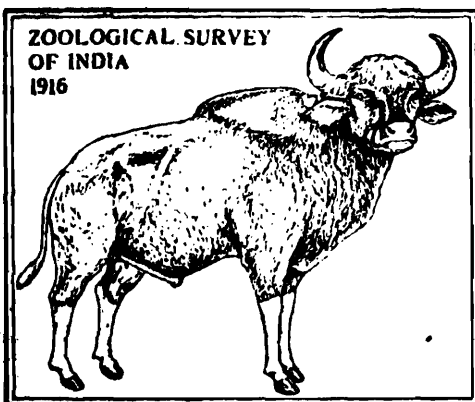


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DEEP-WATER FISHES OF INDIA

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Zoological Survey of India, Calcutta

Introduction

The oceans occupy about 71 percent of the earth's surface and most of their waters are relatively deep. The oceanic fishes form two main ecological groups depending on their relationship to the ocean floor. Swimming and floating between the surface and the deep-sea floor are the pelagic fishes, below these come the benthic fishes living near or at the bottom.

Through experience gained in working with marine organisms, biologists have devised the classification of the following major environmental divisions (Fig. 1): Epipelagic (sunlit) zone reaching the upper 200 metres, followed by the Mesopelagic (or twilight) zone extending to a depth of about 1000 metres, a Bathypelagic (sunless) zone reaching about 6000 metres and overlaying the entire abyssal plain, ultimately a Hadopelagic (Trench) zone occupying the deepest areas below 6,000 metres. The upper 200 metres zone is a distinct habitat and is, on the basis of its characteristic biota, quite distinct from the deeper waters.

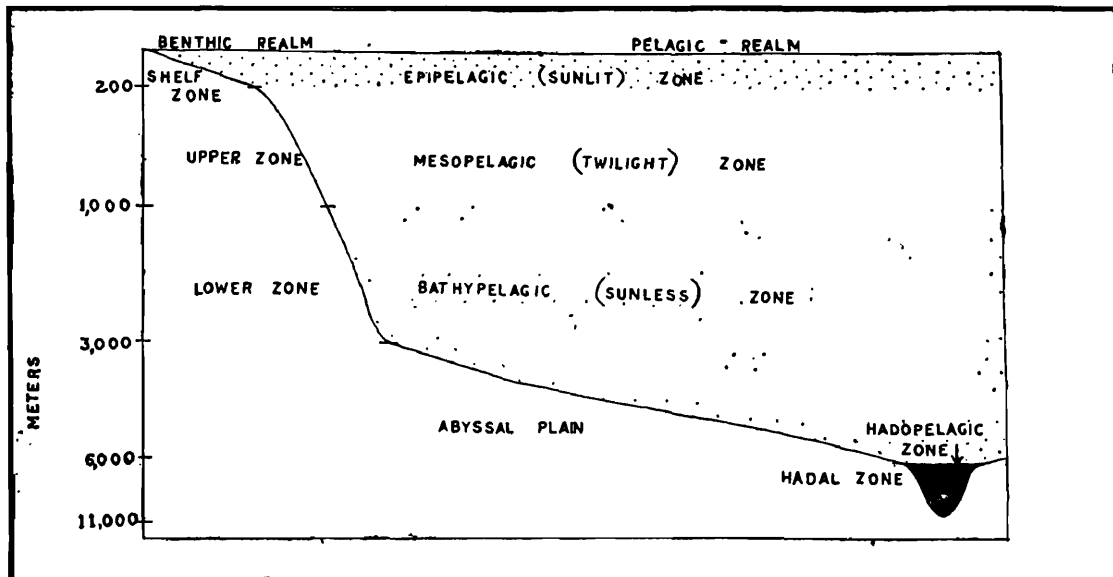


Fig. 1. Classification of marine environments

The epoch voyage of the H. M. S. *Challenger* to explore the seas of the world during the period 1872—1876, marks the beginning of modern oceanography. The *Challenger* dredged the abyssal plain to a depth of more than 5000 metres and found life everywhere. Although the *Challenger* did not work off the coasts of India, many of the fishes collected during its cruise are known to range throughout the world, including off our shores. The success of the *Challenger* inspired other expeditions, some of the most notable in our region being the R. I. M. S. *Investigator* (1885—1925) sponsored by the Asiatic Society of Bengal, and the *International Indian Ocean Expedition*. R. V. *Conch* of the University of Kerala and R. V. *Varuna* of the Central Marine Fisheries Research Institute, Cochin, made several deep-water trawls along the edge of the continental shelf off the Kerala coast between 1959 to 1969 and caught several interesting fishes.

Adaptations

The deep-sea environment creates unique problems for its fishes that the shallow-water species do not encounter. Three factors that probably have the greatest influence upon the lives of the animals living at these depths are the failure of solar radiation to penetrate very far beneath the surface, the lack of seasonal change, and the absence of primary organic productivity. Because of these adversities, deep-living fishes have developed an array of unusual structures, functions and behavioral patterns which increase their chances of survival both as individuals and as species. One of the most striking of these adaptations is colour. Most of the fishes are black or dark brown, and a few species are red (the first portion of the colour spectrum filtered out by sea-water, so red appears black at relatively shallow depths). Since survival ultimately depends upon success in feeding and reproduction, the adaptations exhibited by deep-sea fishes appear to be designed to assist in carrying out these two functions. Food gathering adaptations include angling devices, distensible stomachs, extremely large mouths, formidable and often erectile jaw teeth for catching and holding prey, enhanced visual acuity and many others. Reproductive success may be directly enhanced by development of luminescent photophores which aid in mate recognition, by the development of functional hermaphroditism among many groups, by the presence of parasitic males and by other helpful but less spectacular specialisations.

Deep-sea fishes show numerous other modifications. The skeleton tends to be poorly developed, weakly ossified and lightweight (apparently helpful in maintaining buoyancy with a minimum of effort); many species are scaleless (possibly of hydrodynamic importance); many larvae are transparent and live in shallower environments; larval forms may be stalk-eyed as well as transparent (possibly helpful in floatation and evasion of predators); and some predatory

species have black-lined stomachs, as the luminous fishes swallowed may "light up" during death struggles and make the predator an easy meal for a larger fish. Certain species show behaviour patterns related to morphological features although cause of such may not be obvious. Fishes residing above 1000 metres commonly have well developed gasbladders and demonstrate extensive diurnal migration. Those living below 1000 metres lack well-developed gas-bladders and do not migrate toward the surface at night.

Fishes

Recent work has shown that populations of most deep pelagic fishes are concentrated between depths of 200 and 1000 metres. During the last decade the Zoological Survey of India has been carrying out a systematic ichthyological survey of the neritic deep water and the upper continental slope of our region. Each successive year has yielded additional new-to-science fish species from off our shores. The most recently described fishes from the benthic realm are *Aprobucca trewasae* recorded by Talwar & Sathiarajan from off Madras, and *Ocosia ramaraoi* by Eschmeyer & Poss. One noteworthy feature is that unlike the species trawled in the continental shelf area, those from the continental slope are relatively smaller in size. In addition, the water content in the meat being high, the flesh in most of the species of the continental slope is not firm when compared to shallow-water species.

A glimpse in the fish life beyond 200 metre depth is obtained by dredging or trawling down the continental slope (sea bed) with an otter trawl. The otter trawl is essentially a large baglike net with the foot-rope weighed by sinkers, and the head or cork-line provided with floats. It is provided with a pair of boards or 'doors' which act like kites under water, spreading out the net as it is pulled along the bottom. The commercial trawl which had worked primarily on the bottom had also fished well in the water masses during retrieval, providing the best available assay of the deep-water fishes.

Certain groups of fishes are relatively easy to capture by deep trawling. Among these are the batoid fishes (skates and rays) belonging to family Rajidae. There are several slope species belonging to the genera *Raja*, *Breviraja* and *Cruriraja*. The catsharks of the family Scyliorhinidae are a typical upper-slope group. Two squaloid sharks (family Squalidae) of the genera *Echinorhinus* and *Centrophorus* have been reported quite recently from the upper continental slope in our region.

Flat fishes, which are so dominant on the soft mud of the continental shelf, have been less successful in adaptations to deeper water. One of the remarkable flatfish is the deep-sea turbot (*Chascanopsetta lugubris* Alcock) which is common in the trawl catches at a depth of about 300 metres. Whereas

flatfishes usually have a small mouth capable of catching only small bottom-dwelling animals, this flatfish has an immense gap with long, movable teeth. It has become adapted to catching fish and, like many deep-sea fishes can swallow a disproportionately large prey. Other flatfishes common on the upper continental slope are *Arnoglossus arabicus* Norman, *Cephalopsetta ventrocellatus* Dutt & Rao, *Laeops macrophthalmus* (Alcock), *Poecilopsetta colorata* Gunther and *Cynoglossus carpenteri* Alcock.

Another dominant fish group over the continental slope are the rat-tails (family Macrouridae). There are several of these in our area, the most common being *Malacocephalus laevis* (Lowe). The rat-tailed fishes are confined to deep water, though a few may occasionally venture over the continental shelf. They are extremely typical of their habitat having a large heavily armoured head with striking larger eyes, usually a chin barbel, and a rapidly tapering body which terminates in a thread-like tail tip. Rat-tails also have a well-developed lateral line and it contains pressure sensitive organs. This is essential when the fish frequents deep waters where not even its large eyes can penetrate the absolute dark. The cods (family Gadidae) also form an important contingent of fish on the continental slope. This group is represented primarily by one species, *Physiculus argyropastus* Alcock.

The brotulids are well represented in the trawl catches from the benthic realm. These fishes provide a good example of parallel adaptations while pursuing a common mode of life. In fact, many brotulids so closely resemble rat-tails, that at first sight even a specialist may have difficulty in distinguishing them, though they are not closely related.

In the upper slope one of the most interesting fishes from the point of view of natural history, is the star-gazer (*Uranoscopus crassiceps* Alcock). It is rather clumsily built, having a large, angular head with small eyes placed close together on the top and a completely vertical mouth. They have the habit of burying themselves in the sand only with their eyes visible. They are well protected both by their greyish colour and by their ability to inflict a painful shock by means of electric organs behind the eyes, formed by a modification of part of the eye musculature. Another striking fish discovered in recent years was *Sphenanthias whiteheadi* Talwar which was crimson in colour with the conspicuous 'owstoniid mark', a hidden jet-black blotch on the membrane connecting the maxillary and premaxillary. This fish belongs to the family Owstoniidae, a small family of deep-sea fishes of tropical seas, rather rare and poorly known.

Of the scorpion-fishes (family Scorpaenidae) which are fairly prominent over the continental shelf, few have ventured into deep water. Off the Kerala coast I collected numerous specimens of *Snyderina guentheri* (Boulenger) and

Pontinus tentacularis (Fowler) which were not earlier known from our area. I also obtained several specimens of the genus *Ocosia* which Drs. Eschmeyer and Poss of the California Academy of Sciences, found to represent a new species. The searobins (family Triglidae), very prominent on the continental slope, have a casquelike, bony head, and the lower two or three pectoral fin-rays enlarged and free, used for detecting food.

The strange *Ateleopus indicus* Wood-Mason & Alcock, and *A. natalensis* Regan belonging to the family Ateleopodidae of the order Lampridiformes, are rather rare in our region. The whole of their elongated body is translucent and almost gelatinous, and its skeleton cartilaginous.

The *Investigator* obtained many species having luminescent organs particularly belonging to the families Gonostomatidae, Sternoptychidae and Myctophidae. The greeneye, *Chlorophthalmus agassizi* Bonaparte (family Chlorophthalmidae) with its colossal eyes, is a typical representative of the fishes which inhabit depths where the light is dim, yet strong enough enlarging the eyes to be beneficial. This species occurs in large shoals off the Kerala coast and from bulk of the fish catch within this depth range. Fishes of the genus *Bathypterois* (family Bathypteroidae) represented by three species in our seas, are near relatives of *Chlorophthalmus*, but inhabit even greater depths, possess very small eyes which have probably ceased to have practical importance. As compensation, these fishes have evolved tactile organs in the form of free fin rays, often greatly prolonged. Lantern fishes (family Myctophidae) are less than 15 cm. long when adult as is true of many other deep-water fishes. They have a normal, compact, fish-like shape and eyes large for their size; along the underside are two series of pearly photophores, while in the head and flanks these organs form a pattern by which each species may be recognised. At night many of these fishes approach the surface. Suda (1973) has drawn attention to the large potentiality of myctophids in the Indian ocean and has indicated the importance of this resource in view of their high vitamin 'A' content as well as oil content (110 litres per ton). I, however, believe that the greatest value of the myriads of mesopelagic and bathypelagic fishes is in providing forage for predatory species, some of which (e.g. tunas, sword fishes etc.) are heavily exploited by man. However, some ichthyologists feel that the greatest potential of these fishes is to satisfy man's intellectual curiosity regarding the functional significance of their diversified and sometimes bizarre adaptations.

Stomiid and melanostomiid fishes have rather slim or very elongated black or dark brown bodies, and the dorsal and anal fins set near the tail as in the barracuda. Besides the luminescent organs on the head and trunk, there is a barbel below the mouth which in some species bears luminescent tissue and may well be a lure. Fishes of the family Astronesthidae have

the body covered with small luminous organs and, like the stomiatids, carry a barbel springing from the lower jaw. Angler-fishes (family Ceratioidae) are also found in deeply towed nets. The ceratioids have the first ray of the spinous dorsal fin set on the snout and modified into a rod and bait. In most species the bait is luminous, the lighting being under the control of the fish; the males are much smaller and during the breeding season the males attach themselves to a partner by gripping her skin with their jaws.

The order Zeiformes, including two families (Zeidae and Caproidae), is entirely upper slope: this is represented by *Zen itea* (Jordan & Fowler), *Zenopsis conchifer* (Lowe) and *Antigonia fowleri* Fowler, all surprisingly not reported until recent times from our area. Other slope families of interest in our region are the Triacanthodidae (Spikefishes), Priacanthidae (Bigeyes), Polymixiidae (Beardfishes), Berycidae (Alfonsinos), Holocentridae (Squirrelfishes), Pentacerotidae (Boarfishes), Trachichthyidae (Slimeheads), Nomeidae (Driftfishes) etc.

Remarks

It has been observed that most species of deep-sea fishes are bound narrowly to the continental slopes where food is more plentiful than the abyssal reaches (Marshall, 1954). The pelagic and benthic fish fauna of the trenches is very poorly known in view of the inherent difficulties in collecting them. The perpetual darkness, the temperatures near freezing point, the slight variation in the chemical composition of the water and above all, the pressure determine the special characteristics of the hadal fauna, of which many of the forms are as bizarre and arraying as those of the continental slope.

Acknowledgements

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DEER AND ANTELOPES OF INDIA AND THEIR CONSERVATION

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India was once considered to be an animal paradise, comparable to East Africa. Even to-day few countries in the world have such a remarkably rich and diversified fauna as India has : Asian lion ; tiger ; leopard ; clouded and snow leopards ; Himalayan black, brown, and sloth bears ; rhinoceros ; elephant ; wild buffalo ; gaur ; wild ass, sambar, Manipur thamin, musk, spotted, hog, and swamp deer ; chinkara ; black-buck ; chowsingha ; nilgai ; Himalayan and Nilgiri tahr ; serow ; goral etc. still remain the most precious among Indian wildlife. In the past their populations were spectacular. Swamp deer were known to crowd the reed beds of the Indus and Ganga in herds of thousands. Similar herds of 10,000 blackbuck were estimated in the Punjab. As late as the 16th century, rhinoceros and buffalos which favour moist conditions were to be found in areas of western India which are desert or semi-desert to-day.

The factors responsible for the depletion of our wildlife are (1) destruction or degradation of habitat (ii) hunting by man and (iii) competition from domestic stock. The increasing human population has posed the greatest threat to our wildlife as the needs of man have gradually driven the flora and fauna farther and farther afield. The changes in land use during the last two decades, particularly opening up of forests for agriculture and plantations, and setting up of hydroelectric projects have been responsible, to a greater extent, for rapid depletion of our wildlife. Further, the indiscriminate use of fire-arms, leading to a devastating effect on Indian fauna, can hardly be overlooked. The cumulative effects of the needs of man and ceaseless poaching have brought about such a decline in the country clings to small vestige of its former range.

In the present article, only the deer and antelopes are being included. There is some amount of confusion on the popular level, between the deer and the antelope among the nature's most beautiful creatures of the forest. For a trained observer, however, it is not very difficult to distinguish between the two. The deer belongs to a zoological family known as *Cervidae* and

the antelopes to *Bovidae*. All such animals as oxen, sheep and goats, domestic and wild, as well as the antelopes are members of the same family.

Both of these animals namely the deer and the antelope belong to the great group of hoofed mammals. There are evidently some characters, not clear to general observer which are of importance to the scientists in distinguishing between the two. Here only a few characters are being discussed briefly for the common readers to help them in understanding their distinguishing feature. In the external feature the deer and the antelope are more or less similar, yet they differ in several respects. The most pronounced difference is at once observable in the structure and shape of their horns. The adult male or stag, in most of deer in India, excepting the musk deer, are furnished with solid, graceful, branched horns called antlers, while the adult female or hind is devoid of it. In the yearling *i.e.* young male, the antlers merely form simple spikes, but in the full grown individuals it assumes a more or less complexly branched structures especially during the rut period. After the rut, the deer generally, shed their antlers off, which regrow to the same massive structure by the next rutting season. The facial fissure or the lachrymal fissure in the skull of the deer, below each of its eye, is prominent.

It is believed that antelopes represent the original stock from which oxen on the one hand and sheep on the other were derived. The antelopes, as a group cannot be placed either with the oxen or with the sheep and goats since they bear characters common to both. The antelopes are graceful in built with horns, which may or may not be present in the female. These horns consist of two parts, a hollow outer covering and a core of bone. It is generally long more or less cylindrical and throughout completely ringed. The horns in antelopes are permanent. If lost in accident the antelope is incapable of regaining them again. The lachrymal fissure unlike that of the deer is not prominent.

The canine teeth of the upper jaw are always developed in deer, they offer a ready means of distinction from the antelopes, none of which have upper canine. With the exception of musk deer, no member of the deer family has a gall bladder so constantly present in the antelopes.

In general, both the deer and the antelope are alert, when at rest, they all carry the head well above the line of the back, the ears are always well developed and normally large, the tail is frequently very short. All senses are highly developed, acute scent, hearing, speed of movement and probably sight are the essential means of escape for these animals.

In deer, normally a forest dweller, vision is often greatly restricted and is generally of limited use, but scent and sound are of great importance and are used constantly. The spirit of curiosity is much more strongly

developed in the hind than in the stag, the former being always the first to approach a strange object. The stag seems indeed to be largely dependent on the hind as to its movement in all cases of doubt. The leadership of a herd is usually vested in an old and vigilant female. Most of the deer are well covered with coarse and stiff hair especially in winter but frequently with finer ones in summer. Often this leads to a marked difference between the colouration of the summer and the winter coats which is not only distinct change at the time of assumption of each pelage, but minor changes go on almost continuously throughout the year. On the approach of the pairing season the stags, normally exchange their habitually peaceful disposition and become extremely pugnacious towards one another as a result of sexual jealousy among them. Most of our deer do not have a fixed breeding season.

The population of deer in India has greatly declined. The species that are still found in our land are :

(i) **Chital or Spotted Deer (*Axis axis*)** (Fig. 1) : It is one of the most beautiful of all deer. A well-built stag stands approximately 90 cm. at shoulder and weighs about 85 kg. The antlers are large with three points in each. They can be seen in big herds grazing in the open areas of Indian forests.

(ii) **Hog-Deer (*Axis porcinus*)** : It is allied to chital but slightly smaller and stouter in built. The height at shoulder is approximately 60 cm. They are less gregarious in habit. The name hog-deer has been derived from its hog-like movement. It is essentially a dweller on open alluvial flats where it generally prefers grass-clad.

(iii) **Sambar (*Cervus unicolor*)** (Fig. 2A & B) : It is the largest among the deer of India having an approximate height, 140-150 cm. at shoulder. The weight of a full grown stag varies from 225-320 kg. The antlers are massive with three points in each. They are graceful in movement and are found in groups of one to four in the undulated high hills and thick forests of India.

(iv) **Hangul or The Kashmir Stag (*Cervus elaphus hanglu*)** : This is supposed to be a representative of the European red-deer (*Cervus elaphus*). It is a little smaller and less robust than Sambar, but has a magnificent spreading antlers with 5-8 points in each. In summer with fine weather and abundant food hanguls are scattered in small parties at high elevation from 2785-4000 metres and in winter when food is scarce and the weather severe they shift to lower levels in between 2480-1550 metres. They are migratory in habit and feed on sprouting grass and budding larches, wandering a great deal from one glade to another. Except in the pairing season, adult stags and hinds do not associate freely, but probably lead to some extent independent lives in large or small herds. Once it was widespread in Kashmir but now,

it is restricted to the northern and the adjacent valleys of Kashmir. The decrease in the population of this deer is alarming. They are estimated to be about 200 in Dachigam near Srinagar and about 100 elsewhere in Dessu in the Bringi valley and Chumki, Overa and Khiram in the Lidder valley.

It may be added here that there used to be another species the Shou (*Cervus elaphus wallichi*), inhabiting Chumbi valley of Tibet, which drives a wedge between Nepal and Sikkim, and very occasionally penetrated into Indian limits. They also lived in the wooded valley of the Tsangpo (the river Brahmaputra is known in Tibet) to the east of Lhasa and in north Bhutan, but not in Sikkim itself, though it was commonly called the Sikkim stag. The Shou was similar to hangul, but larger and heavier with long and massive antlers with five points in each. It is unfortunate to mention that a Shou stag that was shot in the Chumbi valley around 1920, is believed to be the last in that region, at the time. It is presumed to be non-existent and completely extinct.

(v) **The Swamp Deer (Fig. 3A) (*Cervus duvauceli*)**: This deer is slightly smaller than the Sambar and a good stag stands 135 cm. at the shoulder and scales between 170 to 180 kg. It is popularly called as barasingha (twelve-pointed) on account of their splendid antlers. Swamp deer is found no where in the world except in India and Nepal. It is represented by two subspecies: One the Swamp dwelling (*Cervus duvauceli duvauceli*) which lives in marshy tracts of the Terai and the Duars from northern parts of the upper Gangetic Plains to Assam, the other (*Cervus duvauceli branderi*) thrives on the hard open grassy ground in Madhya Pradesh. In the population of swampy area, the hooves of the deer are splayed out to give them greater support in soft ground, where as those that are found in the hard open ground have smaller well-knit hooves. They are highly gregarious in habit, sexes are separately moving in larger herds and feed mostly in the mornings and evenings, resting at noon. They live in amity till the rut develops. During rut each master stag fight to acquire exclusive sexual rights over as many as thirty hinds. After the rut master stags reassemble in small parties to lead a separate life. Once it existed in great numbers all over the north and the central parts of the country but now it is among the vanishing species. The population of both the subspecies is estimated to be around 2500.

(vi) **The Brow-Antlered Deer (*Cervus eldi*)**: This beautiful deer is nearly 120 cm. high at the shoulder and differs from all other in having a distinctive brow-shaped antlers. They are represented by three subspecies, one (*Cervus eldi eldi*) (Fig. 3B): in Manipur valley, another (*Cervus eldi thamin*) in Burma, said to be becoming rarer each year and the third (*Cervus eldi siamensis*) in Thailand and other parts of South East Asia reported to be nearly extinct. The Manipur deer, locally known as "Sangai" and often

called as dancing deer of Manipur, lives on floating swamps of tall reeds, grasses and other hydrophytes, which grow on a mat of humus in the Loktak Lake. The deer by living on the swamp have developed splayed out hooves and their pasterns are hairless and horny. They live in small herds and feed on grasses and other vegetation on the floating swamp in the mornings and evenings and resting in cover during the hot hours of the day. After night fall often raid crops in their vicinity. After the rut master stag are seldom seen with the herds. This deer was once common in all the swamps of the Manipur valley, but now confined to only the southern parts of the Loktak Lake (Keibul Lamjao, which is the only floating wildlife sanctuary in the world) in an approximate 16 sq. km. of swamp. It was believed to be extinct in 1950, but upon its rediscovery, necessary protection has helped the rare brow-antlered deer to survive on this floating sanctuary in a small number around 18 individuals only.

