannocalanus minor* (Claus)	+	+	+	+
45.	*Oithona brevicornis* Giesbrecht	+	+	+	+
46.	*Oithona linearis* Giesbrecht	+		+	+
47.	*Oithona similis* Claus	+	+		+
48.	*Oncaea venusta* Philippi	+	+	+	+
49.	*Paracalanus parvus*(Claus)	+	+		+
50.	*Pontella danae* Giesbrecht	+		+	+
51.	*Pontellina plumata* (Dana)		+		
52.	*Pseudodiaptomus serricaudatus* (T. Scott)		+	+	+
53.	*Sapphirina nigromaculata* Dana		+	+	+
54.	*Sapphirina ovatolancoelataa* Dana		+	+	

Sl. No.	Species	South and Little Andaman	Ritchie's Archipelago	Middle and North Andaman	Nicobar Island
55.	*Scoleithrix danae* (Lubbock)	+		+	-
56.	*Temora discaudata* Giesbrecht	+	+	+	-
57.	*Undinula vulgaris* (Dana)				-
	(4) Amphipods				
58.	*Hyperia medusarum*	+	+	+	+
59.	*Parathemisto* sp.			+	+
	(5) Isopods				
60.	*Angeliera phreaticola* Chappuis and Delamare Debouteville,1952				
	(6) Ostracods				
61.	*Conchoecia indica*	+	+	+	
62.	*Cypridina sinosa*	+	+	+	+
63.	*Macrocypris minna*	+	+	+	+
	(7) Leptomedusae				
64.	*Proboscidactyla stellata*		+	+	+
	(8) Crustacean larvae				
65.	Cypris larva of Lepas, Barnacle	+	+	+	+
66.	Nauplii	+	+	+	+
67.	Larvae of *Labidocera pavo*			+	+
68.	Mysis stage of penaeid prawn	+	+	+	+
	(9) Annelid larvae				
69.	Setiger larva	+	+	+	
70.	Spirobis larva	+	+	+	+
	(10) Cladocerans				
71.	*Evadena tergestina*	+		+	+
72.	*Cypris* sp.				
73.	*Podon* sp.	+	+	+	+
	(11) Chaetognaths				
74.	*Eukrohnia minuuta*			+	
75.	*Sagitta enflata*		+	+	+

Sl. No.	Species	South and Little Andaman	Ritchie's Archipelago	Middle and North Andaman	Nicobar Island
76.	*Sagitta hamata*	+		+	
77.	*Sagitta hexaptera*	+	+		
78.	*Sagitta hispida*	+		+	
79.	*Sagitta lyra*	+		+	+
80.	*Sagitta maxima*		+		+
81.	*Sagitta robusta*		+	+	+
	(12) Doliolids (Cyclomyaria)				
82.	*Dolioletta gengenbauri*	+		+	
	(13) Echinoderms				
83.	Bipinnaria larva of starfish	+		+	
84.	Echinopluteus larva of sea urchin	+		+	
	(14) Radiolarians				
85.	*Acanthometron* sp	+	+		+
	(15) Siphonophores				
86.	*Porpita porpita*	+	+	+	+
87.	*Diphyes chamissonis*			+	+
	(16) Molluscs				
88.	*Janthina janthina*	+	+	+	+
89.	*Janthina fragilis*	+		+	
90.	*Spiratella* sp.	+	+	+	
91.	Veliger larva	+	+	+	+
92.	Pedi veliger larva			+	
	(17) Salpids (Desmomyaria)				
93.	*Salpa maxima*	+		+	+
94.	*Salpa (Pegea) confoederata*	+		+	+
	(18) Opithobranchs				
95.	*Crseis acicula*			+	+
	(19) Pisces				
96.	Fish eggs	+	+	+	+
	Total number of species	65	65	80	67
	Species diversity (H')	2.75	2.80	3.45	2.82

Table 16. Density and mean size (shell diameter) of *Trochus niloticus* at different depth in South and Little Andaman

Sl. No.	Area	0 m		5 m		10 m		15 m		20 m		Mean	
		Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No.100 m^2)	Size (cm)
	South Andaman												
1.	Off Burmanella	4	6.80	6	8.76	6	9.21	8	10.25	9	11.21	7	9.25
2.	Off Rangachang	5	4.20	6	7.54	7	9.38	8	10.23	8	11.80	7	10.03
3.	Chidyatapu			2	6.28	8	8.51	9	11.15	8	10.92	7	9.22
4.	Pongibalu			4	8.23	5	8.26	8	11.58	8	11.38	6	9.86
	Rutland Island												
5.	Chain Nalah			5	9.15	7	8.17	7	10.15	8	11.00	7	9.62
6.	Padauk Dikri			6	8.27	5	9.18	6	10.10	7	11.15	6	9.68
7.	Surumai Dikri			3	8.50	6	10.31	7	9.87	6	10.35	6	9.76
8.	Komeo					5	10.20	7	10.25	7	10.35	6	10.26
9.	Mitta Nalah					4	10.18	6	10.20	7	10.11	6	10.16
10.	Arom Point			7	5.61	7	10.11	7	10.35	8	10.28	7	9.09
11.	Aam Dera			3	7.52	5	9.21	7	9.85	7	9.75	6	9.08
12.	North Wandoor			2	8.15	3	9.56	6	9.81	8	9.90	5	9.36
13.	Grub Island			7	9.00	6	10.26	6	10.50	7	10.25	7	10.00
14.	Jolly Buoy Island			8	9.12	7	10.18	7	10.38	8	0.40	8	10.02
15.	Tarmugli Island			6	10.15	8	10.19	10	10.15	9	10.18	8	10.17
16.	North Bay			5	8.21	7	9.17	10	10.28	10	11.12	8	9.69
17.	Off Collinpur	3	6.38	3	7.12	3	8.23	6	11.31	7	11.56	4	11.15
18.	Off Kurmadera	2	5.02	3	7.15			6	11.15	8	11.28	5	8.65
	Mean value	**4**	**5.60**	**5**	**8.05**	**6**	**9.43**	**7**	**10.43**	**8**	**10.69**	**6**	**9.72**
	Little Andaman Island												
19.	Butler Bay			4	8.54	5	8.64	7	9.81			5	8.99
20.	*Kala Pathar*			5	8.23	6	9.28	8	10.23			6	9.25
21.	*Haminder Bay*			6	9.15	7	10.31	9	10.85	8	11.31	8	10.41
22.	*Off Ramkrishnapur*			2	9.21	3	10.56	5	10.36	7	10.50	4	10.16
23.	*Sister Island*			5	7.56	8	10.31	10	10.32	10	10.32	8	9.63
24.	*Hut Bay*			5	7.20	8	10.72	10	10.15	10	10.15	8	9.56
25.	*Dugong Creek*	3	7.36	6	7.92	8	10.52	12	11.41	12	1.41	8	9.72
26.	*Off Light House*			2	8.02	2	10.15	7	10.38	7	10.38	5	9.73
	Mean value	**3**	**7.36**	**4**	**8.23**	**6**	**10.06**	**9**	**10.44**	**9**	**10.68**	**7**	**9.68**

Table 17. Density and Size (shell diameter) of *Trochus niloticus* in Ritchie's Archipelago.

Sl. No.	Area	0 m		5 m		10 m		15 m		20 m		Mean	
		Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No.100 m^2)	Size (cm)
1.	Havelock Island			7	7.81	8	9.56	12	10.38	13	11.31	10	9.77
2.	Inglis Island	3	7.51	8	9.51	10	9.27	13	10.52	12	11.38	9	9.64
3.	Henry Lawrence Island	3	6.23	3	9.27	11	9.18	12	11.18	12	10.86	8	9.34
4.	John Lawrence Island	2	6.68	5	8.28	7	10.27	11	11.02	10	11.56	7	9.56
5.	Outram Island	2	5.21	7	8.20	6	10.15	10	11.51	11	11.28	7	9.27
6.	Peel Island			6	8.15			9	11.26	13	10.56	9	9.99
7.	Wall & Nicolson Island			6	5.21	7	10.70	10	10.45	12	11.26	9	9.41
8.	South Button Island			5	9.32	9	10.10	12	10.38	8	10.54	9	10.09
9.	North Button Island			5	9.50	10	10.11	8	9.28	9	10.28	8	9.79
10.	Middle Button Island			6	7.28	10	8.38	9	11.21			8	8.96
11.	Wilson Island			3	9.15	6	8.80	10	11.81			6	9.92
	Neill Island												
12.	Lakshmanpur			5	8.25	5	8.79	11	11.26	8	11.38	7	9.92
13.	Hawrah Bridge			3	8.30	7	8.59	12	11.15	12	11.51	9	9.89
14.	Middle Point			8	8.45	9	10.15	11	10.92	10	11.86	10	10.35
15.	Ramangar	1	4.38	4	8.15	6	9.38	12	10.71	10	10.11	7	8.55
16.	Sunset point	2	4.55	5	8.16	7	9.81	12	11.38	9	10.56	7	8.89
17.	Little Neil Island	2	5.21	5	8.17	6	9.21	11	10.61	9	10.56	7	8.75
18.	*Pearl Park Beach*			5	7.56	6	8.95	10	10.25	10	11.15	8	9.48
	Mean value	**2**	**5.68**	**5**	**8.26**	**8**	**9.49**	**11**	**10.84**	**11**	**11.01**	**8**	**9.53**

Table 18. Density and Size (shell diameter) of *Trochus niloticus* in Middle and North Andaman

Sl. No.	Area	0 m		5 m		10 m		15 m		20 m		Mean	
		Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No.100 m^2)	Size (cm)
	Middle Andaman												
1.	North Reef Island	3	6.21	7	8.31	10	10.15	11	11.26	10	11.30	8	9.45
2.	Interview Island	4	6.38	8	8.42	7	10.86	10	12.15	12	11.88	8	9.85
3.	Mayabunder	5	6.74	7	8.30	8	10.31	12	12.10	12	11.43	9	9.78
4.	Avis Island	4	6.18	9	8.27	12	0.21	14	11.52	18	10.24	11	9.78
5.	Sound Island	5	5.27	7	9.56	10	11.20	12	11.76	12	10.70	9	9.70
6.	Rail Island	6	5.21	10	10.21	10	11.58	11	11.26	10	10.50	9	9.75
7.	Karlo Island	4	5.75	6	10.76	11	11.30	10	11.28	11	10.57	8	9.93
8.	Karmatang	5	6.17	10	10.28	9	11.16	9	10.24	10	10.22	7	9.61
	Mean value	**5**	**5.98**	**8**	**9.26**	**10**	**10.84**	**11**	**11.45**	**12**	**10.86**	**9**	**10**
	North Andaman												
9.	Ross Island	3	7.21	8	11.12	9	10.51	8	10.76	9	11.13	7	10.15
10.	Smith Island	4	4.28	9	8.52	8	10.26	7	10.39	10	12.27	8	9.14
11.	Ariel Bay	3	4.31	7	8.53	9	10.81	8	10.28	11	11.33	8	9.05
12.	Lamia Bay	3	5.51	8	8.25	8	9.13	10	10.21	9	11.31	8	8.88
	Mean value	**3**	**5.33**	**8**	**9.10**	**9**	**10.17**	**8**	**10.41**	**10**	**11.51**	**8**	**9.31**

Table 19. Density and Size (base diameter) of *Trochus niloticus* in Nicobar Islands.