(vii) **The Barking Deer or Kakar** (*Muntiacus muntjak*): It is a rib-faced deer attaining the height at shoulder from 50 to 75 cm. and weighs approximately 22 kg. The antlers in male are small not exceeding half the length of the head, with only two points in each. Upper canines are well developed, used as a weapon of attack and defence by the animal. It is the peculiarity of the species to possess a long tongue by which the whole face is licked. They inhabit thick forests of the country and are more or less solitary in habits, feeding upon various leaves, grasses and wild fruits, mostly during the day. The hoarse barking cry from which this deer derives its popular name is loud, and are uttered both during the pairing-season and under the influence of alarm. Morning and evening are the usual times when this call is heard echoing through the stillness of the jungle. They appear to breed at all season.

(viii) **The Himalayan Musk Deer** [*Moschus sifanicus* (Alpine musk deer) and *M. chrysogaster chrysogaster* (Forest musk deer) (Fig. 4A)]. It is a small deer of about 50 cm. high at shoulder. It occupies an intermediate position in between the deer and the antelope. The lack of prominence in the facial fissure and the presence of gall bladder in this species is the character of the antelope. The male of the musk deer are hornless but provided with well developed canine of about 3—5 cm. long. Both the male and the female are alike in appearance, having a peculiar tail completely buried in the long hair of the anal region. It is an animal of special interest since the male carries a musk-pod, located beneath the skin of the abdomen. The musk-deer are also more or less solitary animals generally going about alone or in pairs at high elevations in the Himalayas from Kashmir to Arunachal Pradesh in the Indian region. They are still seen in small numbers in the Dachigam, Tons and Rishiganga sanctuaries and Khenchendzonga National Park of India. They rut during the

coldest month of the year. This deer has been so persecuted for the sake of the commercial importance of musk, that it is yet another species on the brink of extinction, at least within Indian region.

India is poor in antelope compared to Africa, which is supposed to be its natural home, only two of its species namely the blackbuck and chinkara are found in India. The nilgai (Fig. 6) or blue bull (*Boselaphus tragocamelus*) and the Chowsingha or four-horned antelope (*Tetracerus quadricornis*) are also found in India and are generally supposed to be the antelopes but in fact these two belong to a separate group called *Bovinae*, having more in common with the oxen than to the *Antelopinae*.

(ix) **The Blackbuck** (*Antelope cervicapra*) (Figs. 5A & B): A full grown buck stands 80 c.m. at the shoulder and weighs nearly 40 kg. The female and young buck are yellowish-fawn on the upper part of the body and white on the lower parts, the males of which have striking blackish brown upper parts at the shoulder height of the animal and white on the lower as it is in the female. The male, in youth have gracefully spiralled-horns and the female have moderate horns or often hornless. The blackbug is exclusively an Indian animal which thrives practically in all the open plains and avoid forest or hilly tracts. The elegant blackbuck is one of the fastest terrestrial animals in the world capable of attaining a speed upto 95 km. per hour when alarmed the buck takes off in a series of prodigious bounds, sailing through the air (Fig. 5B) over a metre off the ground covering 6 to 7 metres in a jump. Hardly 25 years back, large hards of blackbuck were found all over the plains of the country. These animals used to live near the cultivated fields, in the jungles scattered around. The habit of this antelope of living in the open has been the cause of its destruction. They are, now, seen in small numbers in level plains and undulating areas of the country.

(x) **Chinkara or Indian Gazelle** (Fig. 4B) (*Gazella dorcas*): They are small chestnut coloured delicate animals of about 65 c.m. in height at the shoulder and weighs approximately 23 kg. The gazellers are basically the animals of the desert but also inhabit the grassy plains and the scrub zone. They have back-curving lyri-form horns that are strongly ringed. The hornless females are not uncommon, generally sexes are alike but the horns of the female are smooth. Chinkara are less gregarious than black-buck and live in small herds feeding on various leaves, crops and fruits like melons and pumpkins. It is the characteristic of the animal to live without water for a long period, specially in desert, deriving such moisture as they need from herbage and dew, but drink when water is available, particularly in hot months. Their population have decreased in general but still they are seen in some numbers in Rajasthan.

The rapid decline in the population of these animals should be a cause of alarm for not only the lovers of animals but for the society at large. Every

Fig. 1.

A Chital family at Bandipur (Karnataka) (Photo by courtesy Shri N. Sundarraaj, Bangalore)

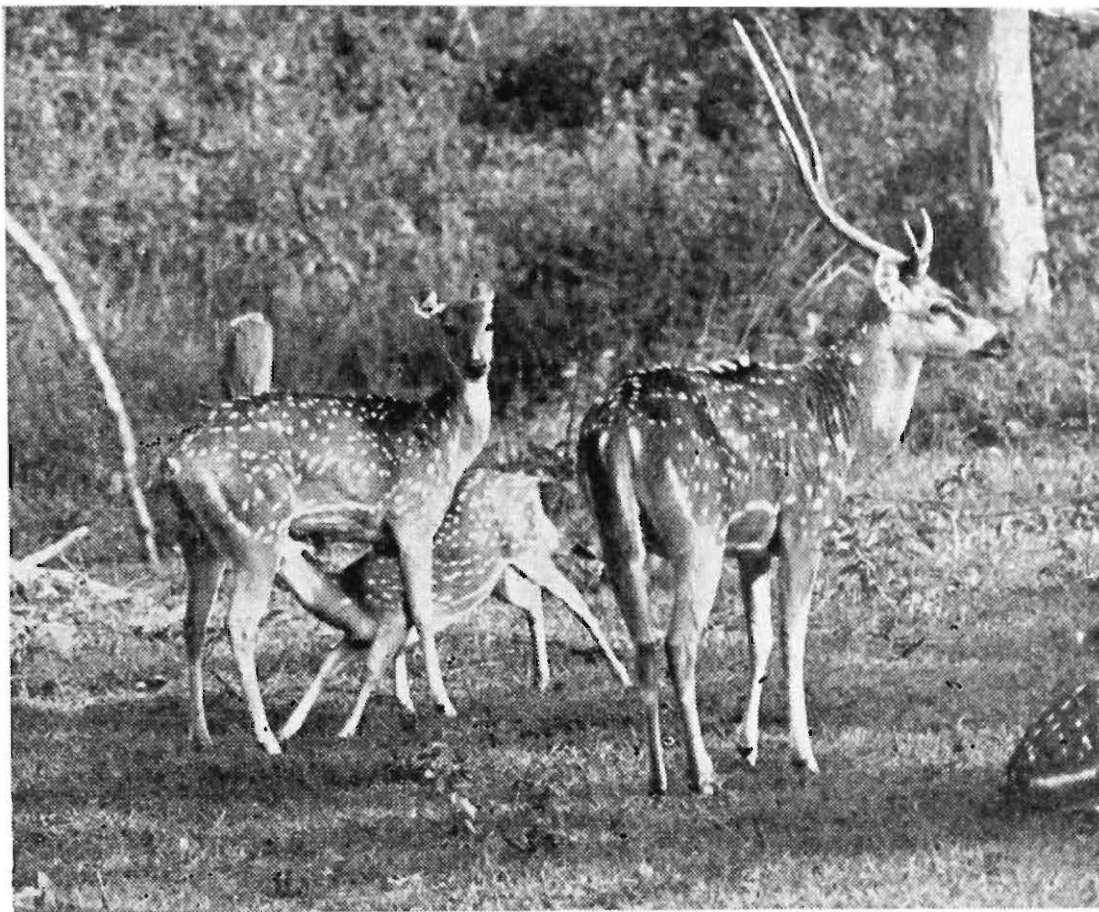
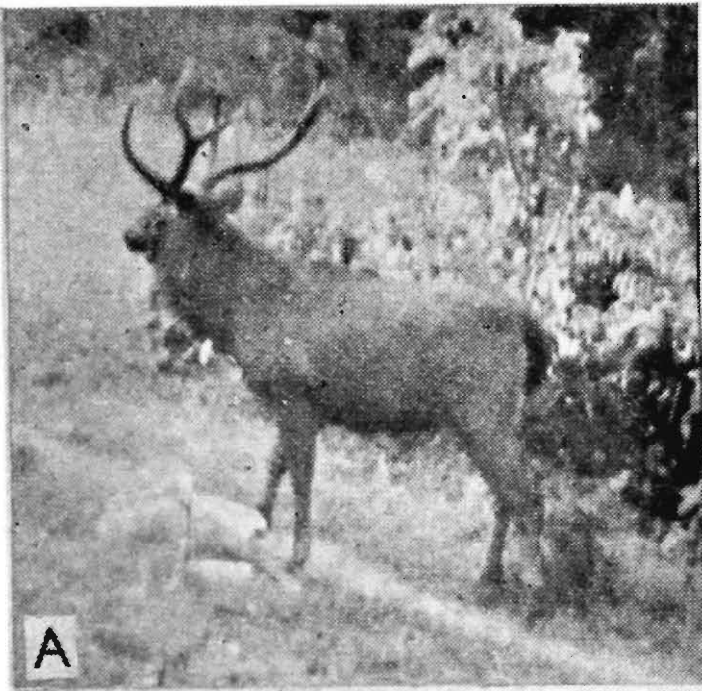


Fig. 2.

A—Sambar stag at Hazaribagh National Park (Bihar).



B—A Sambar hind at Hazaribagh National Park (Bihar).

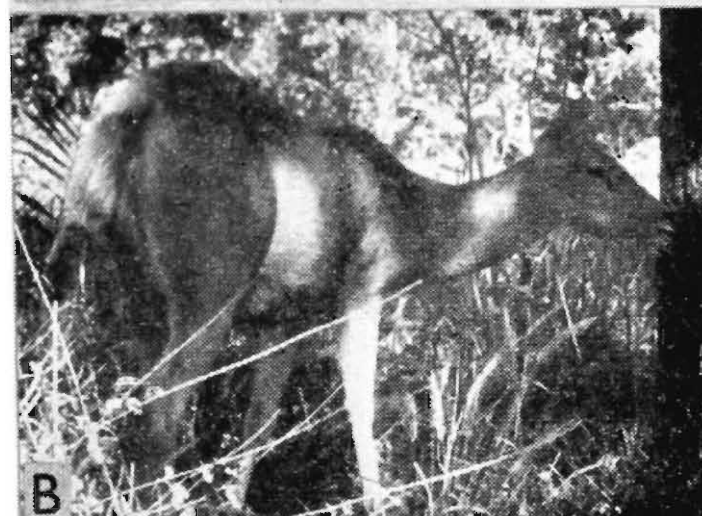


Fig. 3

A—A herd of swamp deer, a stag, hinds and a fawn at Calcutta Zoo.



B—A Sangai with her fawn at Calcutta Zoo.

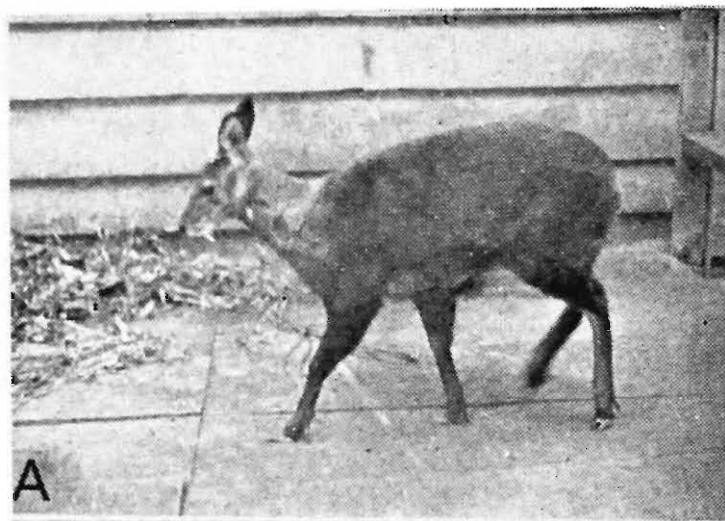


Fig. 4.

A—A forest Musk deer at Darjeeling Zoo. (Photo by Courtesy Shri S. S. Saha, Z. S. I., Calcutta).



B—An Indian Gazelle around Mogara near Jodhpur, Rajasthan.

Fig. 5.

A—A herd of Blackbuck stag at Gudra village near Jodhpur, Rajasthan.

B—A fleeing herd of Blackbuck hind at Mogara village near Jodhpur, Rajasthan.

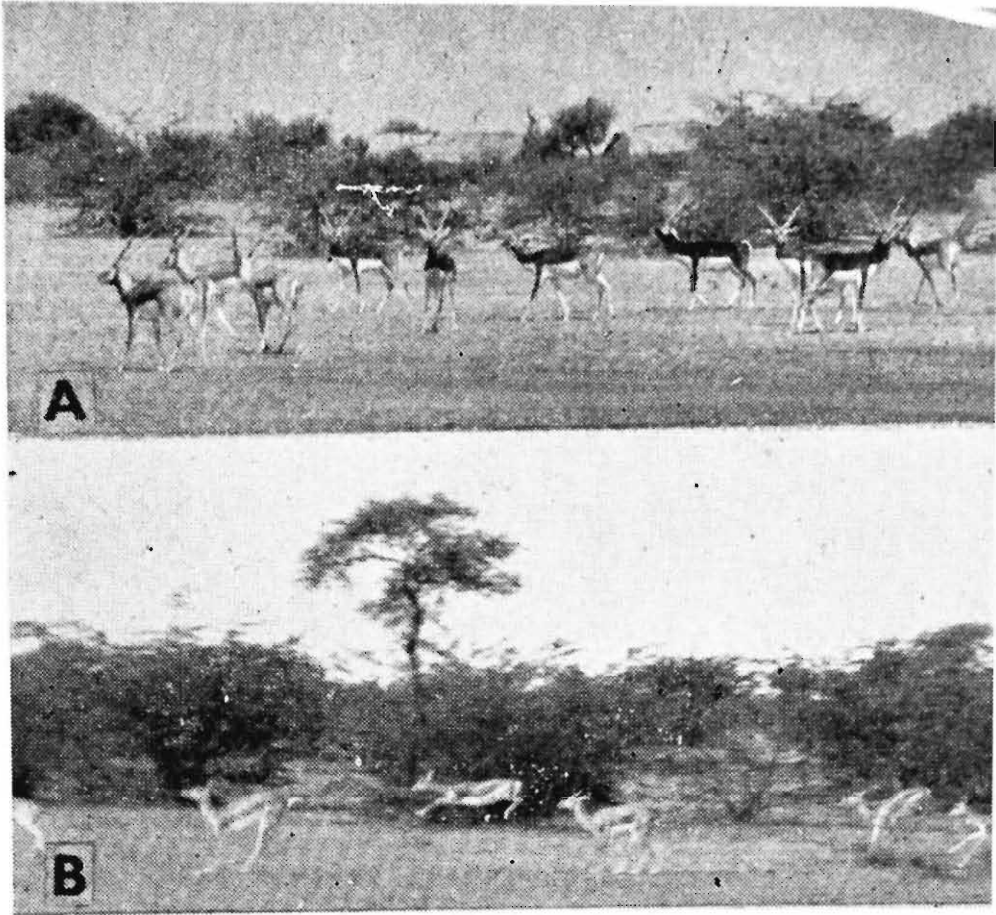
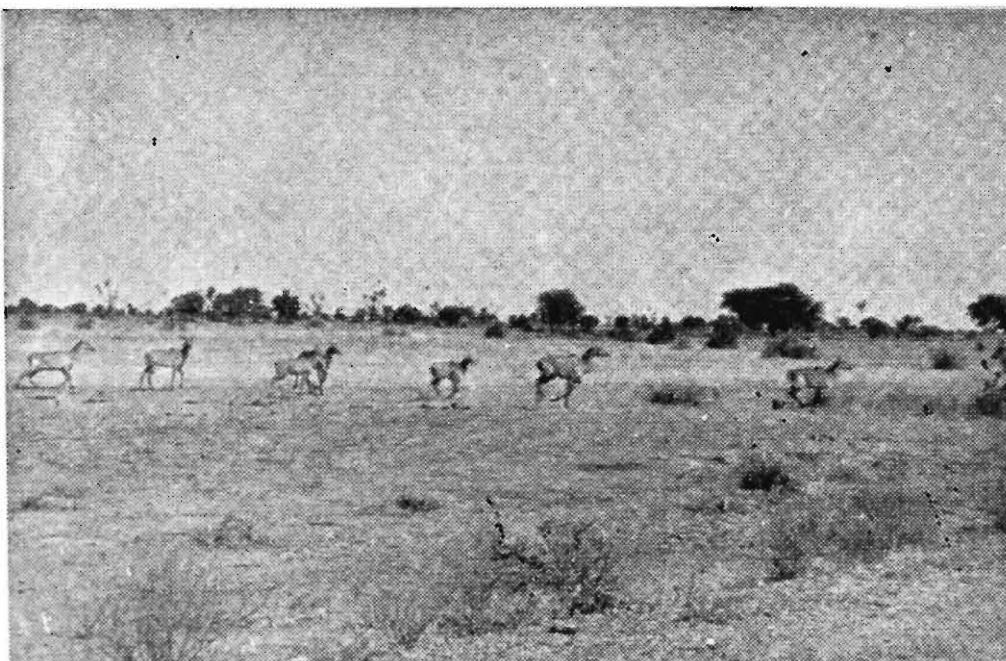


Fig. 6.

A herd of Nilgai near Nagaur, Rajasthan.



right thinking individual should lend a helping hand in the efforts that are being made for their preservation, in our country.

Society has a great responsibility towards not only the preservation of these surviving heads of the love-inspiring vanishing creatures, but also some conscious attempts are required to be made to accelerate their breeding. An elaborate programme to encourage them to increase their population within suitable spots, in captivity, has to be drawn out and implemented.

It should be borne in mind that no species of animals or birds can be re-created by the conscious effort of man nor can a species be re-habilitated if its number has been permitted to dwindle below a critical minimum. It is distressing to note that some of the species, for instance, Indian hispid hare, cheetah, Malabar civet and shou (Sikkim stag), Yak, Pigmy hog etc. have nearly reached a point of no return. Others like ural, markhor, Himalayan and Nīlgiri tahr, the golden and Nilgiri langurs and the lion tailed macaque are facing the danger of extinction. Further, our one-horned rhinoceros, wild ass, thamin, musk, swamp and hog deers, buffalo and several other species of mammal need immediate attention their proper care and protection lest they disappear from the face of the earth leaving only their descriptions and photographs behind to remind us of their existence. Man has now gained near mastery over Nature and is engaged in its ceaseless exploitation. It will be tragic indeed if he cannot do anything to save his fellow animals from extinction, or at least restrain himself from causing their destruction. Man's mastery over Nature has given him enough capability to tap vast natural resources other than the wild animals. His age old enmity with them should not only be forgotten but should change into sympathy and freindliness towards these vanishing helpless creatures.

In a situation like this the only answer is to set apart certain carefully selected forest areas as wildlife sanctuaries and national parks of inalienable character where no shooting, fishing, snaring and collection of specimens is allowed. The wildlife needs the forest, is a wellknown truism, as the animal within the forest is supported and protected by the forest during its entire life from birth to death. The forests also need animal life, though not to the degree that animal needs the forest, such as the insectivorous birds and mammals glean insects including their eggs from the trees round the year to maintain the natural balance. Thus the plant and animal life of the forest has become an ecological unit.

In dealing with our problem to improve the status of wildlife, due care has also to be taken about the forests of our sanctuaries. However the nature, status and problems of our forests are a complicated one, but efforts should be made to achieve our aim through the existing forests of our sanctuaries which should provide three distinct needs of its wildlife : (i) places to breed in safety

(ii) places of refuge and (iii) an adequate food and water. To achieve the above purpose the following steps may be taken, as far as practicable for the conservation of wildlife :

(i) The forest inside the national park/sanctuary should be left unexploited as far as possible. It would be an ideal environment for the wildlife to get the fullest measure of protection, and in such preserved condition of life they can multiply freely.

(ii) If total unexploitation is not possible, the cutting operations of the forest should be in small units, well distributed over the forest. Frequent light cuts are generally better for wildlife than infrequent heavy cuts.

(iii) The forest should not be planted or allowed to grow a single species of plant. Further, fruit bearing shrubs and trees should be encouraged wherever possible and the natural openings of the forest should be preserved.

(iv) Poaching needs to be ruthlessly prohibited in the sanctuaries in particular and generally in other areas outside them where wildlife still exists. Mobile armed units should be attached to all sanctuaries to patrol regularly the entire sanctuary to stop illegal activities.

(v) The water-holes and stream sides should be managed and guarded carefully for the benefit of wildlife. Such critical areas may be of small size, but their importance is disproportionately great because they supply important elements in wildlife ecology for larger areas during the hot months of the year.

(vi) Annual burning of the grasslands in most of our sanctuaries have become an integral part of their ecology since without burning there might be lack of suitable forage during hotter months. Controlled burning has been found to increase forage and to preserve organic material in the soil. Such burning may be done in blocks with unburned areas in between so that areas are burned in rotation. The burning is to be confined to definite blocks by means of fire breaks. Burning at night is favoured unless it is likely to extend the fire beyond the desired limits.

(vii) Provision for dust baths for animals should also be made by leaving some exposed soil for their dusting. These spots may be prepared in the form of small mounds, elevated a few inches above the surrounding forest floor to allow for drainage and to dry it quickly in wet months.

(viii) Some artificial salt-licks are also to be provided in the sanctuaries since the wildlife need them at regular intervals for their normal health. Such salt-licks are necessary for the animals especially in areas where natural salted-clay is scanty.

(ix) Concentrated grazing by domestic stock is inimical to the interests of wildlife since the wildlife primarily can never compete successfully with domestic stock under ordinary circumstances and secondarily, they may be responsible for

transmitting contagious diseases like foot and mouth, rinder pest or surra (sleeping sickness). During 1958 to 1961 the wild asses in Rann of Kutch were suspected to have suffered a heavy loss in population by surra and with this disease again two wild elephants were reported to have died in the Quilon district of Kerala in 1973. In 1968 rinder pest occurred in Bandipur sanctuary among gaur and within a few months not even a single gaur could be seen there ; sambar and chital too were seriously affected.

It may be added that in India there are approximately 250 million cattle and domestic buffalo and 100 million goats and sheep of which at least 10% graze exclusively in the forests where our wildlife survives. Under the above circumstances all domestic livestock grazing be prohibited inside the sanctuary.

(x) Cultivation near the sancturies should be avoided as far as practicable since it may have indirect effect on the wildlife, e.g. chemical control of certain pest is often desirable in the interests of agriculture, but these pesticides can present ecological hazards for the wildlife.

(xi) Scientific studies of the sanctuary's wildlife, particularly of threatened species, be encouraged by qualified persons in order to improve their status even by breeding them in captivity to rehabilitate them in suitable habitats.

(xii) Educational and publicity programme should be undertaken to create public opinion in favour of wildlife. There is a general lack of knowledge in the conservation of nature and value of wildlife in our country. It will be quite difficult to achieve the objective of wildlife preservation unless effective steps are taken to popularise it. Our younger generation seem to be completely oblivious of the rich wildlife that our country possesses. It is essential that their interest is roused by propaganda both in schools and colleges through documentary films, attractive books, charts, posters, broadcast, press etc. Through these educational measures it may also be possible to put a stop to the mass killing of wild animals in the annual tribal hunts, which is even now in practice in some parts of India.

NESTING BEHAVIOUR AND NESTS OF INDIAN TERMITES

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Termites are social, polymorphic insects living in large communes. They have three major castes namely the reproductive adults, the soldiers and the workers, and portray an excellent example of division of labour, each caste going about its duties silently and efficiently.

The workers in the community are the masons and the architects. In higher termites they construct beautiful, fort-like houses of architectural and engineering perfection which give them protection from natural calamities and their enemies in nature. They also regulate the environmental conditions (*viz.*, temperature, humidity and internal atmosphere) in the nests.