Sl. No.	Area	0 m		5 m		10 m		15 m		20 m		Mean	
		Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No. 100 m^2)	Size (cm)	Density (No.100 m^2)	Size (cm)
Car Nicobar Island													
1.	Malacca			8	9.71	12	13.25	13	13.12	14	13.21	9	12.32
2.	Kakaana			7	9.82	12	13.28	12	13.28	13	13.26	11	12.41
3.	Tamoloo			8	10.21	10	13.81	10	13.52	10	12.12	10	12.42
4.	Kimos			6	11.38	8	12.15	10	13.15	15	13.26	10	12.49
5.	Perka			5	11.51	12	12.16	12	13.61	12	13.12	10	10.08
6.	Lapati			7	12.31	13	13.63	12	13.25	13	13.15	11	13.09
	Mean value			**7**	**10.82**	**11**	**13.05**	**12**	**13.32**	**13**	**13.02**	**10**	**12.14**
	Nancowry Islands												
7.	Kamorta Island – Bada Enaka			9	12.57	14	12.80	12	13.26	12	12.56	12	12.80
8.	Champin Island			8	12.38	15	13.40	13	13.26	14	12.21	13	12.81
9.	Trinket Island			9	12.58	8	13.15	16	13.54	15	12.28	12	12.89
10.	Kamorta Island – Kardip			10	12.17	17	13.16	18	12.50	18	13.26	16	12.77
11.	Kamorta Island – Kakkana			8	11.92	18	12.41	20	12.71	20	13.15	17	12.55
12.	Munak Island			9	11.31	20	13.21	19	12.76	20	13.62	17	12.73
13.	Katchal Island			10	11.15	21	13.56	18	12.86	18	12.74	17	12.63
14.	Teressa Island			7	11.80	18	13.71	17	12.87	17	12.15	15	12.63
15.	Kundol Island			8	12.86	20	13.15	20	12.70	21	12.17	17	12.72
	Mean value			**9**	**12.08**	**17**	**13.17**	**17**	**12.94**	**17**	**12.68**	**15**	**12.73**
Great Nicobar Island													
16.	Campbell Bay	4	4.86	8	12.36	18	13.30	17	12.40	16	13.21	13	11.23
17.	Off Laxman Beach	2	6.25	9	13.00	17	13.20	18	12.80	15	13.15	12	11.68
18.	Off Gandhi Nagar			7	13.01	12	13.26	13	13.10	18	13.20	13	13.14
19.	Johinder Nagar			6	13.17	16	12.60	15	13.32	18	13.10	14	13.05
20.	Singam Basti			7	12.16	17	13.40	18	13.26	16	12.56	15	12.85
21.	Navy Dera	2	5.26	4	11.50	10	11.28	15	12.15	13	11.81	9	10.40
22.	Indira Point	3	5.81	7	11.28	12	12.38	16	13.21	12	13.50	10	11.24
23.	Kopen Heat	1	6.21	2	11.20	5	12.50	7	13.11	11	13.20	5	15.00
	Mean value	**2**	**5.68**	**6**	**12.21**	**13**	**12.74**	**15**	**12.92**	**15**	**12.96**	**11**	**12.32**

SIGNIFICANT FINDINGS ON *TROCHUS NILOTICUS*

1. The present survey along 79 stations covering entire Andaman and Nicobar Islands has been conducted during August 2009 to March 2010 to assess the current standing stock on *Trochus niliticus* since its ban for fishing from year 2001.
2. Extensive undersea and intertidal surveys revealed out the occurrence of *Trochus niloticus* throughout the sublittoral zone of continental shelf of Andaman and Nicobar Archipelago up to the depth of 20m.
3. It is surprise to note that absence of turban shell *Turbo marmoratus* in the surveyed area indicated the near extinction of the population of this scheduled gastropod in Andaman and Nicobar waters.
4. The high number of *Trochus niloticus* found in the depth ranges between 10 and 20 m at all the places of study.
5. The mean numerical density of *Trochus niloticus* varied from 6 shells/100m^2 in the coastal waters of South Andaman to 15 shells/100 m^2 in Nancowry Islands
6. The numerical abundance of *Trochus niloticus* was maximum in Nancowry group of Islands and it recorded upto 20 shells/100m^3.
7. The specimens observed from the intertidal region i.e. zero meter depth are always smaller in size when compared to the subtidal one. The mean size of the specimens at intertidal regions varied from 5.33 to 5.68 cm in the places where it occurred. However, in most of the places, increment in the size of *Trochus* corresponding to greater depths has been observed.
8. Among the study area, the minimum mean size of *Trcohus* i.e. 9.31 cm was recorded at North Andaman while maximum mean size (12.73 cm) encountered at Nancowry Islands.
9. Like numerical density, all the islands of Nancowry group shown larger specimens upto the maximum size of 13.62 cm.
10. The epitome of the status survey revealed that the density and size of the *Trochus niloticus* is comparatively higher in the Nicobar group of Islands than Andaman group. Apart from that in Middle and North Andaman were shown moderately high density of animals.
11. The results on standing stock of *Trochus* in Andaman and Nicobar waters estimated in the present study was quite significant as the natural stock of *Trochus* in these archipelago is marginally higher than their density in Great Barrier Reef.
12. It indicates that the ban on fishing of *Trochus niloticus* in Indian waters and inclusion of these gastropods in Schedule-IV of Wildlife (Protection) Act (1972) since 2001 made a greater impact for the recovery of their natural population in an optimal size over the period of 10 years.

ILLEGAL FISHING AND TRADING

1. Although ban has been imposed for fishing *Trochus niloticus* since 2001 as per the Wildlife Protection Act 1972, sporadic reports on poaching, illegal fishing and trading of these species in Andaman and Nicobar waters have been observed.
2. Despite the awareness about its ban, fishermen are engaged in illegal practices for their livelihood.
3. As the entire Andaman and Nicobar Islands is repository for *Trochus niloticus*, illegal fishing on this species is noticed in few localities such as Middle and North Andaman, Little Andaman and some parts of Nicobar Islands especially in Kundol Island.
4. It is also reported that seizure of several tonnes of *Trochus niloticus* trade in North, Middle and South Andaman by the law enforcing authorities.
5. As per the statements received from the local fishermen communities, it is understood that poachers from neighbouring countries especially Burma and sometimes from Indonesia are entering the Andaman and Nicobar waters exclusively for the exploitation of our country's rare and precious biological wealth such as top shell *Trochus niloticus*, turban shell *Turbo marmoratus,* king shell *Cassis cornuta,* giant clams and also for Holothurians as they have lucrative potential in international market. It is also evinced that neighbouring countries boats are being seized periodically by the law enforcing authorities in Andaman and Nicobar Islands for past few years.

SUMMARY

1 *Trochus niloticus* (Linnaeus, 1767) is a marine gastropod belongs to the Prosobranchia subclass, Archaeogastopoda order and Trochidae family. The *Trochus* or topshell is flat-based conical shells found in tropical and temperate waters.

2. A total 72 species within the genus *Trochus* have been reported worldwide. Among them 6 species viz. *Trochus niloticus* Linnaeus, 1767; *Trochus maculatus* Linnaues, 1758; *Trochus (Infundibulum) radiatus* Gmelin, 1791, *Trochus (Infundibulum) ochroleucus* Gmelin, 1791; *Trochus (Infundibulum) pustulosus*, Philippi, 1849 and *Trochus (Belangeria) scabrosus* Philippi, 1850 are found in Indian waters.

3. Among the seas shells, *Trochus* or Top shell and *Turbo* or Turban shell have unique position in commercial point of view. *Trochus niloticus* are commercially important gastropods, distributed in the coral reefs of Andaman and Nicobar Islands. *Trochus* fished for its meat and mother-of-pearl shell.

4. *Trochus* shells are also used in the preparation of ornaments like earings, pendants, necklaces and household articles such as table lamps, ashtrays, agarbatti stands, door hangings etc. These are also used in the lime industry, poultry feed additives and the fine lime obtained from the shell is used in pottery glazes, toothpaste etc.

5. *Trochus niloticus* has been commercially exploited for several decades since from the establishment of a regular *Trochus* fishery in October 1929 at Andaman Islands.

6. World production *Trochus niloticus* is currently estimated to be between 3000 and 6000 tons, making this species one of the most valuable gastropods in the world market both for shell and for meat.

7. *Trochus* grows fast during the first 2-3 years upto a size of 8-9 cm of base diameter and then it slows down. It may take about 10 years for the snail to attain a maximum shell diameter of 12 cm. The age of *Trochus* in the Andamans is shown to exceed ten years, and the incidence of morality due to disease or old age is indicated to be low.

8. It inhabits the intertidal and shallow subtidal zones. Its preferred habitat is the moderately exposed coral reef shore. It is abundant on open coasts exposed to rough weather but rate in protected areas.

9. Its natural distribution ranges from the Andaman Islands in the Indian Ocean to the Pacific Islands of Fiji and Wallis, including Palau, Yap, Papua New Guinea, the Solomon Islands, Vanuatu, and New Caledonia, and the north and north-eastern coasts of Australia.

10. Due to indiscriminate fishing of shells of all sizes by both the licensed and unlicensed fishermen in India, the present day, the *Trochus* beds of the Andaman waters are getting rapidly depleted. In consequence upon the depletion of population, the Government of India, Ministry of Environment and Forests vide notification dated 5th December 2001 brought these species under Schedule IV of the Wildlife (Protection) Act, 1972.

11. The present status survey on *Trochus niloticus* was carried out during August 2009 to March 2010 at 79 stations covering entire Andaman and Nicobar Islands to assess their distribution and standing stock on its natural parameters along the primary and secondary productivities in their ambience.

12. The mean surface sweater temperature ranged from 27.6 to 28.04°C at Nicobar Islands and Little Andaman Island respectively. Salinity of the seawater varied from 33.75ppt at North & Middle Andaman to 34.11 ppt in Ritchie's archipelago. The turbidity of seawater was also measured by Nudson Turbidity Unit (NTU) and it found minimum (577.08) at Middle & North Andaman and maximum (679.44) at South Andaman.

13. A total of 77 species of phytoplankton belonging to 55 genera were recorded from the study area. Among them the maximum of 54 species obtained from Nicobar Islands while the minimum of 45 species recorded from Ritchie's Archipelago. The total mean cell count of phytoplankton was encountered as high, $97.17\times10^{2}L^{-1}$ at Little Andaman and as low $71.30\times10^{2}L^{-1}$ at Ritchie's Archipelago.

14. Altogether, 96 species of zooplankton belonging to 19 groups were recorded from the study area. However, total number species observed at South and Little Andaman, Ritchie's Archipelago, Middle and North Andaman and Nicobar Islands were 65, 65, 80 and 67 respectively. The numerical density of zooplankton varied from 19195 to 23105 no./100m^3 for Ritchie's Archipelago and Little Andaman respectively.
15. Extensive undersea and intertidal surveys revealed out the occurrence of *Trochus niloticus* throughout the sublittoral zone of continental shelf of Andaman and Nicobar Archipelago up to the depth of 20m
16. It is surprise to note that absence of turban shell *Turbo marmoratus* in the surveyed area indicated the near extinction of the population of this scheduled gastropod in Andaman and Nicobar waters.
17. The numerical density of *Trochus niloticus* found in the depth ranges between 10 and 20 m at all the places of study.
18. The mean numerical density of *Trochus niloticus* varied from 6 shells/100m^2 in the coastal waters of South Andaman to 15 shells/100m^2 in Nancowry Islands.
19. The numerical abundance of *Trochus niloticus* was maximum in Nancowry group of Islands and it recorded upto 20 shells/100 m^2 and also the larger specimen upto the maximum size of 13.62 cm has been observe at this region.
20. The observations of the present study revealed that the density and size of the *Trochus niloticus* is comparatively higher in the Nicobar group of Islands than Andaman group. Apart from that in Middle and North Andaman were shown moderately high density of animals.
21. It is inferred that the ban on fishing of *Trochus niloticus* in Indian waters and inclusion of these gastropods in Schedule-IV of Wildlife Protection Act (1972) since 2001 made a greater impact for the recovery of their natural population in an optimal size over the period of 10 years.
22. Certain recommendations have been drawn for the effective management and rational utilization for the livelihood of the fisher-folk of Andaman and Nicobar Islands.

RECOMMENDATIONS

Based on the present stock assessment on *Trochus niloticus* carried out along the Andaman and Nicobar Islands, the following recommendations are drawn for the effective management of the standing stock of these gastropods in these islands :

1. Considering the present population and standing stock of *Trochus niloticus* in Andaman and Nicobar Archipelago over the past 10 years, i.e. 6-20 shells/100 m^2 (mean value) observed through the present survey, ban on fishing of these economically important gastropod species may be lifted initially for three years on temporary basis for the rational utilization/exploitation of these shellfish resources.

2. In view of the present population status of *Trochus niloticus*, it is recommended that the species may be denotified from the Schedule IV category of Wildlife Protection Act (1972) for the period of three years to enable the fisher-folk for rational utilization.
3. The sexual maturity in these gastropods occur when the shells attain 6-8cm maximum diameter, hence, the animals having shell diameter of 9.0cm and above may only be permitted for commercial exploitation from this islands, if ban lifted.
4. It is inferred that the breeding of *Trochus niloticus* in Andaman and Nicobar waters is continuous and the spawning probably begins immediately after warm season i.e. April to September. The period between April and September should be declared as a closing season for *Trochus* fishery.
5. In order to regularize the *Trochus* fishery, licences may be issued to selected fishermen in different fishing zones as adopted in 1930s by the Andaman and Nicobar Administration.
6. As the *Trochus niloticus* is coral reef dwellers, the corals, other scheduled molluscs and holothurians in the reef environment should not be disturbed while picking up this target species.
7. It is also pertinent to conduct a stock assessment studies on *Trochus niloticus* after completion of the three years of fishing to evaluate the status of these animals in their natural beds for the consideration of further extension of fishing permit subsequently.
8. Scientific research should be encouraged to find out the reproductive cycle, spawning behaviour, longevity, fecundity and zoogeography which will helpful to draw effective management strategies for conservation.
9. Creation of awareness about the importance of *Trochus* among the fisher-folk not only for their economic value but also for their ecological significance for the rational utilization, as they distributed only in Andaman and Nicobar waters of our country.
10. Stringent measures may be taken to prevent the intrusion of foreign poachers in the territorial waters Andaman and Nicobar Islands.