In the present contribution, the nesting behaviour of Indian termites is discussed and the nests of some common Indian species are described.

The authors are very grateful to the Director, Zoological Survey of India, for encouragements in their study on termites.

Nesting Behaviour in Indian Termites

As far as the nesting behaviour is concerned the termites can be divided into two main categories *i.e.*, (a) wood-dwellers and (b) soil-dwellers.

(a) *Wood-Dwelling Termites*

These termites live throughout their life in the dead wood of trees, in house-hold timbers, furniture and wooden structures and require very little moisture. The Indian wood-inhabiting species belong to families Kalotermitidae and Termopsidae. Some termites belonging to the families Rhinotermitidae and Termitidae are also seen frequenting dead, dry and living wood for their food but they are not purely wood-inhabiting. These wood termites can be further divided into two groups *i.e.*, (i) Damp-wood termites and (ii) Dry-wood termites.

(i) Damp-wood termites

Termites belonging to the family Termopsidae, of which only one species occurs in the Indian region, and most of those of the family Kalotermitidae are

damp-wood termites. They require a high amount of moisture and are found in dead decaying logs, and in the damaged or living wood of standing trees.

(ii) Dry-wood termites

The termites of genus *Cryptotermes* and some other species of the family Kalotermitidae are commonly known as dry-wood termites. They live in dead and dry woods, house-hold timbers and furniture.

(b) *Soil-Dwelling Termites*

Members of the families, Hodotermitidae, Rhinotermitidae and Termitidae are soil-dwellers ; their nests are either completely in the soil or have some connection with the soil. These can be separated into four groups viz., (i) Partly subterranean, (ii) Purely subterranean, (iii) Mound-building and (iv) Carton nest building.

(i) Partly subterranean termites

Species of the partly subterranean group have their main nest in the soil and which extends into the wood of trees and house-hold structures in contact with the soil. Species of the family Rhinotermitidae fall in this category. Some species of the *Coptotermes* and *Heterotermes* are very destructive in habit.

(ii) Purely subterranean termites

The Hodotermitidae and some species of the family Termitidae are purely subterranean. They do not extend their nests into the plants or wooden structures, but of course visit these places for food. Termites of the genera *Anacanthotermes* (Hodotermitidae) and *Eurytermes*, *Speculitermes*, *Euhamitermes*, *Synhamitermes*, *Globitermes*, *Eremotermes*, *Angulitermes*, *Capritermes*-group, *Microtermes*, some species of *Macrotermes*, *Odontotermes*, *Hypotermes* and most of the Nasutitermitinae (Termitidae) fall in this category.

(iii) Mound-building termites

The common mound-building termites in India mainly belong to the genus *Odontotermes*. Some species of the genera *Macrotermes* and *Hypotermes* have also been observed sometimes, to construct mounds.

(iv) Carton nest building termites

Only a few species of the genera *Microcerotermes* and *Nasutitermes*, in India, are known to make carton nests on the trees (in between the two branches, around the branches, in the damaged portion of trees, on the main stem, etc.) and in the dead stumps of felled trees still in the soil. From the carton nest on the tree there run covered runways to the ground below for the workers to go for the collection of food.

Nests of Some Indian Termites

(a) Nests of Wood-Dwelling Termites

The nests of wood-dwellers are found in dead woods, dead portions of living trees, stumps of trees, wooden structures of buildings and houses and even in wooden furnitures and articles. They are generally established in the living trees through some cracks or joints and in the dead woods through damaged portions where the reproductives alight after the swarming. The nests found in the wooden structures of houses either get transported through the timber brought from the forests or are established afterwards. The instance of the record of a thriving colony of *Cryptotermes dudleyi* Banks in a Calcutta house (Chhotani, 1976) is an example of a nest transported from elsewhere.

The nests of wood-dwelling termites are generally located in the heartwood of the stem and branches of trees but sometimes also in the roots and rootlets as in the case of *Postelectrotermes militaris* (Desneux) (Pinto, 1941), the species which is endemic to the tea districts of Sri Lanka and a serious pest of tea plants. They are in the form of an irregular network of long, narrow, longitudinal galleries which run from the bark to the heartwood where the gallery system is quite extensive and gives a sponge-like appearance (Figs. 1A & B). The galleries are either filled with masses of tiny pellets of excreta which are hygroscopic and serve to condition the humidity inside the nest as in case of the species of the genera *Neotermes* and *Glyptotermes* or have some small, tiny, dried up pellets which often roll down or fall on the ground at the base of the site of the nest as in the case of *Bifiditermes beelsoni* (Gardner) (Chhotani, 1962), *Cryptotermes dudleyi* Banks (Chhotani, 1976) and *C. havilandi* (Sjöstedt). The species of the genera *Neotermes*, *Glyptotermes* and *Bifiditermes* (Kalotermitidae) and *Stylotermes* (Stylotermitidae) make their nests in the dead portions of live trees slowly extending them to the adjacent live tissue as well along the grain of the wood, while the species of *Cryptotermes*, which are generally restricted to coastal areas and are typically drywood termites, usually nest in dried up woods, wooden structures, poles, pillars, and furniture. The galleries in their nests are flattened and enlarged at places (Figs. 1C & D). The species, *Cryptotermes havilandi* (Sjöstedt), however, has also been found nesting in a semi-wild state in *Ficus bengalensis* and *Mangifera indica* trees and has got transported to areas in the interior of the Indian subcontinent (Chhotani, 1963). Roonwal and Sen-Sarma (1955) have described the nest of *Neotermes bosei* Snyder (= *N. gardneri* Snyder) in some detail; Chhotani (1962) the nest of *Bifiditermes beelsoni*; Pinto (1941) the nests of Kalotermitidae of Sri Lanka; and Chatterjee and Thakur (1963) the nest of *Stylotermes faveolus*. *Archotermopsis wroughtoni* (Desneux) (Termopsidae), a typical example of damp-wood termites, is endemic to higher altitudes in the western Himalayas (from Kashmir to Kumaons in India and Hazara in Pakistan) and

North-east of Kabul. Imms (1919) has given detailed description of the various castes of this species, its biology and nesting habits. This termite nests in dead, decaying trees, stumps and fallen trunks of conifers *Pinus excelsa*, *P. longifolia*, *Picea morinda*, *Abies pindrow* and *Cedrus deodara* and makes irregular chambers. The wood is perforated in various directions by large galleries and tunnels most of which are in the longitudinal direction. According to Imms (1919), a number of nests may be found in a big tree trunk making it difficult to determine the extent of a colony since the galleries and tunnels of one colony may intermingle with those of another.

(b) *Nests of Soil-Dwelling Termites*

The soil-dwelling termites have some connection with the soil. Their nests are either completely in the soil or on the trees or in the stumps of trees or in poles of wood, and are connected with the ground below through narrow galleries and tunnels as in case of some species of *Microcerotermes* and *Nasutiterminae*. These nests, as mentioned above, can be referred to four groups *i.e.*, (i) Partly subterranean, (ii) purely subterranean, (iii) mounds and (iv) carton nests, and are described below.

(i) *Partly subterranean nests*

The partly subterranean nests are those which are mainly under the soil and are extended into the trees and plants and wooden structures in houses. The termites which build such nests in India belong to the family *Rhinotermitidae* and the most commonly frequented species are *Coptotermes heimi* (Wasmann), *C. ceylonicus* Holmgren, *Heterotermes indicola* (Wasmann), *H. ceylonicus* (Holmgren), *Reticulitermes assamensis* Gardner and *Prorhinotermes flavus* (Bugnion & Popoff).

The nest in the soil is of diffused type and it is very difficult to trace the extent of galleries and the royal chamber. Above ground, the nest in the trees and wooden structures is a somewhat porous structure of dark brown colour. It is formed of a net-work of strands probably made up of hard wood fibres left over during the process of eating away the wood and partly by the termite excrement cemented together and plastered over the wood fibres as in the case of *Coptotermes heimi* (Fig. 2B). The nest, in the wood, has irregular chambers of varying sizes but no royal chamber. The other *Coptotermes* species in India, also build similar nests although in Australia some species are known to build mounds. The main nests of *Heterotermes* species are also in soil, and in the wood they are formed of long, flat, longitudinal excavations which run along the fibre of the wood and are filled with grayish matter mainly of excrement matter and soil in sheets-like deposits and connected by transverse strands of wood (Fig. 2C). The outer covering of the wood remains intact, thus sometimes these termites are not detected till the wood structures in houses start tumbling down.

Sometimes these termites eat their way through cement and plaster and make earthen galleries to reach wooden structures. The nests of *Reticulitermes assamensis* are recorded from logs of woods and roots of *Pinus longifolia*. The galleries are rather irregular and run parallel to the length of roots; the larger galleries are occasionally filled with earth and excreted material. The outer covering of roots remains quite intact. The nests of *Prorhinotermes flavus* are constructed in the hollows of trees. They are sponge-like, brownish or brownish-black carton structures of irregular shape and size and are made up of earth and faecal matter (Fig. 2D). The insect also makes irregular galleries, in the wood and plants they infest, and which are filled with brownish dust. In India this termite has been found nesting in the trunk of a living *Ficus bengalensis* tree and from Sri Lanka, it is reported nesting in dead trees. Roonwal (1959) has given a detailed biology and nesting habits of *Coptotermes heimi*, Kapur (1962) has described the damage by *Reticulitermes assamensis* and Bose and Maiti (1976) have given the nesting of *Prorhinotermes flavus*.

The termites *Coptotermes heimi* and *Heterotermes indicola* are very destructive. The former species has been recorded from a large number of plant species and house-hold structures and goods (Roonwal and Chhotani, 1962), and was found heavily infesting an old Public Works Department's rest house at Gurgaon in Haryana, and it was being proposed to demolish the rest house for reconstruction when one of authors (O. B. C.) visited Gurgaon in the year 1959 for survey. The latter species has been reported to have virtually ruined the whole township of Sri Hargobindpur and other nearby townships in the Gurdaspur District in Punjab (Roonwal, 1955). The species of *Reticulitermes* are also reported to do extensive damages in Europe and southern China, but the Indian species are not that destructive.

(ii) Purely subterranean nests

The purely subterranean nests are found in the soil in forested areas, semi-open grounds with low bushes and open grounds with patches of grasses. The nests are indiscrete, made up of long, narrow, subcylindrical, subterranean galleries. These galleries run horizontally in all directions just under the ground surface for a distance of a few centimetres to as far as 100 metres and go deep down to a depth of 50 cm. to 200 cm. approximately, in different species of termites. The galleries are flattened into small chambers at places for storage of food such as pieces of grasses and leafy vegetations and open on the ground surface near the source of food which may be wood debris, leaf humus, fallen tree trunks and branches, live trees and plants, cowdung and other matter.

Termites of the family Hodotermitidae (*Anacanthotermes* genus) and a large number of species of Termitidae make such nests. The species *Anacantho-*

Fig. 1. (A) Nest of *Bifiditermes beesoni* (Gardner), showing long and narrow galleries running inside an aerial-shoot of *Ficus bengalensis* L., (B) A portion of the nest of *Neoterme* sp. in *Mangifera indica* L., (C) A portion of nest of *Cryptoterme* *dudleyi* Banks in the frame-work of a door. (D) Wood pieces from a branch of *F. bengalensis* L., showing nest of *Cryptoterme* *havilandi* (Sjostedt).

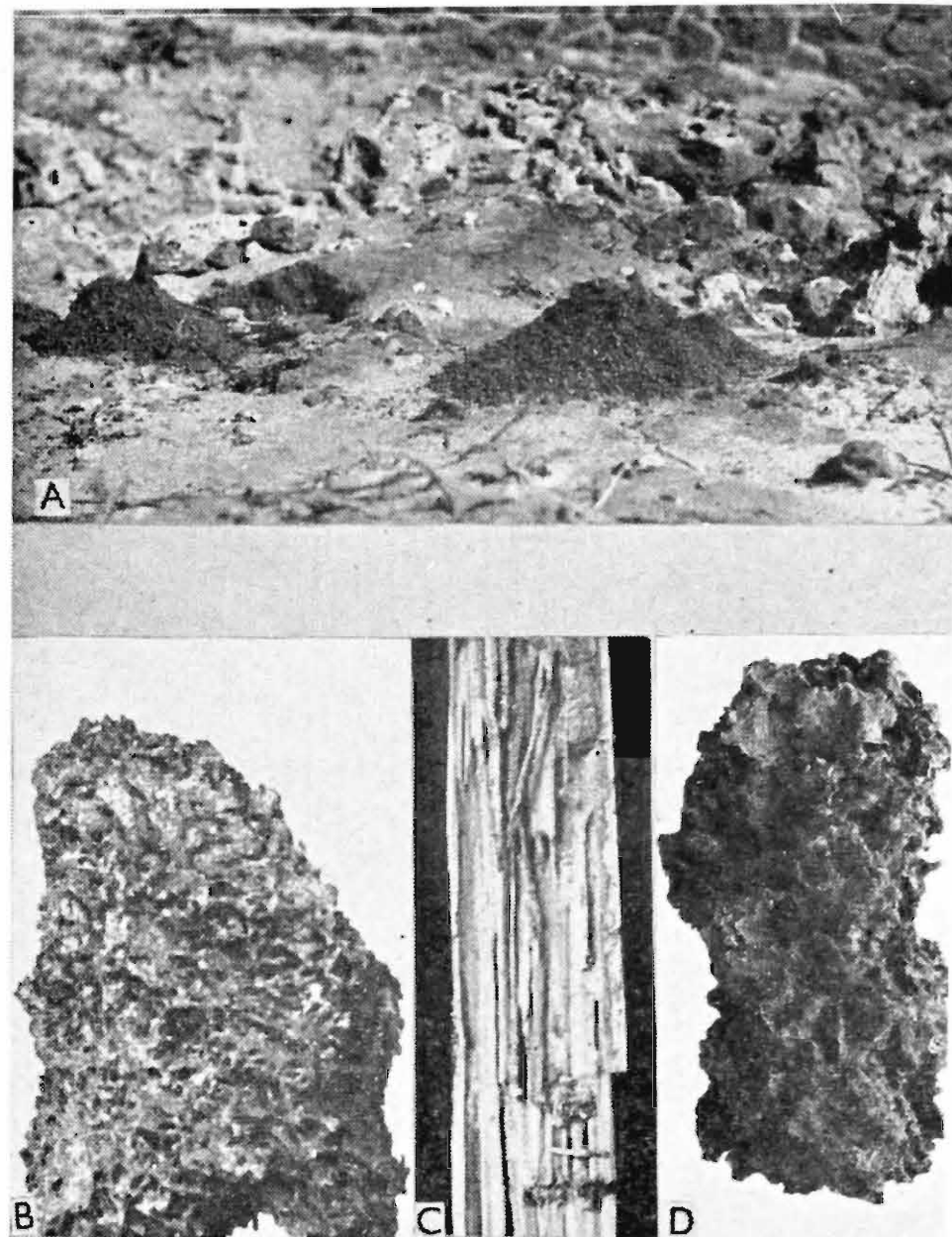
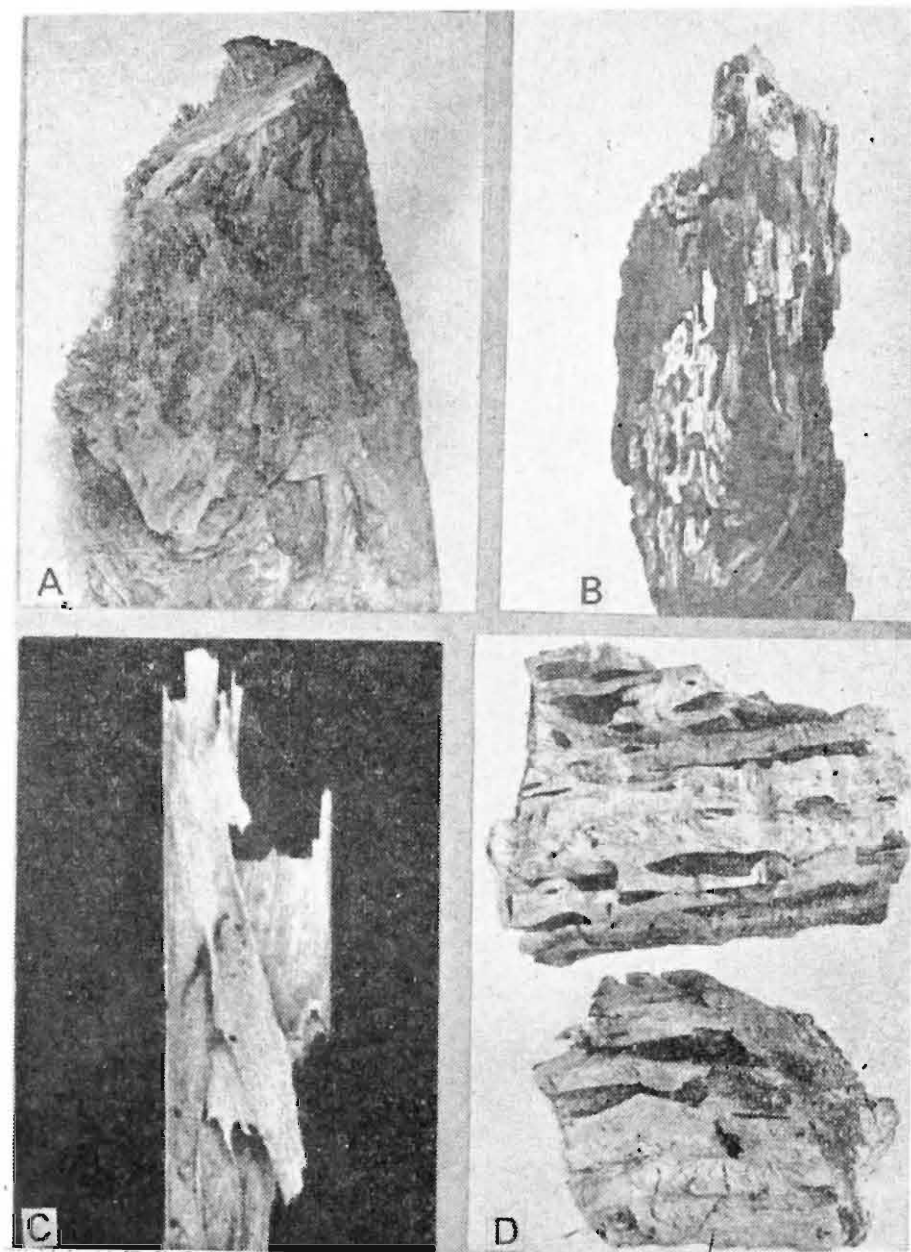


Fig. 2. (A) Small mounds of granular sand made by *Anacanthoterme* *viarum* (König) near the sea-shore at Kanya Kumari. (B) A small portion of the nest of *Coptoterme* *heimi* (Wasmann) from the stem of a tree. (C) A portion of the nest of *Heteroterme* *indicola* (Wasmann) in the wooden-frame of a door. (D) A portion of the nest of *Prorehinoterme* *flavus* (Bugnion and Popoff) from the stem of *Ficus bengalensis* L.

Fig. 3. (A) Carton nest of *Microcerotermes*. (B) Nest of *Pericapritermes tetraphilus* (Silvestri) in the mound of *Odontotermes obesus* (nest is made up of arched chambers in tiers). (C) Mound of *Odontotermes microdentatus* Roonwal and Sen-Sarma, Kanha National Park. (D) Longitudinal section of a mound of *O. microdentatus* Roonwal and Sen-Sarma, Kanha National Park. (E) A small vault with fungus, made by *Microtermes obesi* Holmgren in the wall of the mound of *O. obesus* (Rambur).

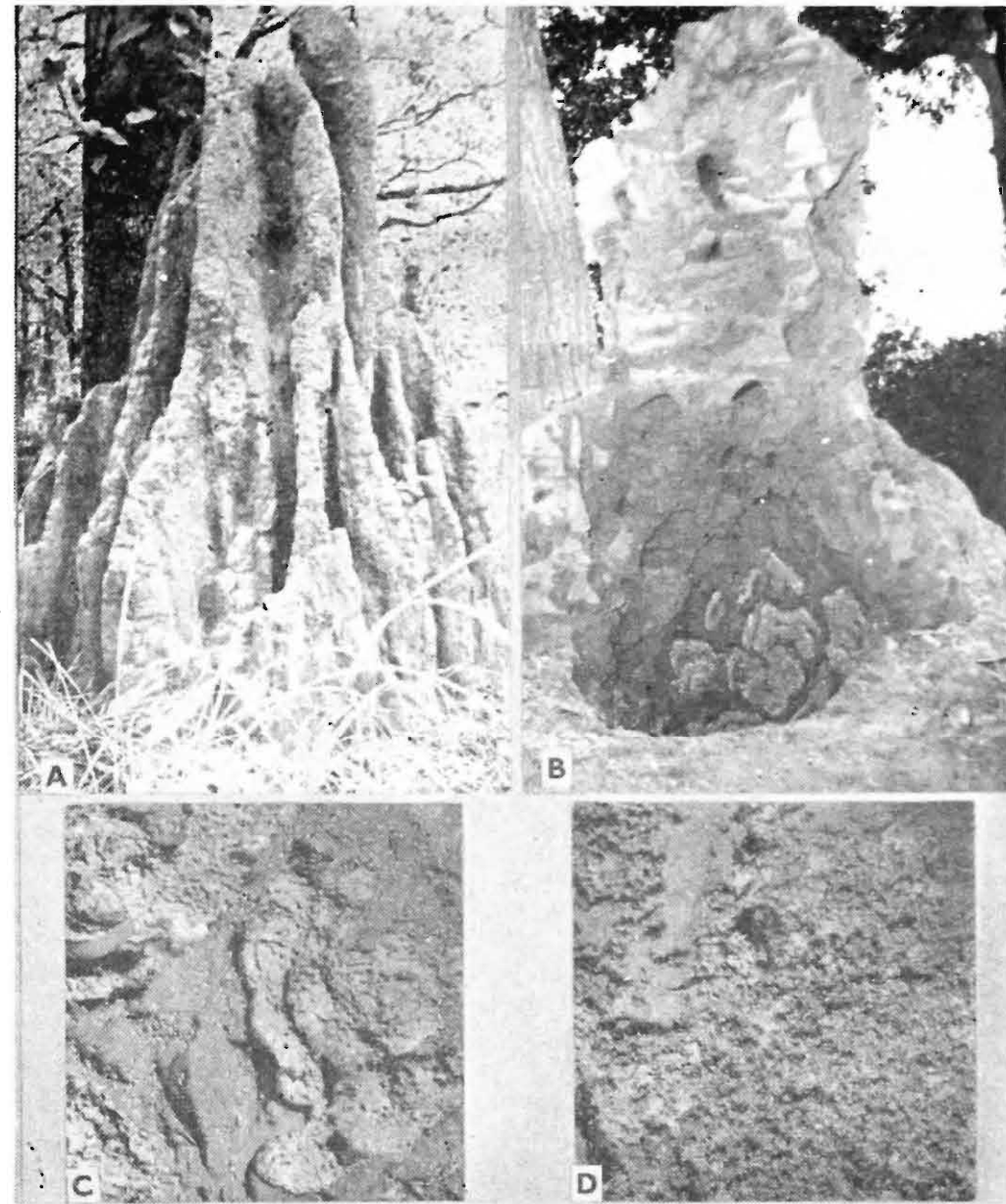
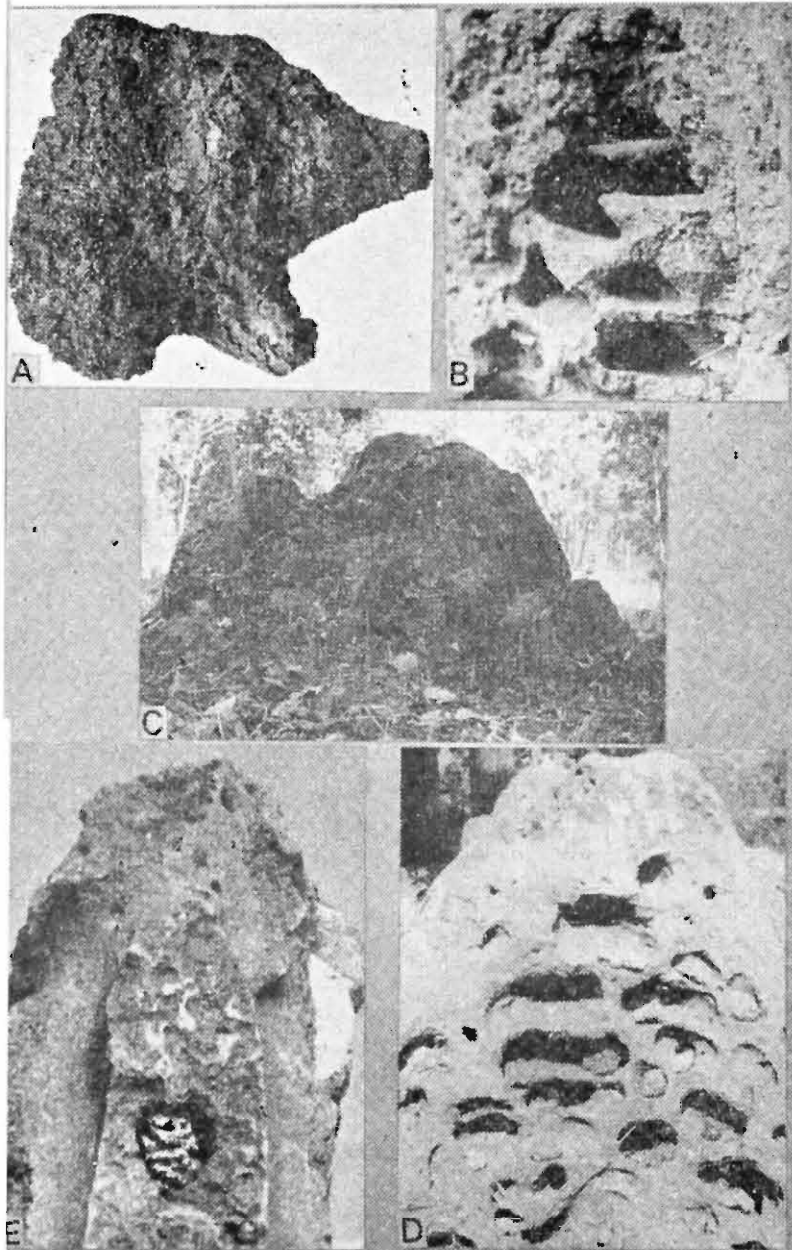


Fig. 4. Mound of *Odontotermes obesus* (Rambur). (A) As a whole, (B) Longitudinal section showing the arrangement of fungus combs, (C) A portion showing the fungus combs. Enlarged. Note the soldiers and workers busy surveying the damage done. (D) Note that the workers have covered the damaged portion with fresh soil (one hour later to C).

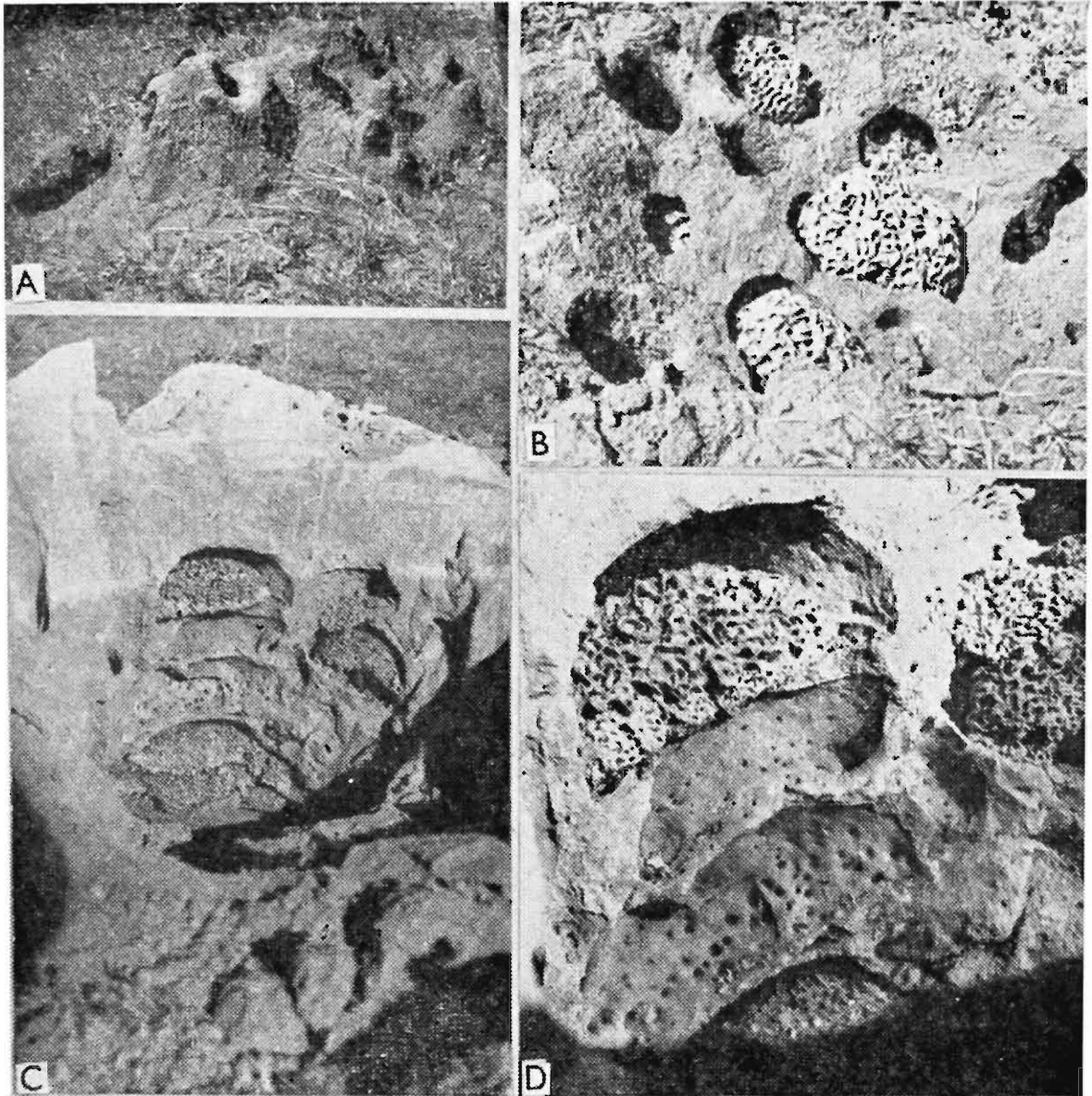


Fig. 5. Mound of *Odontotermes wallonensis* (Wasmann). (A) Mound as a whole, (B) Cross section of mound at the level of ground surface, showing the fungus comb vaults and the tunnels going down into the nest. (C) Longitudinal section of mound, showing the fungus comb vaults arranged in tiers one above the other below the ground-level. (D) Holes and galleries in the earthen partitions of the fungus vaults for communication.

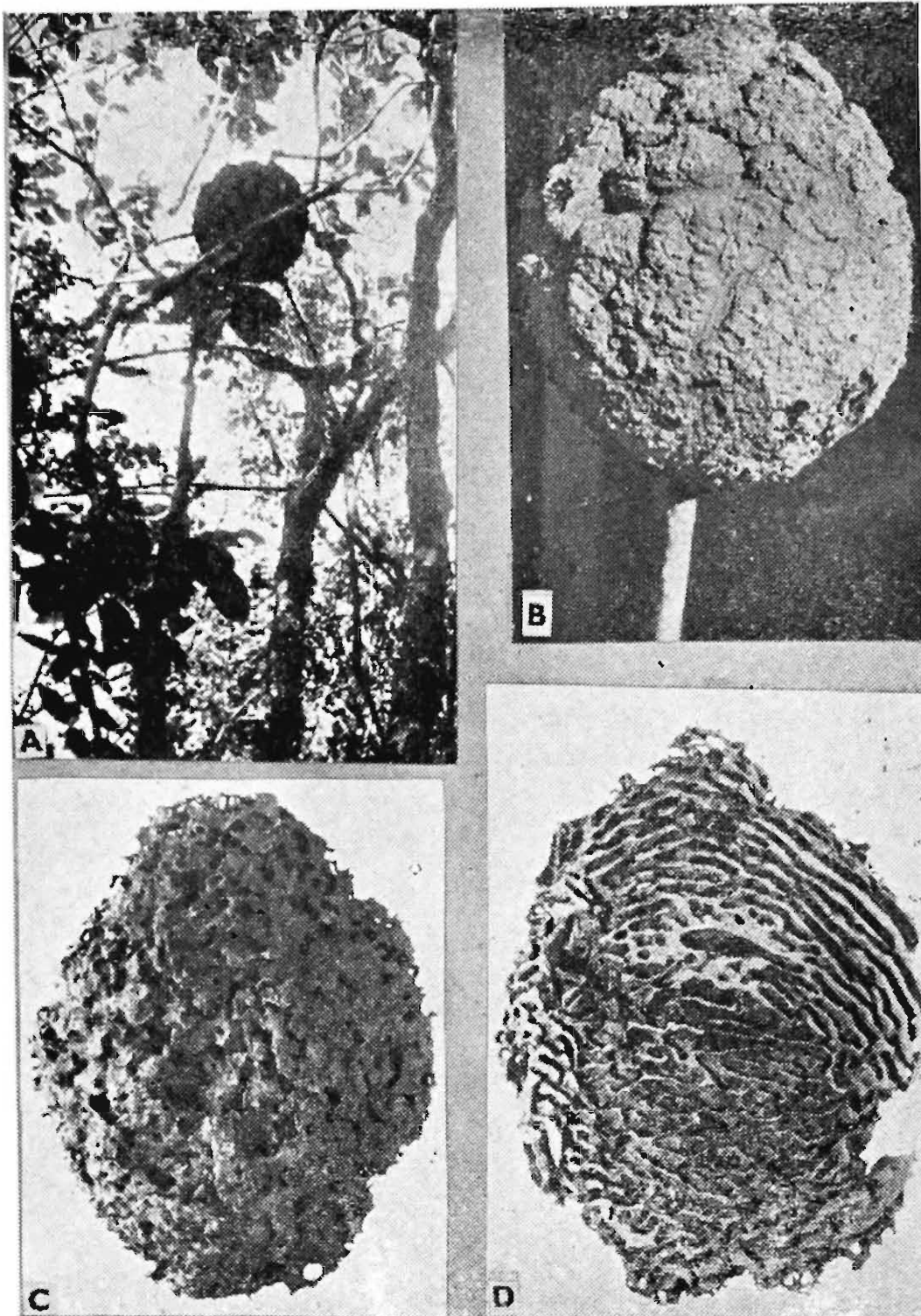


Fig. 6. Carton nests of *Nasutitermes indicola* (Holmgren & Holmgren). (A) A carton nest on branch of a tree. (B) A nest with the outer wall intact, enlarged. (C) A nest, showing the inner comb like structure. The outer wall having been removed. (D) Longitudinal section through a nest, showing the internal arrangement of galleries and chambers. The royal chamber is in the middle.

termes macrocephalus (Desneux) is known from the desert areas of Rajasthan (India), Pakistan and Afganistan. Its nests consist of galleries, running for lengths of 20 m. or more, and horizontal chambers one above the other. From the nest vertical shafts run downwards upto layers of gravel, probably for moisture. At places, small (6-15 cm. in height and 10-15 cm. in circumference at base), conical mounds of granular, excavated earth are thrown out above the ground, and at places the galleries open up on ground surface through which the workers and soldiers go out on expedition for the collection of food (Roonwal, 1970). The species *A. viarum*, which is confind to drier parts of Tamil Nadu, has similar nests, and mounds of excavated earth of 12 cm. height and 30 cm. circumference are of common occurrence in the vicinity of the sea-shore at Kanyakumari (Fig. 2A).

Species of the genera *Speculitermes*, *Euhamitermes*, *Eurytermes*, *Eremotermes*, *Angulitermes*, *Globitermes*, *Syhamitermes*, *Dicuspitermes*, *Procapritermes*, *Pericapritermes*, *Homallotermes* and some of *Nasutitermes* and *Trinervitermes* make such nests in soil. Some of the species of *Macrotermes*, *Odontotermes* and *Microtermes* also have such nests in the soil but have larger chambers enroute the galleries for the fungus combs. Of these, the nests and nesting behaviour of *Speculitermes sinhalensis* Roonwal & Sen-Sarma has been studied in detail by one of us in southern India. The nest is a ramification of narrow (2-5 mm. in diameter), long, cylindrical galleries which run zigzag horizontally just below the ground-level and open on the ground surface either singly or in groups of 4-5, usually under a stone or dry cowdung. Vertically they go down to a depth of nearly 50 cm. and have small pouches or chambers of 10-15 mm. diameter, some of which are filled with bits of dried up grasses collected by the workers for reserve food (Roonwal & Chhotani, 1966a). Many of the species of these genera are found nesting in the mounds of *Odontotermes* species. A nest of *Synhamitermes quadriceps* Wasmann, made up of narrow galleries and small chambers of 20-30 cm. diameter was found in the walls of a mound of *Odontotermes redemanni* (Wasmann) at Barrackpore (West Bengal) and in that of *O. obesus* (Rambur) in Kanha National Park (Madhya Pradesh). The royal chamber is spindle-shaped and is nearly 4 cm. long, 2 cm. wide and 1 cm. high. The species *Pericapritermes tetraphilus* (Silvestri) was observed nesting in a mound of *Odontotermes obesus* in Kanha National Park. The nest comprised thin, flat, galleries (2-15 mm. in diameter) leading into larger, round to irregular, flat below and arched above chambers of variable sizes (30-40 mm. in diameter). At one place near the top of the mound, the galleries led into a set of flat chambers of comparatively larger size (60-80 cm. in diameter) arranged in tiers one above the other (Fig. 3B). The galleries and the chambers were coated with some greyish material probably faecal matter. A large number of soldiers and workers were found in the chambers and galleries but no royal chamber could be traced.

The nests of *Microtermes* species, in the soil, also comprise narrow galleries and chambers (2—4 cm. in diameter) communicating with each other. The chambers have small, walnut-size, fungus combs. Sometime these termites make their nests in the walls of *Odontotermes* mounds (Fig. 3E). The *Macrotermes* and *Odontotermes* species' nests, under the soil, are extended to much larger areas and have large sized chambers for the fungus combs. The galleries in case of *Macrotermes estherae* (Desneux) may run for 100 m. or more and sometimes small hillocks of 2—8 cm. height, of excavated earth may be seen in the vicinity of the nest. The fungus combs of this species are about 5 cm. in diameter and have cavities like the convolutions in the human ear. The soldiers and workers go out on foraging expeditions during which they march in files. A nest of this species having a number of holes of about 1 cm. diameter on the ground surface, in a grassy patch of land at Rambha (Orissa) was noticed and the soldiers and workers were seen retreating to the holes at dusk time. A few soldiers (major) with open mandibles stood at guard at the mouth of the holes. On excavation of the nest two pairs of recently swarmed reproductives were found 15 cm. below the ground-level. The common *Odontotermes* species which build such subterranean nests are *assmuthi* Holmgren, *feae* (Wasmann), *horni* (Wasmann) and *parvidens* Holmgren & Holmgren. The *Trinervitermes* species also build nests of this type and their galleries are coated with blackish material.

(c) Nests of Mound-Dwelling Termites

The nests of mound dwellers are highly specialised. The mounds are fort-like structures in which the temperature, humidity and air circulation are regulated according to the needs and weather conditions. These mounds also give protection to the insects from natural calamities like heavy rainfalls, storms and extreme weather conditions.

A number of *Odontotermes* species are reported as mound-builders in India, the most common of which, in order of abundance, are *obesus* (Rambur), *redemanni* (Wasmann), *wallonensis* (Wasmann), *brunneus* (Hagen) and *microdentatus* Roonwal & Sen-Sarma. The species *assmuthi*, Holmgren, *feae* (Wasmann) (Roonwal & Chhotani, 1966b) and *kushwahi* Roonwal & Bose have sometimes been reported to construct mounds but they generally make subterranean nests. The mound of the termite *Macrotermes gilvus* (Hagen), in the Indian region, has been recorded from Burma (Roonwal & Chhotani, 1961). *Trinervitermes biformis* nest is subterranean but it makes small, mound-like structures in southern India (Sen-Sarma and Mathur, 1961; Roonwal, 1977) sometimes.

Five types of mounds of *Odontotermes obesus*, the commonest termite in India, are reported. Chhotani (1977) has relegated four types of mounds from Kanha National Park to this termite and at the same time opined that they may be belonging to some sibling species, while Roonwal (1977) is of the view that this termite builds five different types of mounds. The most common type of

mound of this species is the tall, subcylindrical, unilocular-type having long, hollow, flat buttresses (Fig. 4). The mound is made up of hard earth, cemented together and its walls inside are pitted with cup-like pits of 5—7 mm. diameter which do not have openings on the external surface. The mound, when well developed, may go as high as 3 m. having a diameter of about 1.5 m. at base. Inside (Fig. 4B) it has numerous irregular cavities, tunnels and canals giving it a honey-comb appearance and has a central hollow near the ground-level containing large chunks of fungus combs. The type of mound having a central hollow is known as the unilocular-type. The royal chamber in this type of mound is a discrete flat, solid, earthy structure, with numerous irregular excrescences or protuberances on outer surface. Inside it has a spindle-shaped, smooth and clean cell of the size of 6—10 cm. length, 5—8 cm. width and 2—3 cm. height, and in it resides the royal pair, the king and the queen. Sometimes more than one queens have been reported (Roonwal & Gupta, 1952 ; Roonwal & Chhotani, 1963). The floor of the cell has a number of small, round holes of 3—5 mm. diameter through which the soldiers and workers come in to attend on the royal couple and carry the eggs to the nurseries in the fungus combs in the vicinity of the royal chamber. The fungus combs are soft, irregular, sponge-like structures. The moisture content of the fungus and its fermentation help in keeping the humidity and temperature inside the mound at the desired level. This type of mound is found in northern India, Bihar, Orissa, Madhya Pradesh and as far South as Bangalore and has been described by Roonwal (1962) in details.

Dome-shaped mounds with a few holes on outer surface and with small turrets, are two other types of mounds built by this termite. Inside both these, there are a number of chambers and vaults for the fungus combs. These mounds are known as the multilocular-type. The royal chamber in these types is generally at ground-level but is indiscrete and liable to be missed during the excavation. The fourth type of mound of this species has large chunks of earthen structures of 15-25 cm. height above the ground ; the main nest is below the ground-level and has a number of vaults and chambers communicating with each other. The royal chamber in this type is also indiscrete. These three types have been described recently by Chhotani (1977) in some detail from Kanha National Park (M. P.),

Roonwal (1977) has described the variation in the mound structure of this species giving figures of the five types of mounds.

The mound of *O. redemanni* is a dome-shaped or subconical, earthen structure, having some openings on the outer surface from which large, chimney-like shafts run down through the mound to its base. Inside, there are a number of vaults or chambers with fungus combs. Thus, it is a multilocular-type mound and is found in eastern and southern India and Sri Lanka.

The mounds of *Odontotermes wallonensis* (Fig. 5) are irregular, earthen structures of the height of 30—140 cm. and of 130—350 cm. circumference at base. They have a number of large, open mouthed chimneys (Fig. 5A) of 5—12 cm. diameter, leading deep into the main nest which is below the ground-level. The nests underground have tiers of chambers and vaults (Figs. 5C & D) containing large chunks of flaky and soft fungus combs. The tiered vaults are connected to each other by means of innumerable, small holes in the earthen partitions separating them. The royal chamber is indiscrete and is situated about 50 cm. below the ground-level. The dimensions of the spindle-shaped cell vary from 12—18 cm. in length, 10—12.5 cm. in width and 4—5 cm. in height. Generally, a single pair of reproductives is present in the cell but upto three queens have been reported from two mounds, of this species, at Sambalpur (Mathur & Chhotani, 1960).

Odontotermes brunneus builds low, dome-shaped, broad-based earthen mounds. Roonwal (1977) has described five types of mounds of this species. The outer surface of the mound may be smooth or rugose or papillose and may or may not have any holes.

The mounds of *Odontotermes microdentatus* (Figs. 3C & D) are low, dome-shaped structures of earth having round swellings. They are 28—90 cm. in height and 460—620 cm. in circumference at base. Inside, the mounds have a central cavity and a number of vaults and chambers for fungus. The central cavity combs are multi-tiered. The mound may extend to a depth of about 80 cm. below the ground-level but the royal chamber is located at about ground-level. The size of the royal cell varies from 14—15 cm. in length, 9—12 cm. in width and 3—4 cm. in height.

Macrotermes gilvus mounds are low sprawling, dome-shaped structures. They are multilocular and have a discrete royal chamber as in *O. obesus* mound with buttresses (Roonwal & Chhotani, 1961).

The species *O. assmuthi* generally makes its nest under the ground in soil, but has been reported to build large mounds in North Karnataka (Basalingappa, 1971). The photograph of the mound given resembles the buttressed-type mound of *O. obesus*.

The mound of *O. kushwahi* is dome-shaped to subconical, hard, earthen structure of about a metre height and has holes of 2—4 cm. diameter leading into underground tunnels. The royal chamber is located at ground-level or above it (Roonwal & Rathor, 1978).

The species of genus *Hypotermes* also build mounds. *H. obscuriceps* though occurs in India also but its mounds are reported only from Sri Lanka where it builds multilocular-type mounds almost similar to those of *Odontotermes redemanni*.

Trinervitermes biformis is reported to construct mounds only in Tamil Nadu and Karnataka. They are low (8—25 cm.), dome-shaped, earthen structures with a bowl-shaped underground nest (Sen-Sarma & Mathur, 1961; Roonwal, 1977).

(d) *Nests of Carton-Nest Building Termites*

Carton-nest builders, in India, belong to the genera *Microcerotermes*, *Nasutitermes* and *Hospitalitermes*. The main nest is generally in a stump of a tree, or on the branch, stem or in between the two branches of a live tree or in the damaged portion of a tree.

The *Microcerotermes* species nests are generally found in stumps of trees and plants left in soil. They are made up of hard material of semi-digested wood and lignin. The shape is also variable, it may be globular, conical, flat or subsquare depending upon the shape of the stump of wood (Fig. 3A). The outer surface of the nest is rough, with numerous holes, and the inner part is honey-combed with flat, thin-walled cells or cavities which communicate with each other through small holes. The cells are larger near the periphery and become smaller and narrower centrally. A larger cell generally has the physogastric queen. Substitute queens may also be found in the same nest. The most common species building such carton nests are *beesoni* Snyder in northern and central India, *annandalei* Silvestri in Orissa and Bihar and *fletcheri* in southern India. Balukhand Forest Range near Puri in Orissa is very heavily infected by *M. beesoni*. The species was found nesting in almost every dead stump of felled *Casuarina equisetifolia* tree, in the year 1960.

The *Nasutitermes* species make nests of dark grayish matter on the boulders and on trees. The species *N. indicola* Holmgren & Holmgren, which is very common in southern India, is arboreal in nesting habits and makes carton nests on and in between the branches and on the stem of trees at a height of 2—10 metres from the ground (Figs. 6A & B). The nests are globular to oval and measure 15—45 cm. in diameter. They are dark brown mottled with black and are made up of vegetable matter. The outer covering is thin, rough and fragile. Inside the outer covering, the structure is rough honey-combed and hard (Fig. 6C). The chambers or cavities inside the nest are thin, narrow and flat, becoming smaller centrally (Fig. 6D). A larger, spindle-shaped royal chamber and the nurseries of smaller chambers are located in the centre of the nest. From the nest in the tree, galleries of earth run on to the branches and the stem to ground below, through which the workers and soldiers go out foraging (Chhotani, 1971).

Hospitalitermes monoceros (König) is endemic to Sri Lanka, it makes large, rounded nest of carton-comb in the hollows of stems and branches of trees. The nest is made up of masses of excrement, plant fragments, etc. and has an

irregularly shaped, fragile blackish structure hanging out probably for the assembly of alates before swarming. The workers go out in columns about six abreast with soldiers standing on guard on long foraging expeditions (Escherich, 1911).