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Raw *Trochus niloticus* shells to be processed

Cleaned and polished *Trochus niloticus* shells

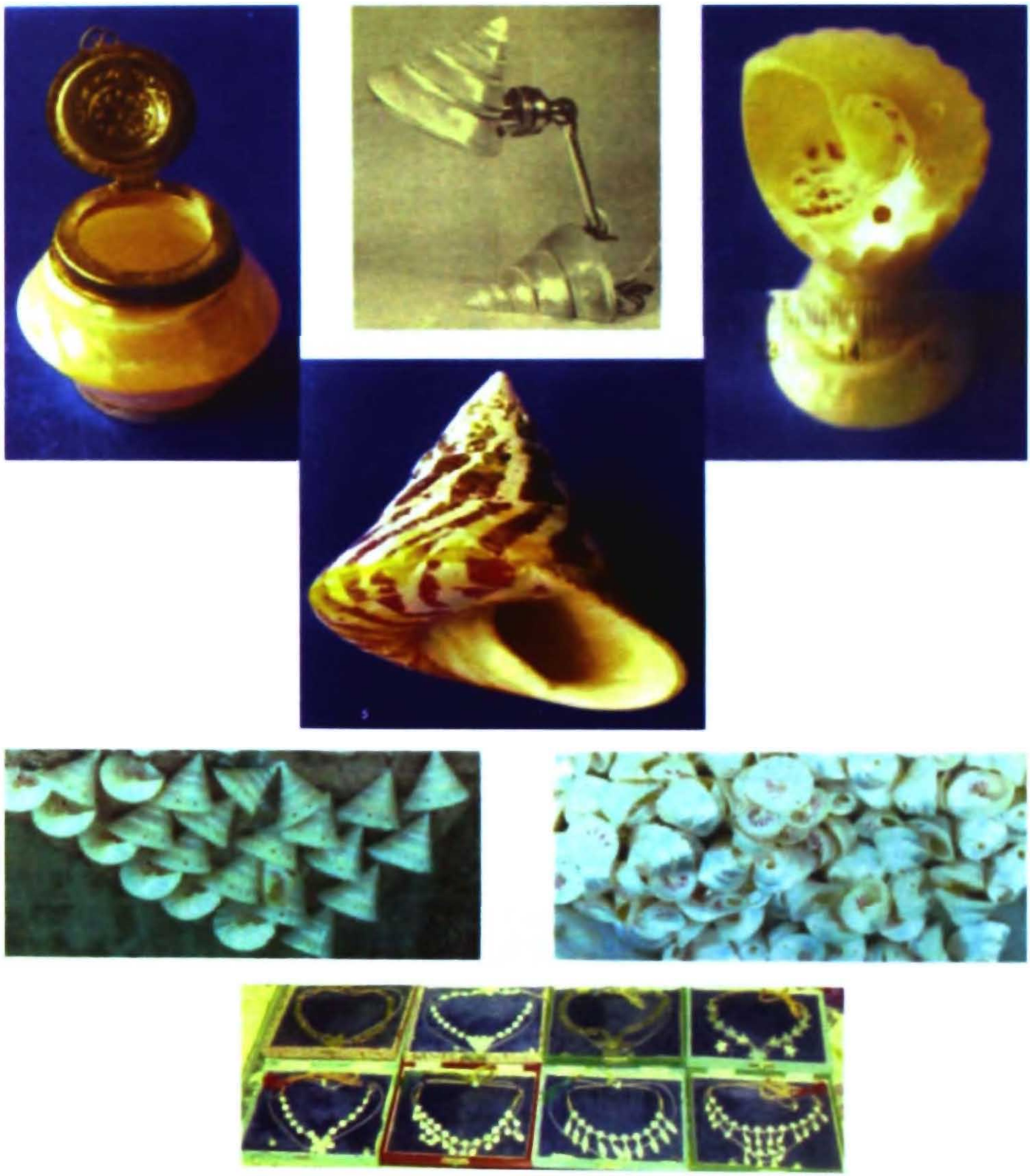
Cutting and grinding of shells

Cleaning of cut *Trochus* with acid

Cleaning of cut *Trochus* with acid

Wire brush for polishing the shells

Processing of *Trochus niloticus* shells



Value added products from *Trochus niloticus* shells

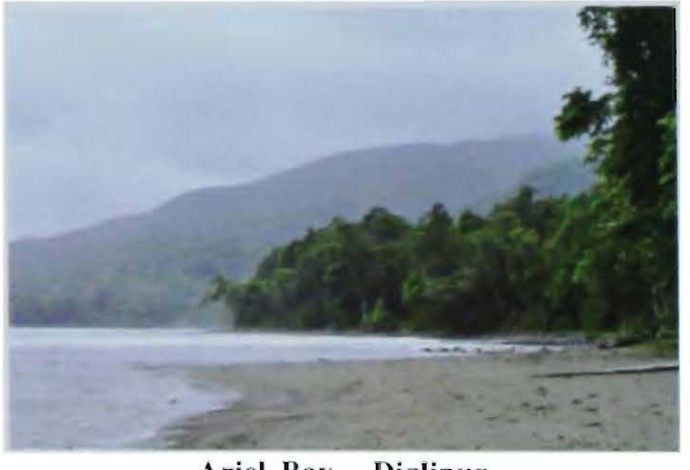
Display of Jewellery made out of *Trochus niloticus* shells

Interview Island

Karmatang - Mayabunder

Avis Island

Sound Island



Ariel Bay - Diglipur

Lamia Bay - Diglipur

North and Middle Andaman

Neil Island

Havelock Island

Inglis Island

South Button Island

John Lawrence Island

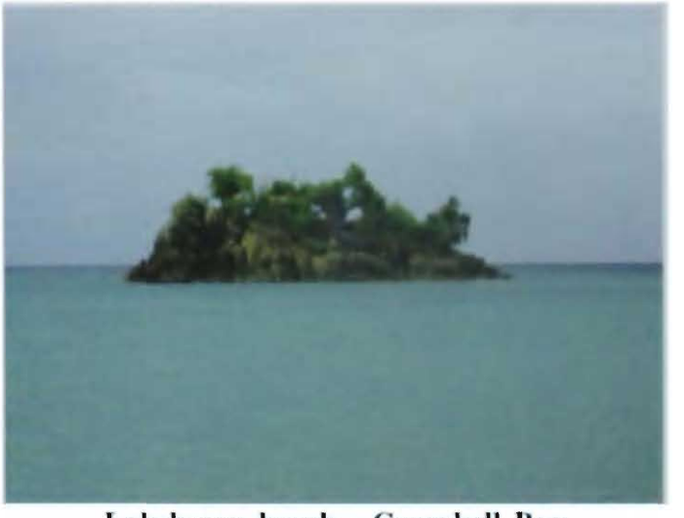
Henry Lawrence Island

Ritchie's Archipelago

Indira Point

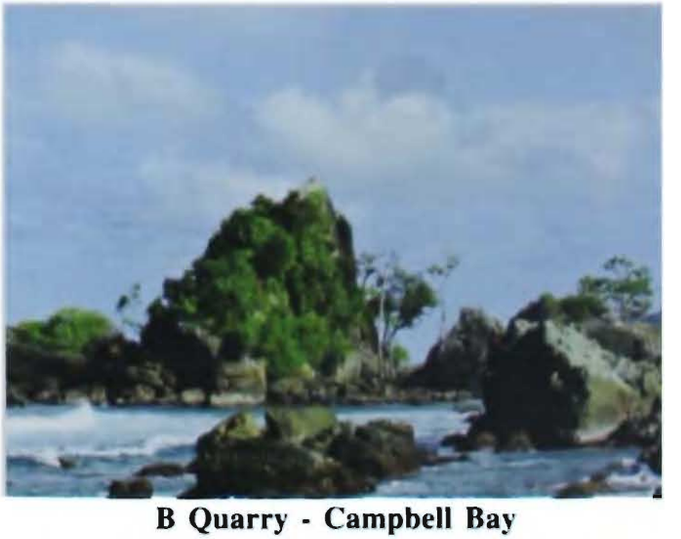
Indira Point

Johinder Nagar



Lakshman beach - Campbell Bay

Kondul Island