Microclimate in Termite Nests

Very little work has been done on the internal atmospheric conditions of the nests of the Indian termites. The nests, whether in wood or soil, or in the form of mounds or arboreal cartons, are dark, enclosed structures and give the termites protection from natural calamities like heavy rainfalls, extreme hot and cold seasons, storms, etc. and their enemies in nature. The climatic conditions (*viz.*, temperature, humidity and internal atmosphere) in the nests are very different from the outside conditions.

The temperature, inside the nests, is generally maintained at an optimum suitable to the inhabitants and varies considerably from species to species. In the nests of wood-dwelling and carton-and arboreal-nest-building termites, the temperature is higher probably due to concentration of a large number of individuals and enclosure of the nests. In the mounds of Macrotermitinae the insects regulate the temperature by different methods such as by constructing the nests in a particular manner, location of nests and by cultivating fungus which produces heat in the process of fermentation. The temperature in the fungus-comb vaults near the centre of the mound is still higher and these vaults are used as the nurseries. Regulated heat is very essential for incubation and rearing of the young-ones.

The termites being soft bodied insects are susceptible to dehydration. The enclosed nature of the nests reduces the evaporation, and so the humidity in the nests is maintained at a higher level. In the nests of wood termites the water contents of the wood they infest and the masses of faecal matter collected by the insects, which are hygroscopic in nature, maintain the humidity at a higher and desired level. Some termites (*Cryptotermes* spp. and some other Kalotermitidae) seem to have adjusted themselves to drier conditions as their nests are found in dry woods and are free of hygroscopic faecal matter. The soil-inhabiting termites get their requirement of humidity from the subsoil waters. In the true mound-building, fungus-growing termites (Macrotermitinae), the fungus combs, with high percentage of water content play an important role in keeping high humidity. The earthen walls and structures, inside the mounds, which are damp probably due to the subsoil water also help in obtaining desired humidity. In the arboreal nests of some Nasutitermitinae and carton nests of *Microcerotermes*, the central portion is very humid due to reduction of evaporation from the inner regions.

Termites, it seems, can stand quite high concentration of carbon dioxide but still the nests, with several thousands of individuals, need ventilation

and change of gases. In case of nests in the wood, the ventilation is probably through cracks and holes and through porous outer coverings in case of carton and arboreal nests. In true mounds of Macrotermitinae the ventilation is either through the walls of the nest or through other devices. The chimneys present in the nests of *Odontotermes redemanni* and *O. wallonensis* help the diffusion of gases and renewal of atmospheric air. In the closed mounds of *Odontotermes obesus* without any openings, the change of gases is, therefore, most probably through the walls of the nest. Noirot (1970) has reviewed the work done in respect of microclimate in termite nests.

Nesting Behaviour in Relation to Phylogeny

The nesting habits or behaviour of the termites is very varied. The lower termites of the family Kalotermitidae are purely wood-dwelling. This family has probably evolved from *Mastotermes* like ancestor and its members have retained the wood dwelling behaviour of *Mastotermes*.

According to Krishna (1970), the Hodotermitidae (including Termopsidae) probably arose from some extinct hypothetical Isoptera which also gave rise to the Mastotermitidae and which combined the characters of both the families. The Termopsidae are wood dwellers whereas Hodotermitidae (or Hodotermitinae) are purely soil-inhabiting, harvester termites of the deserts and drier regions.

The family Rhinotermitidae, which according to Ahmad (1950) has evolved from an extinct ancestral termite having the *Archotermopsis-Stolotermes*-type of mandibles and the ocelli, shows an advancement in its nesting behaviour over the Termopsidae for having its nests partly in soil and partly in wood.

The Termitidae arose from the family Rhinotermitidae. The nesting behaviour also shows evolution in the respect that they are purely subterranean (except some *Microcerotermes* and *Nasutitermitinae*).

The general trend in the evolution of the nesting habits of termites from wood-dwelling to purely subterranean is somehow related to the phylogenetic evolution. But the sudden departures in the nesting behaviour of the purely subterranean, harvester Hodotermitidae and the carton nesting of some *Microcerotermes* can not be correlated with the phylogenetic evolution. However, more intensive study into the nesting habits of termites is required for an accurate analysis of the lines of evolution. Just now it is a little puzzling, since these sudden departures can not be fully explained.

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INSECTS AND MICROCLIMATE

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Biologists the world over have realised in recent years that the immediate environment in which many animals actually live is very different from the total environmental conditions measured by the meteorologist. Within a biome considerable small scale variations exist, such as conditions of temperature, humidity and wind speed at various levels in vegetation, temperature profiles of soil, influence of sun's rays on the northern and southern slopes of terrains etc., and these have come to be recognized in relation to the activity of insects and other arthropods. Such a localized climate is referred to as microclimate and habitats are often determined by them. Smaller microhabitats present an important factor in determining the number of species that may live in an area, such as a dense forest habitat with a variety of microhabitats as rotten logs, humus and litter layers, various levels of tree canopies, tree trunks, under bark etc. Vegetation like cereal crops present situations where pests may be confined within sheaths, in open panicles, underneath leaves and so on. The diverse ways in which the ground surface gains and loses heat during day time and after dark, the decrease in relative humidity during the middle of the day, increase of windspeed above bare ground, changes in vertical distribution of temperature and relative humidity during different times of the day at different heights, say in a growing crop, are aspects which need considerable attention in our understanding of the activities of insects and other arthropods. Credit for propounding a new branch of meteorology called *microclimatology* concerning the meteorological levels of significance in biology, goes to the German scientist Rudolf Geiger. Most agrometeorologists and biometeorologists prefer the term *bioclimatics* to indicate the physical state of a particular biosphere. However, it is Geiger's noteworthy publication "The climate near the ground" (1950) that paved the way for a better appreciation of the need for differentiating the macroclimate from the microclimate. Subsequent works of Macfadyen (1963) Lowry (1967) among others, have gone a long way in establishing the significance of microclimatological studies in ecology.

Modern studies on microclimate attempts to measure the true conditions in which insects and other arthropods occur. Tiny, highly sensory elements fit to be inserted into minute spaces have been developed. Temperature probes or

thermocouples are used to measure localised temperatures ; humidity with hair hygrometers or with cobalt chloride or cobalt thiocyanate papers ; solar radiations with standard type solarimeters ; anemometers for measuring windspeed, evaporimeters to measure evaporation rate and lux meters for measuring intensity of light (Mecfadyen 1963, Cloudsley-Thompson 1973).

Let us examine some examples to illustrate the influence of microclimate on the activities of insects. The grassland microclimate is considerably influenced by height and density of vegetation. During various seasons the height of vegetation changes with the growth of the crop, followed by variations of temperature at different levels both by day and night. Geiger (1950) has demonstrated that where the crop is only 0.25 metres high, the warmest level at noon is seen just above soil surface and there is a reversion as night sets in, since there is a cooling of the ground. As the crop grows, say when it is 0.5 metres high, the temperature is warmest at the crop level at noon, since the crop has become dense and it is also coolest at midnight. This clearly shows that the microhabitats vary with the height of vegetation in different seasons. The microclimate also depends upon the depth of penetration of sun's rays and is determined by their angle which varies diurnally and seasonally. As has been emphasised earlier, the occurrence of temperature inversion during calm, clear nights is an important feature of grass microclimate. Such variations have been related to the behaviour of arthropods. Correlation of microclimatic data, such as localized temperature, humidity, light and windspeed among the vegetation, with the abundance of the species at different times of the day, reveals two essential aspects, viz. there is a considerable change in the numbers caught at different times of the day, and the species occupying different positions on the plant during different times of the day, as a result of vertical migration and by seeking shelter in such places as sheaves and ears in the case of graminaceous plants. For example, in the jowar plant *Sorghum vulgare* (Linn) Pars., there are two microclimatic zones, the inflorescence or panicle zone and leaf sheath zone. Following Cederholm (1963) it is found that panicle zone is exposed and shows rapid changes of temperature and light. With ripening of the ears there is a considerable decrease in the water content and the tissues become hard and so the thrips in this zone find it hard to pierce through the epidermis. The sheath zone on the other hand shows slow changes in temperature ; light and wind currents, as occurring in the panicle zone, are absent and so species like *Sorghothrips jonnaphilus* (Ramakrishna) become established in this zone. Further, there is also a vertical temperature stratification in different crops. Samples of *Anaphothrips sudanensis* Trybom collected at an interval of every two hours between 8 a.m. and 6 p.m. on *Panicum maximum* indicate their abundance in the first two samples, declining in numbers in the subsequent samples (Ananthakrishnan, 1973).

Other examples could be had from the microclimatic conditions in roots of grasses wherein several arthropods abound, such as earwigs, chelonethi,

woodlice, spiders and mites. The reason for their abundance is due to the grass being wet with dew at night, the relative humidity above the grass being 80—85%. This dew runs down into the soil and humus at the roots.

The surface temperature of leaves of such plants as potato and tomato have been measured with fine thermo-electric needles indicating that their temperature is 3—8°C above that of the surrounding air, while in shade they fall by 0·8°C. It has also been observed that differences upto 3°C occur between leaves lying in line with sun's rays and those that are at a right angle. Such differences in temperature have been proved to be useful in studying the biology of leaf miners which spend their life history entirely within leaves. Similarly the microclimate of flowers particularly those with deep corolla tubes and those on a capitulum as compositae are of equal significance to insects. In chrysanthemum flowers, Kato (1943) recognized three types of microclimate—a nearly uniform temperature all over the surface, a higher temperature in the floral disc and the highest on the corolla and correlated these with the behaviour of the dermestid beetle. The incidence of different species of thrips such as *Microcephalothrips abdominalis*, (Crawford) *Haplothrips tardus* Priesner, etc. in the head inflorescence of specific compositae host plants are possibly related to differing microclimatic conditions.

Microclimatic conditions in forests are perhaps the most revealing since the microclimate on tree tops are extremely specialized and has considerable effects on the fauna. Forest insects in particular are very few in areas with dense foliage and those that do occur prefer low light intensities and high humidity and so are not in a position to withstand wide fluctuations. Another aspect of forest microclimate may be seen in the marked influence of shade on both the maximum and minimum temperatures and the impact of these in the distribution and survival of insect larvae, particularly the beetle larvae under a fallen log. According to their actual position in the log, it could be seen that different species tend to inhabit sunny or shaded regions. In the regions exposed to the sun the number of eggs laid by bark beetles is few or negligible, while the shaded regions appear more congenial for larval development.

The effect of the forest in reducing daily fluctuations is considerable and in this connection the work of Edwards (1958, 1959) on the vertical migration of the symphylids *Scutigereilla immaculata* and *Symphylella vulgaris* in an open soil and that under shade, has given excellent results, showing that the effect of shade reduces the daily fluctuations.

Examining another aspect of microclimate, Haarlov (1960) working with danish Soils showed very marked differences in the temperature in the north and south facing slopes of ant hills. On the north side the maximum reached was 28°C and the South ; 44°C ; the greatest fluctuation of temperature was seen in the southern side where 85% of all individuals were found 0—5 cms below surface

with 65% concentrated at 0—1 cm ; on the northern side 94% were in the upper 5 cms with 91% concentrated at 0—2 cms. Therefore the southern side of the ant mound seems to have the most homogeneous distribution.

A further example concerns the mosquitoes which concentrate at different heights at different times of the day. Air is more moist at the ground level, but the humidity gradient being variable during the day, the mosquitoes by moving up and down adapt themselves so as to remain in a fairly constant microclimatic zone.

Yet another interesting instance may be had from the microclimatic condition in a living animal, say the sheep. The development of the larvae of the blow fly *Lucilia sericata* is directly correlated with the microclimate of the fleece of sheep and it has been shown that when conditions are sufficiently humid, there occurs a 'strike' of blowfly incidence and the absence of humidity or very little of it, prevent their incidence.

The significance of microclimatical studies as could be inferred from the few examples discussed is considerable and any work on population ecology of terrestrial arthropods, whether it be on the himalayan heights or deep below the soil or in crevices of bark or within plant galls, must necessarily take into consideration the role of microclimate in arriving at proper conclusions. In an overall analysis one cannot but agree that as microclimate changes, new species better adapted to the changed conditions than the existing species in the community find their way in, resulting in a change in species composition of the community.

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ASPECTS OF INDIGENOUS AND EXOTIC FISHES OF INDIA

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Introduction

The freshwater resources of our country are rather extensive comprising rivers, lakes, ponds, tanks and pools besides many man-made reservoirs. The major riverine resources include the Ganga, Yamuna, Brahmaputra, Nerbada, Tapi in north and Mahanadi, Godavary, Krishna and Cauvery in the south. These principal rivers including their main tributaries involve a total length of about 27,359 km. apart from the canals and irrigation channels (Jhingran, 1975). All these rivers are invariably connected to many lakes and ponds, and harbour a good many species of fishes, besides invertebrates such as crustaceans and molluscs. Among these fishes are the purely primary freshwater fishes spending their entire life history in freshwaters, while the secondary species partly live in estuaries, in tidal zones and even occasionally in the sea. About 220 genera under 64 families of such freshwater fishes are known to occur in India and the adjacent countries (Jayaram, 1979). The bulk of such fishes inhabiting these resources, include the Cyprinids (Carps) and Siluroids (Catfishes) followed by Clupeids and others.

Indigenous Fishes

Each of the major river systems enumerated above has its own specialised piscine fauna besides other common species (see table 1). Considering the natural distribution, excluding the artificially introduced fishes, it will be seen that every river system can be identified as the major indigenous home of certain species of economic value. Thus, the Ganga and Yamuna are known for their major carps and catfishes such as *Aorichthys aor*, *Aorichthys seenghala*, *Pangasius pangasius*, and Clupeids such as *Hilsa ilisha*, *Setipinna phasa*, *Gudusia chapra* etc. Likewise the Cauvery is known for the white Carp, *Cirrhinus cirrhosa*, *Puntius carnaticus*, *Puntius dobsoni*, *Puntius kolus*, *Labeo kontius*, *Mystus menoda*, *Tor khudree* etc. The Krishna and Godavary rivers have in common many fish species, though each has its own characteristic fishes (see table 1). *Pangasius pangasius*, *Labeo fimbriatus* appear to be more in Godavary than in Krishna. *Mystus malabaricus*

and *Mystus menoda* grow to large commercial sizes in the Krishna river system than in the Godavary. *Rita chrysea*, is abundant and is endemic in the Mahanadi. *Accrossocheilus hexagonolepis*, *Tor* species are more prevalent in the Brahmaputra river system than in others. *Labeo bata*, *Tor tor*, *Rita gogra* occur more in the Narbada, Tapi river systems than in others.

It is necessary to emphasize here that the fishes enumerated above are not only the main species, but listed only to indicate the peculiarity of each river system in relation to its piscine composition. Also it should be borne in mind that these species do not remain confined only to the principal watersheds, but also spread to the many tributaries, reservoirs and ponds connected to the main rivers.

The Prime Genetic Material

It is a common experience in fishing that we find isolated pockets or stretches in a river system which abound in such prime species as detailed in table 1. It is obvious that these areas provide the optimum conditions required for the survival and propagation of these valuable stocks. So long these habitats are left undisturbed they flourish. It is perhaps Nature's blessing that most such areas are in very isolated insignificant pockets where a normal fisherman will not ordinarily attempt to fish nor other outside human agencies would dare to venture merely because it may not benefit him economically in his designs.

Thus, these areas are the very sources where the stocks of pure breeds of our indigenous piscine fauna thrive producing pure strains of genetic material for the continued and successful propagation of its progeny.

Introduction of Exotic Species

Since a century, a number of exotic species of fishes have been introduced into our riverine and lacustrine systems. As already indicated though some of the species discussed below may not normally enter a lentic habitat, there are possibilities of their straying into connected rivers, rivulets, channels, etc.

The history of transplantation of exotic species in our waters is more than a century old (see Jones and Sarojini 1952). Perhaps what began as a source of recreation for the then English rulers became a force of habit. The first such transplantation can be said to be that of the English Trout *Salmo trutta fario* which Day in 1863 and 1867 attempted to introduce in the Nilgiri waters. However, it was Wilson in 1906 who succeeded with the rainbow trout.

The species of trout found in different areas of our country are as below.—

- i. *Salmo trutta fario* (Brown Trout). —Himachal Pradesh,
Kashmir, Kumaon.
- ii. *Salmo gairdneri gairdneri* (Steel head trout) —Nilgiris.

Table 1. Major Economically Important Species of Fishes Found in the Principal Rivers of India

River Ganga and Yamuna	River Brahmaputra	River Mahanadi	River Krishna	River Godavary	River Cavuery	River Narbada-Tapi
*Cirrhinus mrigala	Cirrhinus mrigala	Cirrhinus mrigala	*Labeo fimbriatus	*Labeo fimbriatus	Labeo potail	Puntius pulchellus
Cirrhinus reba	Catla catla	Catla catla	Labeo porcellus	Labeo porcellus	Labeo kontius	Puntius filamentosus
*Catla catla	Labeo rohita	Labeo rohita	Labeo potail	Labeo potail	Labeo porcellus	Puntius neilli
Labeo rohita	Labeo calbasu	Labeo calbasu	*Labeo boggut	Labeo boggut	Labeo calbasu	*Puntius sarana
Labeo calbasu	Labeo pangusia	Labeo fimbriatus	Labeo rohita	*Labeo calbasu	Labeo rohita	Labeo calbasu
Labeo bata	Labeo gonius	Notopterus chitala	(transplanted)	(transplanted)	(transplanted)	(transplanted)
*Aorichthys aor	Tor tor	*Rita chrysea	Cirrhinus mrigala	Labeo rohita	*Labeo ariza	*Labeo bata
*Aorichthys seenghala	Tor progenius	Tor putitora	(transplanted)	(transplanted)		
*Wallago attu	Accrossocheilus hexagonolepis		Puntius kolus	Puntius kolus	*Puntius kolus	Labeo fimbriatus
Silonia silondia	Semiplotus semiplotus		Tor mussullah	Tor mussullah	*Puntius dubius	*Labeo boggut
Pangasius pangasius	*Puntius sarana		Tor khudree	Tor khudree	Puntius dobsoni	*Tor tor
Bagarius bagarius	*Notopterus notopterus		Hilsa ilisha	*Hilsa ilisha	*Puntius carnaticus	*Cirrhinus mrigala
Rita rita	*Notopterus chitala		Catla catla	Catla catla	Puntius micropogon	*Rita gogra
Eutropichthys vacha	*Aorichthys seenghala		Channa sp.	*Cirrhinus mrigala (transplanted)	Puntius curmuca	Aorichthys seenghala
Clupisoma garua	Pangasius pangasius		Aorichthys seenghala	Cirrhinus horai	*Cirrhinus cirrhosa	Wallago attu
Ompok bimaculatus	Silonia silondia		*Mystus cavasius	Thynnichthys sandkhol	Cirrhinus fulungee	Mystus cavasius
			Schismatorhynchus nukta	Osteobrama belangeri	Cirrhinus mrigala (transplanted)	Clupisoma garua
				*Wallago attu	Cirrhinus reba	Ompok bimaculatus

River Ganga and Yamuna	River Brahmaputra	River Mahanadi	River Krishna	River Godavary	River Cauvery	River Narbada-Tapi
Ailia coila	*Wallago attu			Silonia childreni	Mystus punctatus	Silonia childreni
Notopterus chitala	*Clupisoma garua			*Pangasius pangasius	*Mystus montanus	Mastocembelus sp.
Setipinna phasa	*Eutropichthys vacha			Bagarius bagarius	*Aorichthys aor	
*Hilsa ilisha				*Aorichthys aor	*Aorichthys seenghala	
Gudusia chapra				Aorichthys seenghala	Silonia childreni	
Aspidoparia morar				Channa sp.	Pangasius pangasius	
					*Wallago attu	
					Glyptothorax madraspatanus	
					Osteocheilus brevidorsalis	
					Osteocheilus nashi	
					Channa marulius	
					*Catla catla (transplanted)	
					Tor khudree	

* Indicates dominant fishes in landings

- iii. *Salmo gairdneri shasta* (Rainbow Trout) —Travancore high ranges.
- iv. *Salmo salar* (Atlantic Salmon) —Kashmir
- v. *Salvelinus fontinalis* (Char)

These have been mainly introduced originally for game purposes and even now to a large extent they are fished for similar reasons. Besides the Trout two other species have also been transplanted again for sport or ornamental purposes. These are : *Tinca tinca* (The Tench) and *Carassius carassius* (Golden carp). Both were introduced in the Ooty lake in 1874 by MacIvor. The tench was brought from England and the Golden carp from Central Europe. These are now fairly well established in Nilgiri waters.

We shall now discuss the species of fishes which have been introduced for commercial purposes and which have established themselves in our waters as a source of good to moderate fishery.

1. *Cyprinus carpio* (Linnaeus) (The Mirron Carp).—This species has been extensively introduced in our waters from its original home in China. It breeds in confined waters and is ideally suited for culture in ponds, tanks and other such lotic water bodies. At present the species enjoys a global distribution since it is easily acclimatized to a variety of habitats (Alikunhi, 1966). It is non-predatory, but competes for food with *mrigal* and *kalbasu*. Three different subspecies occur in India according to the pattern of scaling on the body :

- (a) *Cyprinus carpio communis* (Scale carp)—This is the the original form.
- (b) *Cyprinus carpio specularis* (Mirror carp)
- (c) *Cyprinus carpio nudus* (Leather carp)

2. *Hypophthalmichthys molitrix* (Valenciennes). (Silver Carp). This fish, a native of South and Central Chinese rivers (Rivers West, Yangtze), has now been introduced into India and many other countries. It is mainly a phytoplankton feeder, breeding in rivers and with a limited tolerance to brackish waters as well. This species was brought to India from Japan in 1959 and introduced into the ponds of the Central Inland fisheries research Institute's fish culture division at Cuttack. Several consignments of fry successfully bred at this institute have been sent for introduction to different states of our country.

3. *Ctenopharyngodon idella* (Valenciennes) (Grass carp)

This fish is also called the "White Amur" in Russia. It has been introduced into India from Hong Kong. Though a riverine fish of freshwater habitats this species can also tolerate slightly brackish waters. Adults are exclusively herbivorous whereas the juveniles subsist on zooplankton and other animal matter. The first consignment of grass carp was brought to Cuttack,

in 1959 by the Central Inland Fisheries Research Institute from where other states were supplied.

4. *Tilapia mossambica* Peters (Tilapia)

This again is a riverine fish introduced from its original home of East coast of Africa and very well established in our country. It can also tolerate varying salinity conditions. Adults are herbivorous but when food is scarce feed on worms, insects, crustaceans, fish larvae etc. It breeds prolifically throughout the year and has been found unsuitable for culture along with Indian major carps since it causes adverse effects on growth and production of carps and also because of its deprecation on carp fry (Jhingran, 1975). It was brought to India from Bangkok in 1952 and also from Sri Lanka and is one of the exotic species which is very common in most river systems of our country and in many areas it has become almost a pest.

5. *Osphronemus gorami* (Lacépède) (Gourami)

The common occurrence of this species as in the case with *Tilapia* has led to the unawareness of its being an introduced species into our country from the freshwaters of Indonesia, Thailand, Malaya and Vietnam. It breeds naturally in ponds, streams, the adults feeding mainly on aquatic vegetation, but becoming omnivorous devouring insects, frogs, flesh, and small fish under conditions of stress. This breeds naturally in streams and ponds. It was first introduced in Calcutta during the first half of the last century from Java. A second lot was brought to Tamil Nadu from Mauritius in 1865. the breeding of which was reported by Raj in 1916. From Tamil Nadu the species was transplanted to other states. Like *Tilapia* this is also a very common fish in any fishery operation.