B Quarry - Campbell Bay

Great Nicobar Island

Chidiyatappu

Rutland Island

Rutland Island

Grub Island

Jolly Buoy Island

Wandoor

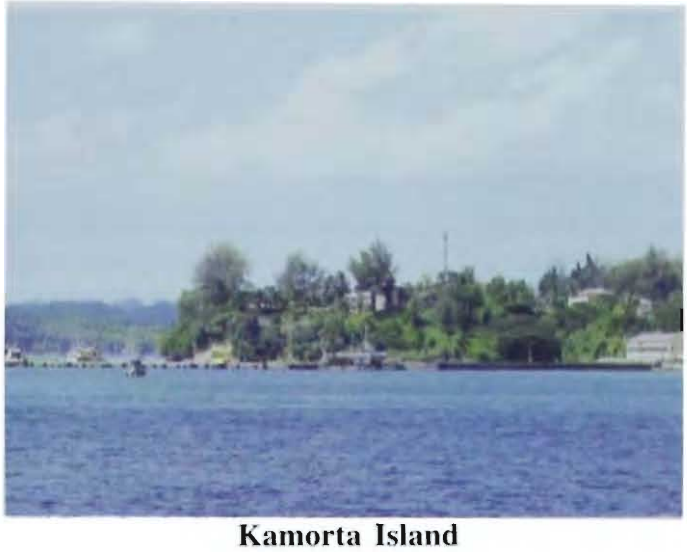
South Andaman

Car Nicobar Island

Katchal Island

Katchal Island

Teressa Island

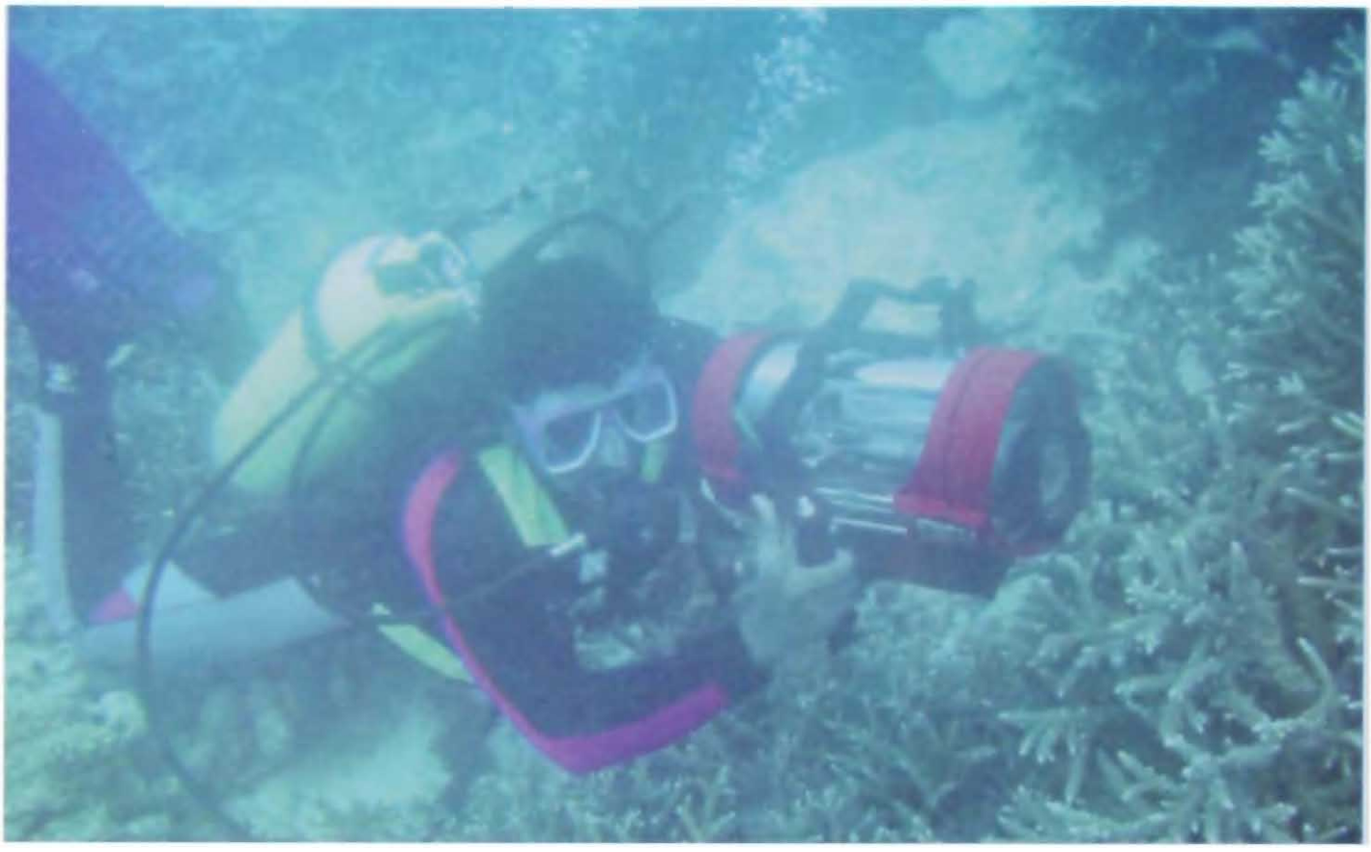


Kamorta Island

Kamorta Island

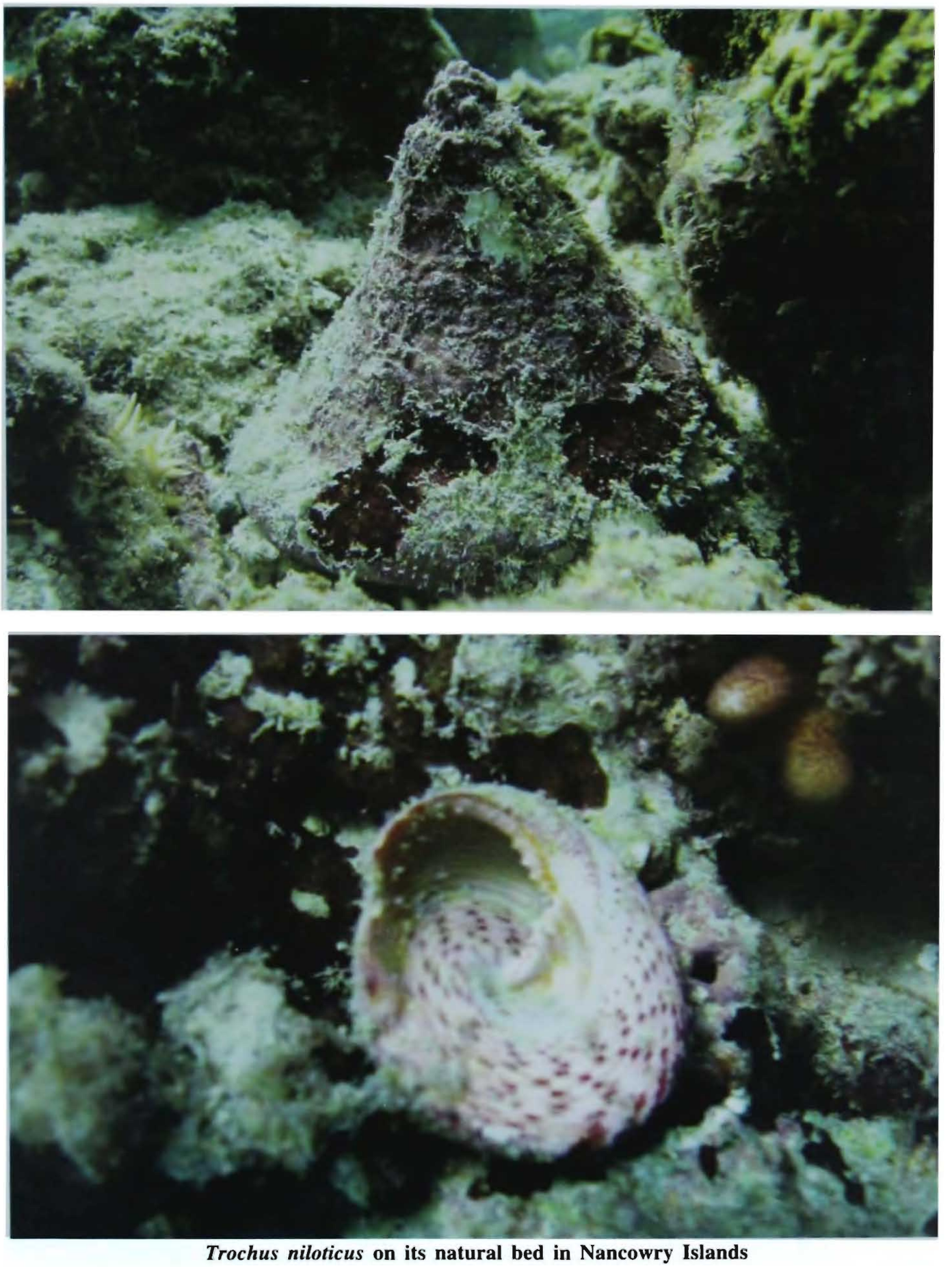
Tinket Island

Nancowry Group of Islands

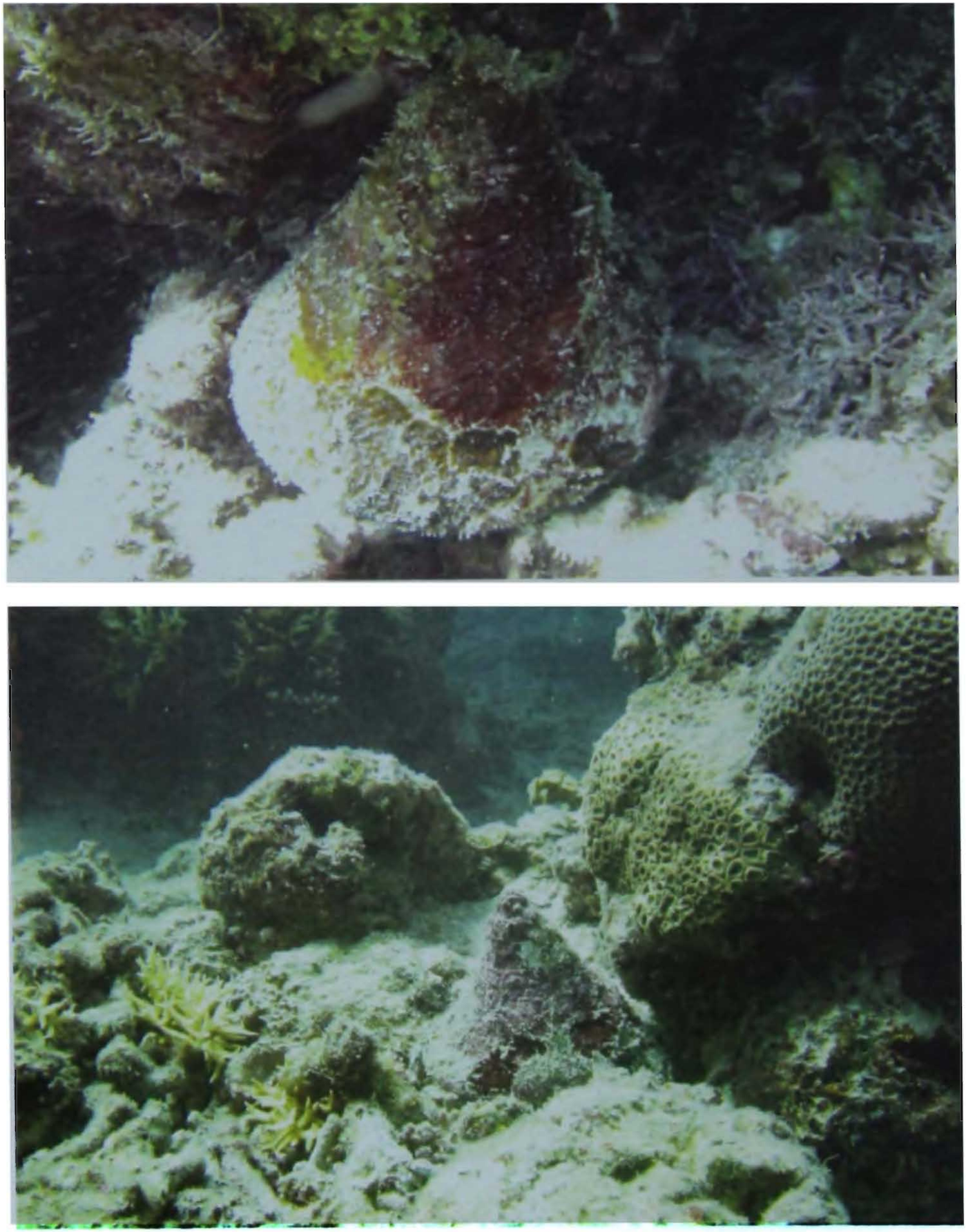