Discussion

One of the major reasons for transplantation of exotic species in our country was that our indigenous major carps normally do not breed in confined waters and also they do not grow fast as the others. But this hold good for *Tilapia* and *Gourami* which are stream dwellers and which breed both in lentic and lotic habitats. What prompted the early fishery naturalists to introduce them will only be of historical interest. The immediate need is to investigate the effects such introductions have caused in our ecosystem. How far these artificially released stocks are successful in competing with the already existing natural stocks, how the available food is shared by the new arrivals and the old inhabitants, when, how and in which ecological niches these new stocks have moved in and above all how they have influenced the ecosystems as a whole, whether they are disturbed or not and how they have adjusted are all points of enquiry requiring attention by ecologists and biologists. Initiation of urgent steps to conserve the existing stock of prime genetic material from being

affected by these exotic species would appear important. An intense location survey and stock assessment of this genetic material would equally appear essential.

Acknowledgements

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BIRD MALARIA : ITS PERSPECTIVE AND PREDICAMENT

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Despite remarkable advances in bio-medical science, few people, even the biologists, are fully aware of the occurrence of malaria in birds. To the malariologists, bird malaras are of immense importance as they lend themselves well to experimentation and until the discovery of malaria (*Plasmodium berghei*) in Congo tree rats in 1948, the researcher has had to rely on the birds as the only experimental animals in which malaria could be experimentally studied. In fact, all the drugs screening for antimalarials in World War II was carried out in birds (Wiselogle, 1946).

Bird malaria, like malaria in man, caused by unicellular parasitic organisms belonging to the genus *Plasmodium*, which invade cells of blood and various other organs of the body. There are over 25 species of *Plasmodium* infecting a wide range of birds—some of them are highly pathogenic to domestic and game birds. *Plasmodium gallinaceum*, causing a disease known as chicken malaria, is a serious threat to poultry farming. This species is largely used as a most useful tool in the study of experimental chemotherapy, immunity and veterinary preventive medicine.

History

Malaria, as a disease, has been known since the earliest days of recorded history. The symptomatology of malaria in man has been recognized in ancient history and other writings, The Vedic medical literature refers to it as the "King of Diseases" The very name of the disease, malaria, is derived from the Italian words *mala* and *aria*, i.e. 'bad air', and conveys an association of it with miasmatic vapours. However, the causative agent of malaria, *Plasmodium*, was unknown until 1880 when Charles Louis Laveran, a French army surgeon stationed in Algeria, showed the parasite under a microscope after spending much of his time looking at the unstained preparation of the blood of malaria patients in the military hospitals of Bone and Constantine. He observed the formation of active filaments around a pigmented body in the blood and called them "*Oscillaria malariae*".

About ninety years ago, Basil Danilewsky in the Russian Ukraine was assembling the first information of the avian malaria parasites and other protozoa. He may be rightly called as the father of avian malariology. The puzzle of the transmission of malaria was settled by Sir Ronald Ross, a British Physician in India, who while working in Calcutta, first demonstrated the development of malaria parasite in the mosquito in 1898 with an avian species of *Plasmodium*. The discovery of preerythrocytic cycle was first shown by James and Tate in 1937 in chicken infected with *P. gallinaceum*. The tissue phase (exoerythrocytic development) of malaria parasite was first demonstrated in avian malaria in 1934 and after about 14 years, *i.e.*, in 1948 it was discovered first in *P. cynomolgi* of Macaque monkey, then in *P. vivax* and lastly in *P. falciparum* in the years 1948 and 1949 respectively (*vide* Boyd, 1949 ; Garnham, 1966 ; Ross, 1923).

Life Cycle

The avian malaria parasites have two stages or cycles of development—one, in the birds and the other, in the culicine mosquitoes. The methods of reproduction in the two hosts are different ; in birds, it is by asexual method whereas in the mosquitoes, it is by sexual method. The life cycle for chicken malaria caused by *Plasmodium gallinaceum* is shown in Fig. 1.

Avian Cycle

Infection of the birds originates when the sporozoites are introduced into the blood by the bite of an infected mosquito (always a female, as males are incapable of piercing the skin). The sporozoites are in the form of filaments which pass a very brief period (about half an hour) in the blood. They rapidly disappear from the circulation and are soon picked up (or perhaps invade) by the receptive cells in various organs (chiefly in macrophages of the skin), where they gradually grow into enlarged cysts (schizonts), containing 100-200 elongate merozoites known as cryptozoites. The cryptozoic merozoites enter adjacent macrophage cells, and now in much larger numbers they invade other organs of the bird except the brain and bone marrow. The products of this second generation are called as metacryptozoites. The metacryptozoites are now capable of invading erythrocytes and the prepatent period comes to an end between 72 and 75 hours after the introduction of sporozoites. This constitutes the preerythrocytic stage of the cycle during which the subject remains symptoms free. At the conclusion of this portion of the life cycle, the progeny spill over into the blood stream and enter red blood cells (erythrocytes) to start the blood cycle. However, there are a few species of malaria parasites occurring in birds which, in heavy infections, predominantly parasitize primitive blood forming cells (erythroblasts and their precursors).

Once in the erythrocyte, the parasite grows rapidly, utilizing as food mainly the hemoglobin and glucose derived from the host cell and the blood plasma. The earliest stage often has ring-like appearance and is known as ring; from it develops the vegetative stage or trophozoite. Soon nuclear

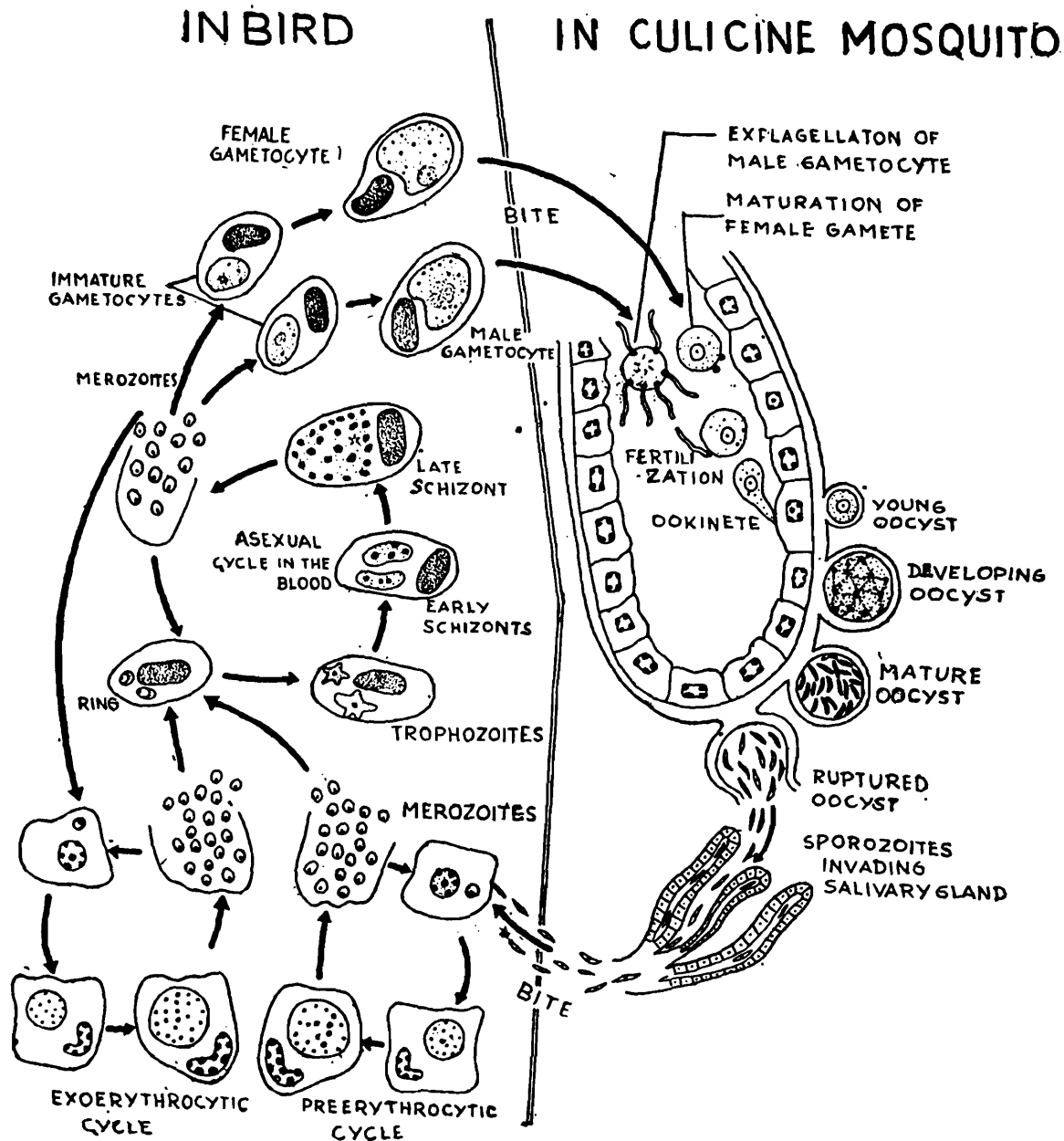


Fig. 1. Life cycle of Chicken malaria parasite *Plasmodium gallinaceum*.

division begins, and after several such division, the cytoplasm also undergoes fission—the process culminates with the formation of about 16—20 merozoites. With the formation of merozoites the red cells burst and the merozoites are liberated into the blood stream. The liberated merozoites are capable of infecting more red blood corpuscles and the multiplication continues. It is this periodic breaking of erythrocytes that causes characteristic chill and fever in human malaria. It is interesting that in the avian malarias, even though the periodic nature of the asexual cycle may be even more marked than in the species of *Plasmodium* infecting man and other primates, fever is usually

absent. *Pinottii* malaria of pigeon is an exception. The fever following chill is due to the liberated foreign protein, globin, and other cell products.

In avian malaria the exoerythrocytic cycle may originate from stages in the blood, and gametocytes, at least in certain subgenera (*Haemamoeba*), may arise directly from the merozoites of exoerythrocytic schizonts. That is why those tissue stages occurring before the invasion of erythrocytes are often termed as primary exoerythrocytic or preerythrocytic stages and those occurring after the invasion of the blood are referred as secondary exoerythrocytic or paraerythrocytic stages. Exoerythrocytic multiplication, thus, is believed to result in feedback into the blood and probably the chief cause of relapse in bird malaria.

For reasons not yet understood, some of the merozoites invading erythrocytes fail to repeat this cycle and differentiate into male and female gametocytes. No further development of these forms occurs until blood is ingested by a female mosquito during the bite.

Mosquito Cycle

In the gut of the mosquito, five hours after the infective meal, the gametocytes promptly undergo gametogenesis (the differentiation of gametes). The changes in the transformation of microgametocytes into male gametes are profound and visible. The parasite free of its host cell, soon gives rise to 8 minute filament-like microgametes by a process known as "exflagellation" (as often appearing like an undulating membrane or flagella). By 12 hours, the microgamete swims off, and after union with a macrogamete; the zygote (the only stage in the life cycle which is diploid) is formed. The zygote is worm-like and actively motile, known as ookinete (or "vermicule") which makes its way through the gut wall of the mosquito to finally coming to rest under the gut epithelium where it develops into oocysts at about 48 hours after the infective meal.

At 53 hours, reduction division occurs which results in the formation of a haploid binucleate oocysts. The oocysts, afterwards, undergo mitotic division and gradually transform into a spherical body resembling a tumor on the outer surface of the gut. By ninth to tenth day the gut becomes studded with such masses, but there is no evidence that they cause injury to the host mosquito. At a temperature of 28°C, on maturity hundreds and thousands of infective sporozoites are liberated into the body cavity, wherefrom they migrate to the salivary glands. The sporozoites may live as long as the mosquito does and are introduced into the blood of the victim whenever the mosquito bites.

Relapses

Relapse is a renewed manifestation of the clinical symptoms. The parasitaemia of a malarial infection involving an increase in the surviving

population of erythrocytic forms is known as recrudescence, and the multiplication of parasites in the blood from a secondary exoerythrocytic source is termed as recurrence or the true relapse. It is a striking feature of many malarial infections of mammals. In avian malaria the constant presence of parasites in the blood stream is ensured from premunition, and the decline of premunition results in their reactivity, *i.e.*, in a recrudescence. The secondary exoerythrocytic schizogony in avian malaria, in general, has a limited existence as it is inhibited by the development of immunity; thereafter recurrences could not occur. In primate malaria, on the other hand, secondary exoerythrocytic schizogony is usually unlimited in duration as it is not affected by immunity, and recurrences are common. Relapses in malaria are especially frequent in the weeks immediately following the apparent recovery from the acute attack, but they also occur at much longer interval—sometimes years after the initial infection.

Diagnosis

Diagnosis of bird malaria, whether an acute infection or a relapse, is always made by finding parasites in the blood. Serological tests are available but are seldom used. Blood films may be either thin or thick, the former are more easily diagnosed, but the latter save much time and will also detect parasites when it would be very difficult to find them in a thin film.

Differences between Avian and Mammalian malaria

The points on which avian malaria differs from mammalian malaria are as follows :

1. There are certain species of malaria occurring in birds where other types of blood cells (*i.e.*, erythroblasts) may also be invaded.
2. In the avian malarias fever is usually absent. *Pinottii* malaria of pigeons is an exception.
3. Whether gametocytes even originate from the exoerythrocytic cycle in human malaria is unknown, but they may do so in some of the avian malarias.
4. In avian malaria the exoerythrocytic cycle may also originate from stages in the blood. This probably does not occur in mammals.
5. The preerythrocytic forms of simian malaria are non-infective on subinoculation to other clean animals, but infection may occur in avian malaria.
6. Tissue phase (preerythrocytic and exoerythrocytic schizogony) of simian malaria takes place inside the parenchymatous cells of the liver and not in the reticulo-endothelial cells as in avian malaria, *i.e.*, in birds the preerythrocytic and exoerythrocytic cycles are much more versatile in their ability to develop in a variety of sites (in mesodermal tissues), not being limited to the liver.

7. Tissue phase of simian malaria consists of only one generation of preerythrocytic schizonts, the cycle lasting for 8 to 9 days, whereas in avian malaria there are several generations and each cycle occupies about 42 hours.

8. The exoerythrocytic cycle of mammalian malaria is comparatively of shorter duration than avian malaria which probably usually lasts for the life of the bird.

9. In avian malaria, the pathology is greatly influenced by the site of secondary exoerythrocytic schizogony in the capillary endothelium of various organs, and particularly in the brain in case of *P. gallinaceum*. Whereas in primate malaria the tissue stages are entirely harmless.

10. Transmission of human and monkey parasites is effected by anopheline mosquitoes while transmission of bird parasites is effected by culicine mosquitoes, and very rarely by *Anopheles*.

Pathogenicity

Avian malaria parasites vary greatly in host specificity, in the pattern of exoerythrocytic schizogony and in pathogenicity. The important pathological differences among various infections of avian and mammalian malaras are summarized in Table I. Bird malaria, not unlike human malaria, may show a widely varying pathological picture and may even simulate other diseases. The basic pathological processes include the destruction of erythrocytes and the production of pigment haematin and toxic damage to various tissues.

In chicken malaria (*P. gallinaceum*), the overwhelming parasitaemia is accompanied by an intense anemia in which the red blood count sinks below a million per cu mm.; toxemia is followed by centrilobular necrosis in the liver with all the disastrous effects on metabolism caused by this lesion. The parasite, *P. gallinaceum*, exerts its pathogenic effect on the chicken in two ways; firstly by the parasitaemia, and secondly by the exoerythrocytic development in the brain. In epizootics, the disease may run a very acute course, the bird, according to Crawford (1945), lying in a corner with its face and comb much congested; it becomes pale, suffers from diarrhoea and dies within a week of an intense parasitaemia. But if quining is given, the life of the birds is prolonged, only for it to become paralysed, however, and to die in the second and third week, with the cerebral capillaries blocked with exoerythrocytic schizonts. Lesion on the eyelids develop after a week, with severe necrosis.

Barretto and de Freitas (1945) showed that *P. gallinaceum* caused a mortality rate of 100 per cent in young chicks, less than 250 g in weight, of 87 per cent in chickens weighing 300—350 g, and of 45 per cent in fowls weighing 1000 g. Adult birds usually survive, both in nature and in the

laboratory, and the parasitaemia is relatively low throughout the infection, although it may persist in an occult form for years.

The malaria parasite, *P. relictum* causing disease to pigeons mourning dove, pintail, cinnamon teal, falcated duck, black swan, and various passerine and other birds, is highly pathogenic especially for the pigeon but less so for the mourning dove and canary. Affected squabs become weak and anemic, with enlarged and heavily pigmented spleens and livers. A few cases of splenomegaly and hepatomegaly were noted by the author in weaver bird, *Ploceus philipinus* infected with *P. relictum* which produce an acute anemic condition that may be the principal cause of death of the birds.

In turkey malaria, *P. durae* causes an acute often fatal disease in birds less than a year old. According to Purchase (1942), at necropsy of acute cases of turkey malaria the liver, spleen and kidneys are dark and congested, the lungs slightly edematous, and the pericardial cavity contains an excess of clear fluids. In chronic naturally infected birds, the spleen is reduced in size, hard and fibrous, the liver is firm, with chronic congestion of much fibrosis. The villi of the duodenal loop are packed with large pigment granules.

Treatment

Drug effects may vary with the species of parasite, the different stages of the parasite in the host and with the geographical region in which the parasite resides. However the bird malarias, in general, respond to treatment with quinacrine, chloroquine, primaquine and other antimalarial drugs. These were, in fact, discovered by screening against bird malarias. Chloroquine at the rate of 5 mg per kg, chloroguanide at 7.5 mg per kg and pyrimethamine at 0.3 mg per kg. protect chickens against *P. gallinaceum* infections. But, as a practical matter, treatment is usually hardly worthwhile, and preventive measure are recommended instead.

Prevention and control

Since the antimalarial drugs are not totally effective and allowed the persistent appearance of drug-resistant forms, the means to avoid infections are widely being suggested. The methods used in prevention and control may often differ not only in emphasis but also in actual technique. Since bird malaria is carried by mosquitoes, prevention depends upon mosquito control. Residual spraying of insecticides such as DDT or lindane are mostly effective. Bird can also be raised in screened quarters where mosquitoes can not get to them.

Perspective and predicament

An extensive volume of research has been conducted on avian malaria because of its close similarity to malaria in man. Most experimental work on bird malaria has been carried on with captive birds. Field studies on the

epizootiology of these parasites in wild populations have very limited so as to provide an understanding of true prevalence of the parasites and their impact on the wild population. It is well known that wild birds exhibit fluctuations, sometimes cyclic, and that some species become extinct. Many government agencies and private groups are increasingly aware of this phenomenon and are conducting studies to determine causes, developing methods to preserve endangered species, and instigating operations to combat causes of populations reductions. However, in an attempt to interpret the impact of disease on wildlife populations, one must be aware of other ecological factors.

Classically survival is dependent on availability of shelter, food and water, while other related factors include behaviour and population density. Disease is a product of adverse habitat. Even when all factors in the habitat are favourable to a species, disease still can become a controlling factor.

Table 1. Some representative of avian and mammalian malaria parasites (*Plasmodium* spp.)

Species	Host	Periodicity (Hours)	Outcome
In man			
1. <i>P. falciparum</i>	Man	48	Mortality variable
2. <i>P. malariae</i>	"	72	Chronic
3. <i>P. ovale</i>	"	48	Relapsing
4. <i>P. vivax</i>	"	48	Relapsing
In monkeys			
5. <i>P. knowlesi</i>	Kra monkey (<i>Macaca irus</i>)	24	Chronic
	Rhesus monkey (<i>Macaca mulatta</i>)	24	Death
6. <i>P. shortti</i>	Bonnet monkey (<i>M. radiata</i>)	72	Resolution
7. <i>P. cynomolgi</i>	Kra monkey (<i>M. irus</i>)	48	Resolution
In mouse			
8. <i>P. berghei</i>	Mouse	24	Death
In birds			
9. <i>P. gallinaceum</i>	Chicken	36	Death
10. <i>P. lophurae</i>	Duck	36—48	Mortality variable
11. <i>P. durae</i>	Turkey	24	Death
12. <i>P. relictum</i>	Sparrow	30—36	Mortality variable
13. <i>P. circumflexum</i>	Thrush	48	Chronic
	Canary	48	Mortality variable
14. <i>P. elongatum</i>	English Sparrow	24	Fatal
15. <i>P. vaughani</i>	Robin	26	Never fatal
16. <i>P. pinottii</i>	Toucan	24	Non-pathogenic
	Pigeon	24	Death

Plasmodium durae in turkeys in Kenya (Purchase, 1942) and of penguins in zoo collections (Fiennes, 1967) certainly suggests a potential for severe epizootics. Markus (1974) is of the opinion that the widespread distribution of avian haematozoa and the high prevalence of parasitism, especially in temperate regions, coupled with the obvious and well-documented epizootics in commercial flocks in such regions, marks it tempting to conclude that such parasites are indeed limiting (or potentially limiting) factors of avian populations.

But, what occurs in *Plasmodium* infections among wild birds under "natural" conditions is extremely difficult to determine with the limited techniques so far developed. This might be the reason why no investigator has succeeded to uncover positive evidence of epizootics losses in any species of wild bird in nature. Methods of therapy and immunization developed during the past 5 to 8 decades for combating disease in man and his domestic stock are usually not feasible as approaches to wild life disease, especially of birds being winged species. It is, therefore, essential to study the dependency of disease on habitat and its ecological relationships in addition to other factors such as viral and bacterial agents, toxic pollutants, etc., in an effort to uncover ways in which we can develop management of habitat as a tool in controlling disease losses among wild avian populations.

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FISHES IN RELATION TO MAN

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Fishes are the most numerous of the vertebrates. There are from 15,000 to 17,000 recent species. Hora (1927), Chatterjee (1934), Gravely (1937), made observations on the larvicidal nature of certain fish species. Prashad and Hora (1936), emphasized that survey should be conducted of special areas on systematic lines for the larvicidal fishes. Hora and Nair (1938), Job (1940, 1941a, 1941b, 1943 and 1944) and John (1940) have suggested that study of life history and bionomics of some species have proved their utility as larvicidal fishes. A thorough taxonomic study is required to assess our fish wealth. In the present paper an attempt has been made to evaluate the importance of fishes. This information is supposed to be of immense value to common man.

The average diet of an Indian is deficient, due to the lack of protein but also due to the shortage of minerals. The fish serves as an excellent source of protein. It also provides good energy food and it contains minerals and vitamins. The marine or freshwater fishes contain less of carbohydrate and for these reasons the fish is considered superior to cereals. The marine fishes are richer in iodine than the freshwater fishes. The liver of fishes is a good source of vitamins A and D, but it also contain other vitamins. Vitamin B₁ and B₂ also occur in the flesh of fishes in the same amount as in meat. The flesh contains organic and inorganic compounds. They are : water 80%, protein 15—25%, minerals 1-2% (is made up of calcium, phosphorus, sodium, potassium, sulphur and chlorine).

Proteins are found in the muscles and contribute the most important item of food. These proteins are easily digested and are much superior to other animal proteins such as egg, beef and milk. Fishes are noted for these vitamin contents namely A, C, D and B-Complex. The liver of several species of fishes are very rich in vitamin A and D. Fish eggs are also good source of B-Complex and also Vitamin C. The fish fauna of Indian waters, both fresh and marine are rich and several varieties of fishes are commonly used as food. Few important species of food fishes of Madhya Pradesh are as follows : *Catla catla*, *Labeo rohita*, *Labeo calbasu*, *Cirrhinus mrigala*, *Wallago attu*, *Mystus seenghala*, *Mystus aor*, *Rita rita*, *Notopterus chitala*, *Notopterus*

notopterus, *Hilsa ilisha*, *Clarias magur*, *Heteropneustes fossilis*, *Anabas testudineus*, *Ophicehalus marulius*, *puntius*, *sarana* and *Tilapia mossambica*, etc.

The mackerel is also an important commercial fish on the west coast of India. The following species of mackerel occur in Indian waters, *Scomber microlepidotus*, *Scomber brachysoma*, *Scomber jamsaba* and *Rastrelliger kanagurta*. The Bombay duck (*Harpodon neherus*), the bulk of the catch is dried in the Sun and eaten as curries etc. The ribbon fishes, *Trichiurus haumela*, *T muticus* and *T. sauala*, constitute an important fisheries on the Madras coast.

Shark and rays are also valued for the oil that is contained in their liver. Shark liver oil is a cheap source of vitamin A and D, besides they are also converted into fish meal and manure. The shark and rays that are used in the liver oil industries are namely, *Galeocerdo tigrinus*, *Carcharhinus melanopterus*, *C. gangeticus*, *C. limbatus*, *C. menisorrhah*, *Scoliodon palasorrhah*, *S. walbechmi*, *Sphyrna blochi*, *Chiloscyllium griseum*, *Stegostoma varius*, *Nebrius ferrugineum*, *Dasyatis bleekeri*, *Aetobatus flagellum*, *Actomyxus milvus*, *Pristis cuspidatus*, *Pristis microdon* and *Rhinobatus granulatus*.

Besides providing food to man, fishes are source of numerous by-products, of which oils are the most important. Fish oils are of two kinds (a) liver oil (b) body oil.

Liver oil

The medicinal oil is extracted from the liver of shark, Sawfishes, Skates and rays. In Kerala, Bombay and Tamil Nadu the production and marketing of shark oil are carried by the Fisheries Dept. of these states. The annual production is about 70,000 gallons. Fish liver oil is considered important because it is one of the natural source of vitamin A, D and C. Fishes like Cod, halibuts, tunas, sharks and rays yield the best liver oil. Before world war II Norway and Sweden were the leading countries in this field.

The Indian sharks and rays are valuable source of liver oil. Vitamin E is also an important constituent of fish liver oil. Vitamin A is essential for proper vision and vitamin D for healthy bones. Both the vitamins are essential for the growth of infants and children, especially in India where malnutrition is much prevalent. These vitamins are also essential constituents for the poultry and livestock.

Body oil

The oil derived from sardines, mackerels and catfishes are put to many uses. The oil Sardine (*Sardinella longiceps*) is a very valuable fish owing to its food value and the oil contents. Body oils are prepared side by side with

the manufacture of fish-meals. Body oil is also extracted from filet waste (all the left-over like tail, fins and bones). Body oil is also extracted from whole shark after liver is removed for oil.

Mackerel and oil Sardines are the chief sources of the body oil industry which flourishes mainly on the Malabar Coast. Fish oil is used extensively for the manufacture of edible oil, margarine, lard-substitute, soap, paints, varnishes, leather, jute and steel industries.

Fish by-products

There are numerous by-products, besides oil, which are economically useful. The most important are fish meal, fish flour, fish proteins, fish glue, fish guano isinglass and fish skin.

Fish meal is prepared from waste collected from fish market, or from factories concerned with oil extraction and canning or from surplus fish during period of glut or abundance. The chief composition of fish meal is 55.70% proteins, 2—15% fat, 10—12% minerals, 6—12% water, besides small quantities of iron, calcium and phosphorus and traces of vitamin A, D, B and K.

Therefore, fish meal is considered as a valuable source of food material. High quality fish meal is used on animal farms to supplement the daily diet. While the low-grade variety is used as manure in plantation of coffee, tea and tobacco. Approximately 1.5 lakh maunds of fish-meal is manufactured in India. Karwar and Cape Comorin are the main areas on the West coast for the production of fish-meals.

Fish flour is the fine, superior quality of fish meal, which is good for human consumption. It can be blended with wheat or maize flour as supplement to protein diet. It is used in bread, biscuits, cakes, sweets, soup and gruels as an enriching compound.

Fish proteins in their purest forms are extracted after fat is removed from fish meal. Refined fish proteins are used as a substitute for the white (albumen) of the egg in baking cakes, fine ice-creams, etc. It is a valuable ingredient in certain pharmaceutical products. *Fish-glue* is prepared from skin, and in trimming and bones. This glue is used as an adhesive in book-bindings, backing for labels, for paper-boxes in furniture making.

Isinglass is obtained from the air bladder of the perches and Indian Salmon (polynemids). An inferior quality is procured from the gem fishes (Scianidae) and certain species of catfishes. Isinglass is used as a substitute for the gelatin in confectionery. It is also used for the clarification of wines and beer. It is also used in the manufacture of plasters and special cement.

Fish skin : The skin of sharks and rays are tanned and marketed as ornamental leather. Tanned fish skin is used in the manufacture of shoes,

handbag, wallets and tobacco pouches and ornamental boxes. Sardine guano is used as manure in the coffee, tea, coconut, sugarcane and tobacco plantation. The powdered fish, guano is used as feed for pig, cattle and poultry. Surplus fishes instead of being allowed to rot are dried, then they are converted into a coarse powder. This powder is used as a manure as well as food in the form of soup. Few fishes are applied directly in the field as manure *e.g.*, Sardine, mackerel, and horse mackerel, when they appear in larger shoals in the coastal area. The waste products of the fish curing yards (pit manure) is also used for manurial purpose.

Larvicidal fishes

The following species of fishes are useful for controlling the malaria. These fishes eat the mosquito larvae and in this way help in controlling this disease.

Exotic : *Gambusia affinis holbrooki*, *Lebistes reticulatus*, *Carassius auratus*.

Indigenous : *Notopterus notopterus*, in young stage this fish may feed on mosquito larvae.

Chela laubuca, *Rasbora daniconius*, *Danio devario* and *D. acqipinnatus*, *Esomus danrica*, *Puntius phutunio*, *Labeo rohita* and *Catla catla* feed on insects and small crustaceans during their earlier stages and are thus useful larvicides during this limited period of their life.

Aplocheilus panchax : Indian Top minnow. The most suitable indigenous fish for destroying mosquito larvae. It can live both in fresh and modern brackish water and is a perennial breeder. *Oryzias melastigmus* : This fish has been very useful as larvicidal fish and it can breed in confined water.

Colisa fasciata : This fish is regarded as good larvicidal fish. This fish can easily breed.

Anabas testudineus : Southwell (1920) found it very useful for destroying mosquito larvae. *Ambassis ranga* and *Ambassis nama* : These fishes are valuable cyclopsivores, their use in mosquito control is of secondary to cyprinodonts.

Badis : These fishes have been found to feed on mosquito larvae (Chaudhuri, 1911) and Southwell (1920).

Glossogobius : Murphy (1914) found it useful for destroying mosquito larvae.

The fishes of the family cyprinodontidae—the top minnow of India (genera—*Aplocheilus*, *Oryzias* and *Aphanius* constitute the most efficient larvicidal form.

From the foregoing account it is clear that the fishes are of much significance and use. But there is mass killing of fishes due to the pollution

caused by the discharge of industrial wastes and effluents. It is suggested that the industrial wastes should be treated and recycled before they are discharged into the different water-bodies.

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MITES INFESTING FIELD CROPS IN INDIA

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Mites have gained tremendous agricultural importance in India as many of those cause immense damage both directly and indirectly to various types of field crops bringing significant loss to the growers.

Nearly, 152 species of phytophagous mites belonging to Tetranychidae (52 species), Tenuipalpidae (22 species), Tarsonemidae (5 species), Eriophyidae (71 species) and Tuckerellidae (2 species) are known to occur on different types of field crops in India, of those, 30 species are of major or potential importance while the rest are relatively less important or are casual visitors doing apparently little or no damage to the crops.

An attempt has been made here to discuss the mites infesting field crops, viz., cereals, millets, pulses, vegetables, fruits, oilseeds, plantation crops, fibre crops, sugarcane and tapioca, ornamental plants, timber crops, spices and condiments and fodder crops, in the light of their nature of damage, distribution in India and wherever possible, their host range and period of occurrence, etc. basing on author's own observations as well as from literature.

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Mites infesting cereal crops

Among the cereal crops in India, paddy, wheat and maize are often attacked by mites. Paddy is attacked by two species, viz., *Oligonychus oryzae* (Hirst) and *Schizotetranychus andropogoni* (Hirst). The former is prevalent in South India (Nagarjan, 1957 ; Nair, 1975 ; Rai *et al.*, 1977) while the latter occurs in eastern and north-eastern India as well as in Andaman & Nicobar Iss. (Gupta, 1976). The attack of *O. oryzae* turns the leaves whitish and the infested plants show stunted growth. Shredding of interveinal areas and rupture of fibres along leaf blade was also reported. This mite remains active in field during May-June and the population dwindles during monsoon months. *S. andropogoni* on the other hand causes the appearance of small oval whitish patches arranged irregularly on either sides of midrib. It is also

a premonsoon pest. Gupta (1975) studied the relative susceptibility of different varieties of paddy to the attack of this pest. *Oligonychus indicus* (Hirst) occurs on paddy but causes no apparent damage to the crops. *Petrobia latens* (Muller) is assuming the status of pest in unirrigated wheat crops in India (Gupta *et al.*, 1973 ; Sandhu *et al.*, 1976) an infestation remains in the field from December till harvest. Because of feeding of leaves by thousands of mites, which in case of severe infestation is not uncommon, the leaves turn drying from tip backwards. It has a wide host range (Khan *et al.*, 1969) of these, barley and maize are important. It is known from Punjab, Haryana, M. P., and Delhi. Gupta *et al.* (1973) studied the relative susceptibility of different varieties of wheat to the attack of this mite. *O. indicus* also infests maize in northern India (Sandhu *et al.*, 1973) causing reddening of leaves and stunted growth.

Mites infesting millets

Four species, namely, *O. indicus*, *S. andropogoni*, *Tetranychus neocaledonicus* Andre and *Aceria sorghi* ChannaBasavanna are known to infest millet crops in India. Sorghum (*Sorghum vulgare*) is infested by *O. indicus* in southern India (Cherian, 1933) causing appearance of whitish spots on the leaves and ultimately those spots develop into reddish patches. Jowar (*Andropogon sorghum*) is infested by *S. andropogoni* and the feeding produces similar symptoms as are produced by this mite on paddy. *T. neocaledonicus* though occurs on bajra (*Pennisetum typhoideum*) and *A. sorghi* ChannaBasavanna on sorghum, respectively but none of these cause any apparent injuries to crops.

Mites infesting pulse crops

A number of mites are known to occur on different types of pulse crops in India. However, only *Tetranychus cinnabarinus* and *T. neocaledonicus* are of significant importance while others viz., *Schizotetranychus fluvialis* McG., *S. cajani* Gupta, *Eotetranychus broodrykei* Meyer, *Oligonychus indicus*, *Polyphagotarsonemus latus* (Banks) and *Aceria cajani* ChannaBasavanna are either have just been casually recorded or their infestation is of insignificant nature. *T. cinnabarinus* and *T. neocaledonicus* attack a number of pulse crops, *Phaseolus mungo*, *P. radiolatus*, *P. aconitifolius*, *P. aureus*, *P. lanulatus*, *Glycine egypticum*, *Vigna sinensis*, *Dolichos biflorus*, black gram (Prasad, 1974 ; Bindra and Singh, 1970). The attacks of both the species cause the appearance of thick webs completely covering the leaves where dust particles adhere and thus affect the normal physiological activities of the plants. This results in substantial fall in yield. In view of the wide host range of these two species these mites remain in the field throughout the year. *Schizotetranychus cajani* was seen to infest pigeon pea in West Bengal (Gupta, 1976) causing yellowing of leaves and stunted growth. Gupta *et al.* (1971) studied relative susceptibility of different varieties of pigeon pea to attack of a *Schizotetranychus* sp.

Aceria cajani ChannaBasavanna also attacks pigeon pea in south India and Seth (1962) attributed this species to be the vector of pigeon pea sterility virus. Das and Naik (1977) recently reported from Orissa a serious attack of *E. broodrykei* causing severe chlorosis and stunted growth in red gram during January-April.

Mites infesting vegetables

As many as 18 species are known to infest various types of vegetables in India, of these, *T cinnabarinus*, *T neocaledanicus*, *T macfarlanei* and *P. latus* are of major importance bringing about significant loss to the growers. The others are relatively less important or do not cause any injury at all. *T cinnabarinus* and *T neocaledonicus* infest a large number of vegetables (Rahaman and Sapra, 1940; Khot and Oatel, 1956; Bindra and Singh, 1970; Prasad, 1974; Gupta, 1976). By continuous sucking from leaves as well as by covering the leaves with thin webs, the normal physiological activities of the plants are affected causing the leaves to dry up and fall off prematurely. All these affect the yield. Though both the species remain active in the field throughout the year but infestation is more during April-June and again during November-January. *T macfarlanei* Baker and Pritchard is essentially a pest of cucurbitaceous plants and has been reported from M.P. as well as from Nicobar Is. (Bindra and Kittur, 1961; Gupta, 1976). The infested leaves turn yellow and fall off. *P. latus* is also a major pest of vegetables attacking chillies, tomato, potato, brinjal etc. in Punjab, West Bengal, Karnataka, Maharashtra, Bihar and U. P. (Prasad, 1974). The infested leaves suffer downward curling and later turn rusty red with shining white coating (Dhooria and Bindra, 1977). Infestation is more during August-December. *Aceria lycopersic* (Wolff.) is widely distributed in India and is known to infest brinjal and tomato. A serious attack of this species was seen in Punjab (Gupta *et al.*, 1975) causing the appearance of excessive growth of hairs on leaves and stems. The infested plants turn greyish white and loose vitality. *Brevipalpus californicus* is also known to infest a number of vegetables (Prasad, 1974; Sadana and Joshi, 1976; Nagesha Chandra and ChannaBasavanna, 1976b) causing yellowing and browning of leaves and stem affecting yield. The other mites known to infest vegetables in India are: *Brevipalpus phoenices*, *Bryobia praetiosa*, *Oligonychus coffeae*, *Eotetranychus multigituli*, *Eutetranychus bredini*, *Aceria tulipae*, *Oxypleurites convolvuli*, *Tarsonemus krichneri*, *Tuckerella indica* and *Bakerina orissaensis* but most of these are casual visitors doing little or no damage to the crops.

Mites infesting fruit trees

Gupta (1974) in his review of mites of fruit trees, listed 41 spp. Presently, as many as 53 spp. of phytophagous mites are known to occur on fruit trees

in India, of these, 23 belong to Tetranychidae, 11 belong to Tenuipalpidae, 17 belong to Eriophyidae and 10 belong to Tarsonemidae. The species which are of major importance are *E. orientalis*, *B. praetiosa*, *Eotetranychus hirsti*, *Oligonychus mangiferus*, *Brevipalpus californicus* *B. phoenices*. *Aceria mangiferae* *A. litchii*. *Eutetranychus orientalis* poses a serious threat to citrus cultivation all over India and occurs round the year. Mites in all stages of development are found to suck sap from leaves, fruits and tender barks. Besides, the leaves are heavily covered with thick webs where dust particles get adhered and affect the normal physiological activities of the plants. All such leaves dry up and fall off. In addition to citrus, it attacks *Ziziphus*, almond, etc. *Bryobia praetiosa* though essentially a pest of pear but also occurs on litchi, almond, clover, loquat, etc. specially in northern India (Menon and Ghai, 1968 ; Gupta *et al.*, 1975). Infested leaves turn yellow, later bronzy and finally fall off prematurely. In severe cases the entire tree gets denuded. *E. hirsti* is a pest of fig in India (Bindra and Verma, 1966) and has been reported from West Bengal, Punjab, Tamil Nadu, Delhi and Orissa. Transparent green patches are produced on the under surface of leaves which later turn brown. Infested leaves finally fall off. In case of severe infestation the entire tree gets denuded. *O. mangiferus* is an important pest of grapes, mango and black berry specially in northern India (Sadana and Chandra, 1973). Mites live on the upper surface of the leaves and the attack causes the appearance of characteristic yellow spots on the middle of lamina. In case of grape vines the upper surface turns brown while the lower surface becomes light yellow. The infested leaves become crinkled and fall off prematurely. *B. californicus* is also a serious pest of citrus all over India and in addition to citrus it infests a number of other fruits also (Sadana and Joshi, 1976 ; Nagesha Chandra and ChannaBasavanna, 1976b). Mites suck sap from under surface of leaves as well as from twigs and fruits. The feeding causes the appearance of yellowish spots on the leaves and those later turn brown. The petiolar attachment becomes very loose resulting in heavy defoliation (Gupta *et al.*, 1971). *B. phoenices* mainly infests custard apple, jackfruit, guava, citrus and pomegranate. The infested leaves develop brownish patches and the infestations may lead to splitting of fruits (Nagesha Chandra and ChannaBasavanna, 1976a). *Aceria mangiferae*, known as mango bud mite, is gaining tremendous importance in India because of its suspected association with malformation and bunchy top diseases of mango (Narasimhan, 1954 ; Puttarudriah and ChannaBasavanna, 1961 ; Nariani and Seth, 1962). In view of attacking the terminal and accessory buds, those get dry up stop growth and produce close lateral buds which are also attacked at the later stage and ultimately produce crowded group of buds at the top of the axils. The disease is prevalent in Punjab, Haryana, Delhi and Karnataka. *A. litchii*, the litchi blister mite, causes the development of yellow or greyish yellow

velvety growth on the under surface of the leaves which later turn chocolate brown (Roy and De, 1950; ChannaBasavanna, 1966). Curling, spitting and twisting of leaves may also be caused. Its infestation has been noticed in Karnataka and in many parts of eastern India.

In addition to the above, there are some mite pests of minor importance in India which are ; *Schizotetranychus hindustanicus* on citrus, *Oligonychus punicae* on pomegranate, *Panonychus citri* on citrus, *P. ulmi* on stone fruits, *T. cinnabarinus* on papaya, *T. neocaledonicus* on mango and papaya, *T. fijiensis* on coconut, *Raoiella indica* on coconut, *Tenuipalpus punicae* on pomegranate, *Phyllocoptruta oleivorus* on citrus, *Eriophyes cernuus* on wood apple, *E. vitis* on grape vines and for the information regarding their nature of damage etc. reference may be made to Gupta (1974).

The other 32 spp. of mites also known to occur on fruit trees in India do not cause any apparent damage to the trees.

Mites infesting oilseed crops

About 7 spp. are known to infest oilseed crops in India, of those, *T. cinnabarinus*, *T. hypogaeae*, and *R. indica* are of major importance. *T. cinnabarinus* infests castor (Srivastava and Mathur, 1962 ; Gupta *et al.*, 1977), groundnut, mustard, etc. (Prasad, 1974) throughout India producing characteristic damage symptoms. *T. hypogaeae* was seen causing significant damage to groundnut crops in West Bengal as all the plants were seen heavily covered with thick webs where dust particles get adhered and affected the normal physiological activities of the plants. The entire field looked sickly. *R. indica* is known to infest coconut crops in south India causing the appearance of small reddish spots on the leaves. The attack caused by *T. fijiensis* on coconut, *E. orientalis* on castor and *B. californicus* on *Brassica* are hardly of any major importance.

Mites infesting plantation crops

As many as 9 spp. are reported to infest plantation crops in India. *Oligonychus coffeae* is one of the most serious pests of tea in India (Das, 1959). Continuous sucking by all stages of this mite from leaves and petioles the yellowish spots are produced at the points of feeding. Those at later stages turn brown and the entire leaf turns copperish brown. All such leaves ultimately dry up and fall off. Attack is more severe on old leaves than on the young ones. In case of severe attack the young plants may be killed. The mites are abundant during March to June, scarce during rainy seasons and reappear during September to October. *B. phoenices*, popularly known as tea scarlet mite and *B. obovatus*, also attack tea causing severe damage to the crops (Das, 1961). The bark and leaf petioles of the affected shoots turn brown and dry up. *Acaphylla theae*, known as pink mite, causes disco-

louration of leaves and those ultimately become leathery (Das and Sengupta, 1958). *Calacarus carinatus*, the tea purple mite, is another important pest of tea in India (Das and Sengupta, 1963). The affected leaves turn copperish brown and later to purplish bronze. *R. indica*, *Dolichotetranychus* sp. and *Oligonychus biharensis* are known to infest arecanut crops in India (Puttarudriah and ChannaBasavanna, 1958, 1959).

Mites infesting fibre crops

Six spp. are known to infest fibre crops in India, of those *T. cinnabarinus*, *O. coffeae*, and *P. latus* are of major importance. *T. cinnabarinus* infests cotton crops in Punjab and Gujarat causing crinkling and malformations of leaves. American variety of cotton is more susceptible to the attack of this mite than the local varieties. This species also infests jute producing similar symptoms. *O. coffeae* is an important pest of jute in India (Misra, 1913; Das, 1948). The infested leaves become brown, crinkled and fall off prematurely. The yield is adversely affected. Though this species also infests cotton but the damage is never of any serious nature. *Polyphagotarsonemus latus*, the tiny glossy mite, is a serious pest of jute in jute growing belt in India. The infested leaves become curled and twisted. All such leaves fall off prematurely affecting the yield. Sometimes the leaves are malformed, turn copperish brown and the internodes get shortened. The attack starts from apical portion of leaves and spreads downwards. *Aceria gossypii* (Banks) and *A. puttarudriahi* ChB. also infest cotton causing excessive growth of hairs on both the surfaces of leaves. Heavily infested plants show distorted and lack of fruiting branches. The bolls may also fall off.

Mites infesting sugarcane and tapioca

Butani (1959) reviewed the mites infesting sugarcane crops in India. Presently, out of 9 spp. which are known to infest sugarcane and tapioca, *O. indicus*, *S. andropogoni* on sugarcane and *T. cinnabarinus* on tapioca are of significant importance. *O. indicus* is widely distributed in India and the infested leaves turn reddish and the crops look as if burnt. *S. andropogoni* also infests sugarcane specially in northern India producing irregular whitish patches on either sides of midrib (Gupta *et al.*, 1972). In case of heavy infestation 1300—1500 such patches per leaf may be seen. The affected leaves look sickly and gradually dry up. *O. sacchari* (McG.) and *S. spireaefolia* (Garman) have been reported on sugarcane in West Bengal causing no apparent injuries. The attack of *Aceria sacchari* occurring on inner surfaces of leaf sheath and *Abacarus sacchari* occurring on laminar furrows on upper surface of tender leaf sheath of sugarcane do not bring any damage to the crops. One tarsonemid species, *Stenotarsonemus bancrofti* (Michael) infests sugarcane leaves resulting the appearance of scabby and corroded patches at

the internodes. Recently, *T. cinnabarinus* has been reported to cause damage to tapioca crops in Kerala (Saradamma and Nair 1975). Mites remain on under surface of leaves on either sides of midribs turning the leaves yellow. This affects adversely on yield.

Mites infesting ornamental plants

Bindra and Singh (1970) in their review of mites infesting ornamental plants in India, reported 25 spp. Out of 27 spp. now known to infest ornamental plants, 5 spp., viz., *T. cinnabarinus*, *T. neocaledonicuss*, *Eutetranychus orientalis*, *B. californicus* and *B. phoenices* are of major importance. Both the species of *Tetranychus* infest a large number of ornamental plants causing the appearance of various types of symptoms including yellowing, curling, drying and premature leaf drop. All these affect growth and flowering of plants. Both the species remain active in the field throughout the year. *E. orientalis* affects *Cassia fistula* seriously. *Brevipalpus californicus* and *B. phoenices* are also known to infest a large number of ornamental plants (Sadana and Joshi, 1976; Nagesha Chandra and ChannaBasavanna, 1976b) producing characteristic damage symptoms. All the other spp. (Bindra and Singh, 1970; Prasad, 1975a, 1975b, 1975c) infesting ornamental plants in India are of little importance economically.

Mites infesting medicinal plants

Lakshman Lal, and Mukherjee (1977) listed 33 species of mites infesting 79 spp. of medicinal plants in U. P., of these, excepting *E. orientalis*, *T. cinnabarinus*, *B. phoenices* and *B. lewisi*, which are of little importance, the occurrence of others have just casually been recorded. *E. orientalis* alone infests 28 spp. of medicinal plants and remains active in the field throughout the year. *T. cinnabarinus*, *B. lewisi* and *B. phoenices* also occur on number of plants. The first two species occur in summer months while the other one prevails in winter months.

Mites infesting timber crops

Three species, viz., *S. hindustanicus*, *B. californicus* and *Aceria dalbergiae* infest timber crops but none of these species are known to cause any damage to the crops.