Underwater videography

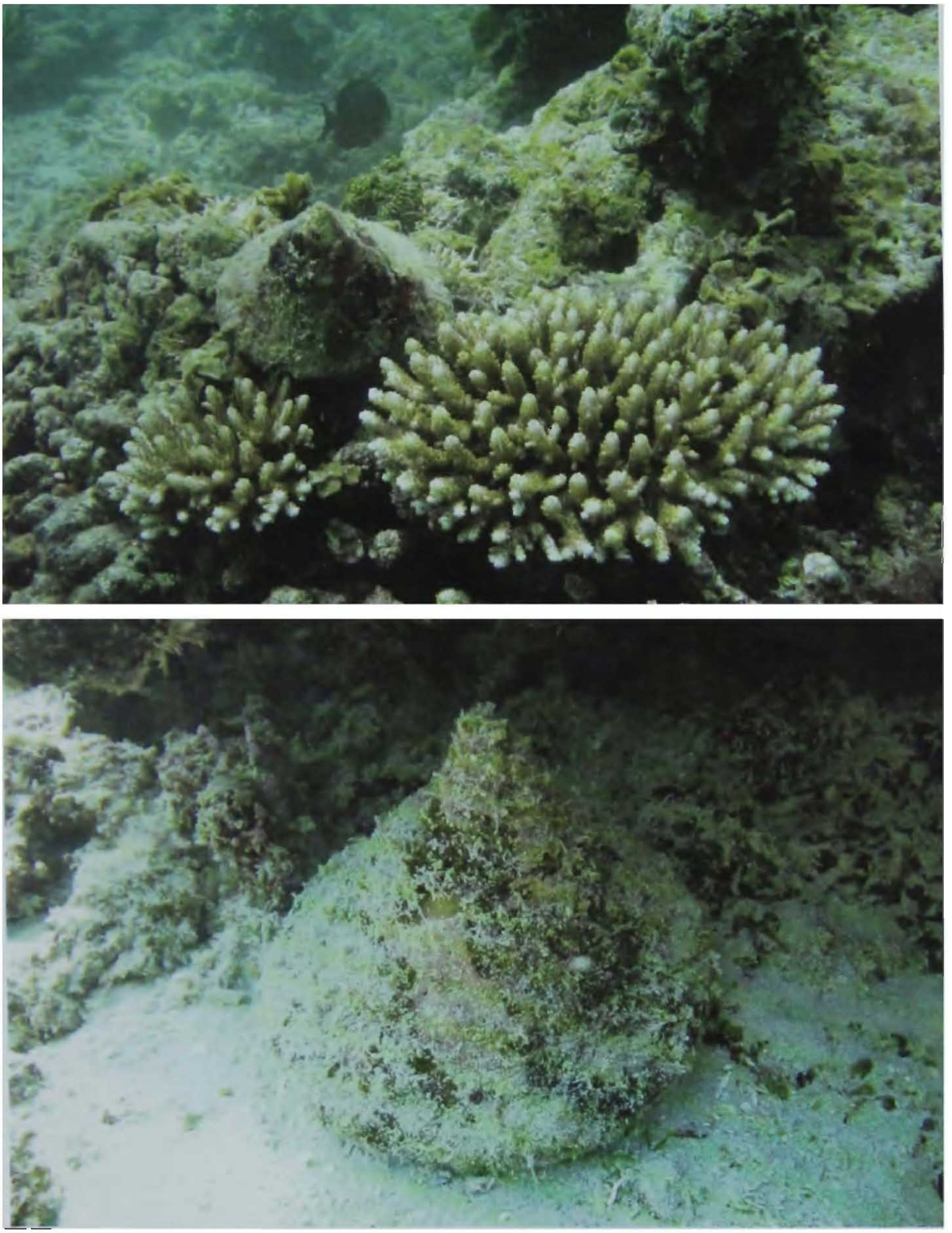
Underwater photography and data collecting



***Trochus niloticus* on its natural bed in Nancowry Islands**



Trochus niloticus **on its natural bed in Car Nicobar Islands**



***Trochus niloticus* on its natural bed in North and Middle Andaman Islands**

Trochus niloticus in Ritchie's Archipelago

***Trochus niloticus* in Avis Island**

Trochus niloticus **in Rutland Island**