Mites infesting spices and condiments

Four species, viz., *T. cinnabarinus* on coriander, *T. neocaledonicus* on melolonthus, *B. deleoni* on cardamom and *Dolichotetranychus floridanus* also on cardamom are so far known to occur on these crops but in no case those have been reported to be of any significant importance.

Mites infesting fodder crops

As many as 10 spp., viz., *O. indicus*, *T. cinnabarinus*, *T. neocaledonicus*, *P. latus*, *Aceria sorghi*, *A. medicaginis*, *Eriophyes cyperi*, *Mesobryobia terpoghossiani*, *M. jobneri* and *B. californicus* infest nearly 10 spp. of fodder crops in India but except for *O. indicus*, the others are not known to cause any damage.

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MANIPUR DEER AND ITS PRESENT STATUS

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Introduction

There have been only few deer species in the country as magnificent as Manipur Browantlered deer, *Cervus eldi eldi* McClelland, 1842, also known as dancing deer or Sangai. This beautiful deer which was once fairly abundant in Manipur valley is now facing the extreme danger of extinction. At present alarmingly small population of this species survives in a small pocket of Manipur. The main factor for the decline of its population is due to the loss of its habitat. Realising the danger of its extinction the present habitat of this deer, though small, has been declared as National Park and serious attempts are now on foot to protect this species from total extinction.

Manipur state lies on the north-eastern part of Indian Union with its capital at Imphal. It is bounded on the north by Nagaland, on the south by Mizoram, on the west by Assam and on the east by Burma. The land of this small beautiful state can be divided into two tracts—the hills and the valley. Manipur valley is surrounded by hills and the inhabitants of these two areas have their own dialects, customs and modes of dresses. The valley is inhabited by Vaishnavas who speak Manipuri language whereas the hills are inhabited by about 29 colourful tribes who have their own languages and most of them are Christians. Manipur situated at an altitude of about 785 metres is well known for its dance and the women have a social position that is not found in any other state of India. During the world war II, Indian National Army advanced nearly upto Imphal and occupied many areas in the south.

The climate of the state is salubrious. The winter lasts from October to February and in some parts of the hill areas the winter is severe. The winter temperature varies from 0·5°C to 25·00°C and the summer temperature varies from 14·45°C to 28·80°C. Rains start from April and continue upto October. Summer is practically unknown. The nearest railway station is Dimapur which is about 215 km from Imphal. The National Highway No. 39 connects Manipur with the rest of India and passes through Nagaland. The newly constructed 224 km long Cachar road links the capital of Manipur with

Silchar in Assam and it passes through Jiribam. The population of Manipur is now estimated to be about 14 lakhs and the total area of the state is about 22,356 sq km. Racially the Manipuris are an admixture of various races, including Aryans, Mangolians and various tribes with a background of Indian culture and civilisation.

There are many ponds in Manipur but the Loktak lake is one of the largest fresh water lake in the country. It is about 45 km south of Imphal and is about 64 sq km in extent. The importance of this lake is its scenic beauty with islands in the centre and floating marshes on which the fishermen live in temporary huts. This lake is famous for fishing. South of this lake and separated from it lies another low lying swampy area which is known as Keibul Lamjao National Park. The Manipur or Browantlered deer which is locally known as Sangai are found only in this National Park.

Ecology of the Keibul Lamjao National Park

Most of the hill ranges in Manipur run north to south with the result that the rivers and their tributaries which after draining the hills and the valley combine to flow southward and finally discharge the water into Chindwin river of Burma. This is the reason that many lakes including the Loktak lake is found in the southern part of this state. Keibul Lamjao National Park (Fig. 1) is situated at a distance of about 52 km on Tiddim road from Imphal. This National Park covers an area of about 40 sq km of floating swamp. The Imphal river, which is the main river in Manipur, forms the eastern boundary of this park and it finally joins Chindwin river of Burma. To the east of this river there is another marshy area known as Khodum Lamjao and is equally good in habitat for Sangai. This habitat is now reclaimed and cultivated and is no more under the control of the forest department. There was also an equally good area west of this park which had its own population of deer in the past but is now under cultivation.

There are three small hills in the park—Chingjao, Pabot and Toya. There is an observation tower on the Pabot hill. A canal (Fig. 3A) has been cut through the tall grasses upto the base of this hill and the observation tower can be approached by boat. Toya hill, which is a little less in height than Pabot, can also be used for observation of wild animals of the park. The entire park is covered with thick tall grasses and reeds (Fig. 2) which is locally known as Phumdi. The grasses and reeds grow on the decaying Phumdi which forms the mat of organic matter. This mat floats on the water and their thickness varies from place to place. On walking on this Phumdi one can feel as if he is walking on an air-mattress but where the thickness of the mat is less he can go right through it into the stagnant water below upto his knees or to his waist depending upon the depth of the water. Major portion of Phumdi remains under water and a part remains outside

the water. The reeds and the grasses that grow belong to different species. There are no tall trees inside the park and the vegetations on the three hills are also very poor.

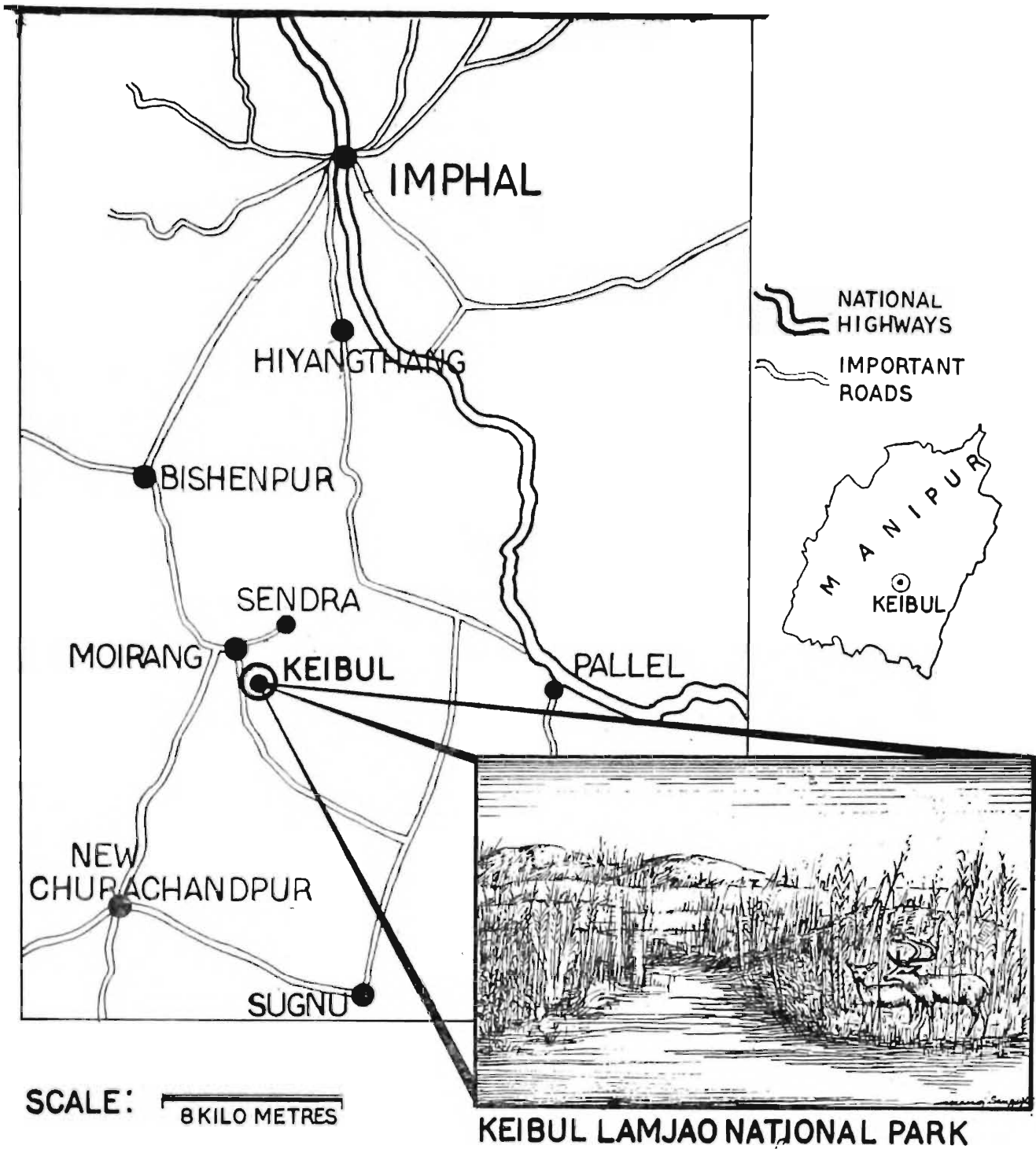


Fig. 1. Map of Keibul (Manipur)

The Browantlered and hog deer and the wild pigs live in this floating park. During summer the Phumdi settle to the ground but during the monsoon they again start to float. On the onset of monsoon the park is flooded and it takes some time when the submerged Phumdi began to float again. These few days when the park is under water the deer move on to the two hills but they return to the Phumdi when it again starts to float.

Browantlered deer of Keibul Lamjao National Park

There are three sub-species of this deer that are found in the world.

The Manipur sub-species, *Cervus eldi eldi* McClelland, 1842, is also known as Browantlered deer (Fig. 3B) or Sangai is now found only in the Keibul Lamjao National Park. The second subspecies, *Cervus eldi thamin* Thomas, 1919 is found in Burma and some parts of Thailand. The third subspecies, *Cervus eldi siamensis* Lydekker, 1915, is found in Thailand, Vietnam, Cambodia, Laos and Hainan.

The Browantlered deer can easily be distinguished from other deer by the peculiar shape of the antlers. The shape of the antler is more or less like a prostrate letter "C". The pasterns of this subspecies are hairless hard and horny and well adapted for movement in the swamp. The fawns are spotted. They move in groups and a group may consist of few stags, hinds and fawns. Due to the tall grasses and less number of this deer in the National Park it is very difficult to see it in its natural habitat.

In the past and before country attained independence Manipur was a princely state and it was under a Maharaja. During that time this deer was strictly protected and severe punishment was given for its killing but in recent years its number has declined considerably due to the slackness of the rules, shrinkage of its habitat and poaching and now this deer is on the verge of extinction. Earlier accounts show that this deer was widely distributed in Manipur and was found in almost all the marshes of this state. In 1951 this deer was regarded as disappeared from the face of the world but subsequently in 1952-53 this was rediscovered in the floating swamps of Keibul Lamjao National Park.

A number of surveys were carried out by many workers including the present author on the population of this deer. The present author conducted three surveys during different seasons and studied the behaviour particularly the breeding behaviour of this deer. The first survey of this deer was conducted by E. P. Gee in 1960 and the latest survey was conducted by the Forest Department of Manipur in the month of March, 1978.

Gee estimated its population at 100 when he surveyed the area in 1960. The present author estimated its population between 50 to 60 in 1974. Ranjit Singh in 1975 reported that there were only 14 deer in the Park. In his second survey conducted in 1977, he sighted 18 Sangai. On 4th March, 1978 the forest department of Manipur conducted a survey and counted a total of 23 Sangai. The same park when surveyed again on 10th March, 1978 by the forest department they encountered a total of 21 animals. The area when surveyed again on 24th March, 1978 by the forest department they have counted 21 Sangai. Based on this they have estimated that there are 23 Sangai at present in this National Park.

Fig. 2.

Keibul Lamjao National Park.



Fig. 3.

A—The Canal cut through the grasses.



B—Sangai-Stag and hind.

The various surveys that were conducted since 1960 revealed that their present number is much less than that was estimated by Gee in 1960. It is also believed that the flood in 1966 and the drought of 1972 affected the population of this deer.

Some of the factors for the decline of their population

The record shows that the Sangai was widely distributed in Manipur in the past and almost all the grassy areas in this state were inhabited by this deer. Few years back the areas around the present National Park were under forest. The extension of cultivation and increase in human population lead to the shrinkage in habitat of Manipur deer and they are now pushed into the swampy area of the Keibul Lamjao National Park which they have adopted by necessity. Even in this National Park their existence is threatened. This Park is now surrounded almost from all sides with villages. In the past the Vaishnavas of Manipur were strictly vegetarian but now there is lot of change in the dietary habit of the present generation. Outside this park this species is found in some Zoos and it was reported that they are breeding well in these Zoos. It is advisable that the Zoos which are having this threatened species should try to provide better habitat and to encourage breeding so that it can be introduced in some other suitable areas. It is high time now that a second home or a Sangai park should be set up in some suitable site preferably in some part of eastern or north-eastern India.

Many workers including the present author after studying this deer in its natural habitat gave their recommendations for the conservation of this species and for further improvement of the park. It was observed by the present author during his study period that the people go inside the park without any check for collection of grasses and tubers and for fishing. The grazing of the domestic animals in and around the park was very heavy. These animals also feed on the grasses that are liked by the deer. Thus these animals not only consuming the food of the deer but they also act as potential source of danger of various cattle borne diseases to Sangai and hog deer of the park. During the dry period the villagers burn the dry grasses and reeds inside the park which was observed burning hours together. The author has collected some traps from the park during his survey which were put for trapping birds and other animals. The people go inside the park with their spears with the plea that this can be used against the attack of wild pigs.

Loktak hydro-electric project when completed may affect the ecology of the park. It may affect the water level of the park which in turn affect the vegetation and the Phumdi may not settle on the ground during the dry period. It will be interesting to conduct a survey on the ecology of the park and the effects on the deer population when the project will be completed.

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ECHINODERMS AND MAN

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Among the natural objects most likely to attract the attention of the visitor to the seashore, particularly if the coast be somewhat rocky, are the five pointed star shaped creatures known as starfish, the zoological name being Asteroidea (aster-star ; eidos-form). These are often found abundantly clinging to the rocks and sea weeds when the tide is low.

Among the sea weeds below the reach of the tides are somewhat similar animals, which have five slender, wriggling, snakelike arms, commonly known as serpent stars, the zoological name being Ophiuroidea (Ophis-snake : oura-tail ; oidos-form).

Just below the reach of the low tide also are other related animals, of rounded form, covered with coarse spines, which are commonly known as sea-urchins, the technical name being Echinoidea (echinos-hedgehog ; eidos-form).

When digging in the sand between tides or even on the sandy bottom one may encounter dark green or black worm-like animals, without distinct appendages, but which nevertheless are able to cling to the hand and they may belong to the group of animals known as sea-cucumbers since these species have resemblance to the vegetable from which they take their popular name. The zoological name is Holothuroidea (Holothurion-water polyp and eidos-form).

And, finally, at moderate depths, among rocks, coral colonies and sandy and muddy bottoms occur flower (lily) like or feather like fixed permanently throughout life or temporarily forms which are commonly called as sea-lilies or sea-feathers, the zoological name being Crinoidea (Crinon-lily ; eidos-form).

These five classes of animals occur abundantly along the shores of India and careful search and critical examination will reveal the fact that there are several species of each.

All these animals belong to the division of the animal kingdom known to zoologists as Echinoderms. Although the starfish, sea-urchin, serpent star, sea-lily and sea-cucumber may be seen at first glance to differ from each other about as widely as any animals can, yet a careful study of their internal

anatomy shows that all are built upon the same general structural plan. They furthermore have in general a similar embryology and life history. Hence, the zoologist and evolutionist believe that they are all related to each other, and have no hesitation in placing them together in a single group, or phylum, known technically as the Echinodermata.

These echinoderms may be distinguished from other animals by certain well marked characters. As the name implies, the skin in most forms is provided with calcareous spines which project out from all sides of the body. Such spines are wanting however in the sea-cucumbers. Other calcareous plates are found in the skin. In most forms such plates unite to make a more or less complete shell which serves to protect the delicate internal organs. Most of them have likewise a distinct radial symmetry, in that similar parts are repeated around the central axis, as illustrated by the arms of the starfish or serpent star. With few exceptions they have a well developed water-vascular system, consisting of a circular canal around the mouth, with radial branches leading out to the periphery of the body. From the radial canal numerous branches lead out into the skin in certain regions of the body, and grow out into delicate tubular or finger-like projections.

These delicate projections are variously modified in different parts of the body for the performance of certain special functions. In all cases they serve as sense organs and as respiratory organs. If they have no further function they are known as tentacles ; but in many cases they serve also in the locomotion of the body, and are variously known as tube feet, sucker feet or pedicells.

Habits and Habitats

These animals are exclusively marine, with the exception of a single species of sea cucumber, *Synapta similas*, inhabiting brackish water, in the mangrove swamps of the tropics. The living forms are found in depths ranging from tide mark down to 6000 m. (3.75 miles) in practically all seas and at all latitudes except the very coldest. Some echinoderms live between tide marks and a few of them can survive when partially exposed to the air by the receding tide ; but the majority of them are found beneath low water mark, in the deepest recesses of the ocean. They are often tossed up on the beach, especially along the warmer coasts, from their deep water homes, by storms. Their distribution is, however, determined by food as well as water disturbance.

Some sea lilies are permanently attached, but most echinoderms are free living ; a few are pelagic, but none is parasitic. Some echinoderms can swim and a brittle-star can walk stilt like on the tips of its points, but the majority of them slowly creep about on the sea bottom, feeding on small animals and plants and organic matter in the sand and mud. Their voracity is well illustrated by the fact that a large star-fish (*Luidia clathrata*) with arms 145 mm long

had died because it swallowed a sand dollar (*Mellita* sp.) 70 mm in diameter but failed to disgorge its shell.

They are characteristically gregarious in habit and prefer to live in huge colonies, assemblies or gardens. During the Challenger Expedition, 10,000 feather stars were dredged in a single haul from fairly deep water. Star-fish and brittle stars are also known to be present in great abundance. In Pamban and Rameswaram area one can see numerous holothurians for example, *Holothuria scabra* and *Holothuria atra* in the coral as well as sandy bottom.

Of all the echinoderms, the sea cucumbers, the sea urchins and the star-fishes are of much economic value to man.

Holothuroidea

Sea cucumbers are commonly used as food by man, among the Pacific Islands, shores of south Pacific ocean, China, Japan, Eastern Asia, Malaya Archipelago and Australia. In the Indo-Pacific region a large trade is carried on in dried cucumbers, which under the name of trepang or beche de mer are sold to China and South-East Asian countries for use as a delicacy in cookery. Trepang is made of large sea cucumbers such as *Thelonota ananas*, *Holothuria nobilis*, *H. mauritiana*, *H. scabra*, *H. lecanora*, *H. argus*, *H. edulis*, *H. echinites* and *Stichopus variegatus* and *S. japonicus*. The methods of preparation of holothurians to make trepang vary in different regions, but in general the cucumbers are first boiled in fresh water to cause them to eviscerate and to shorten and thicken. The body wall is then dried in sun or by smoking or dried by combination of sun and smoking ; drying must be thorough or spoilage will occur. This dried object is cut into small pieces which are added to soups and stews and are said to impart a delicate flavour. When so cooked the pieces of trepang swell into a gelatinous condition and are also eaten as tidbits. Trepang appears to be highly nutritious. The Indo-pacific product contains 15 to 30 per cent ash, 35 to 52 percent protein, and 21 to 23 per cent water ; carbohydrates are wanting but some fat is present. (Greshoff and Sack, 1900 ; Greshoff and Van Eek, 1901). The Mediterranean product is even more nutritious, containing 56 to 65 per cent protein, 13 to 24 per cent ash, about 0.7 per cent fat and 10 to 11 per cent water (the Sellas, 1940). According to Frankel and Jellnek (1927), the protein constituents of trepang are completely soluble in pepsin, so that the product appears highly digestible. In some localities in the Indo-pacific sea cucumbers are irritated until they eviscerate and the cuverian tubules, gonads are then eaten raw and entire cucumbers may be eaten raw also.

In India, *Holothuria scabra* is the species that is almost exclusively used for the preparation of 'beche de mer' and it has been recorded that about 30,000 kg of 'beche de mer' is produced and exported annually from this country for about 20 lakhs rupees. The trepang of *Holothuria scabra*

is also equally nutritious, containing 26.30-59.43% protein, 12.75-21.60% fat, 5.32-14.64% carbohydrate (Krishnan 1970). The industry is restricted to some of the fishing villages bordering the Gulf of Mannar and along the south-east coast of India (James 1968). Recently such an industry is started at Port Blair of Andaman and about 10 tonnes of Trepang valued at one lakh rupees is exported (James 1977). In Japan even the salted entrails (intestines) 'Kenowata' is consumed by the people as food. After induced evisceration, the holothurian *Stichopus japonicus* is left in the fishing grounds within three months the regenerated alimentary canal is equal to the normal one. Then the holothurians are harvested, induced evisceration and again left in the fishing grounds (Choe 1962). The studies on evisceration and regeneration on *Holothuria scabra* (Mary Bai 1971) may help to launch holothurian culture in these coastal areas as in Japan which in turn may be of great economic value.

Echinoids (sea urchins)

They are eaten by crabs, sea-stars, large fish, mammals and birds; the last may crack them by flying up with them and dropping them on rocks. People sometimes use the egg masses of sea urchins as food: they are sold as 'sea-eggs' in the West Indies and as frutta di mare in Italy. The gonads when ripe are highly nutritious and are eaten, either raw or after roasting in the half shell, by man in various parts of the world. Echinoid gonads are commonly eaten in Mediterranean, especially those of *Paracentrotus lividus*. Along the coast of Peru and Ecuador there is much eating of the gonads of *Loxechinus albus*, roasted in the half shell. Ricketts and Calvin (1953) recorded that Italians along the California coast eat raw the gonads of the big purple urchin (*Strongylocentrotus franciscanus*). *Tripneustes ventricosus* is eaten in the West Indies, and *Evechinus chloroticus* is extensively used as food by the natives of New Zealand. In India, ripe gonads of sea urchins, *Salmacis bicolor* and *Stomopneustes variolaris* are eaten by man along the coast of Madras, Tuticorin and Cape Comorin (Iyer 1966 and Mary Bai 1977).

Eggs of urchins and other echinoderms are widely used in research in experimental embryology and cytology. The experiments on echinoderm eggs have an important bearing upon heredity. A mention may be made here of fertilization of the ova of one species with the sperm of another, and the fertilization of enucleated fragments of sea urchin's eggs with sperm of another species.

Some sea urchins secrete a highly poisonous substance on their spines and hence are dangerous to handle. The stinging urchin *Diadema sectosum* is a beautiful black creature but has sharply pointed 4 inch black spines that inflict very painful wound.

The serpent stars are not economically important even though they are eaten by fish.

Star-fishes

Star-fishes are of particular concern to man as they destroy clams, oysters and other marine molluscs that serve as human food. Star-fish visiting oyster beds, succeed in pulling open the shells and eating large numbers of these bivalves. A star-fish in an aquarium devours nearly 10 oysters or clams in a day. Thus they inflict serious losses to commercial oyster beds by devouring the oysters. They are universally hated by oyster and clam fishermen because of the tremendous damage they do to these commercially important food animals each year. To capture star-fish, the owners of oyster beds use a rope drag or a mop-like tangle of threads behind a boat across the oyster beds. The star-fish, that grab on to the drag with their pedicellariae are hauled up and destroyed in hot water or carried ashore to dry up. Formerly, the captured star-fish were chopped into pieces and thrown back into the water when they multiplied their numbers tenfold the next season due to regeneration. But the practice was given up when the folly of the act was discovered. Now-a-days star-fish is killed effaciously by sprinkling quick lime on oyster beds in a strength which is harmless to the oysters but destroys the star-fish. Another successful method of destroying these very durable animals seems to be to dry them on the beach. The dried bodies are then ground up and used for fertilizer, thus being put to some beneficial use.

Star-fish, sea-urchins and sea-cucumbers are good scavengers. The latter are perpetually ingesting mud and sediment of the sea-bottom to extract the contained organic food, thus helping in the decomposition processes of the organic material continuously accumulating at the sea-bottom. Their food includes sea-weeds, small crustaceans, molluscs, tube-worms, dead animal matter and other small organisms and bottom debris. It has been said that an ocean without echinoderms might become a putrid cesspool. In turn, they are eaten by fishes, crabs, predaceous birds and mammals.

The dried skeletons of echinoderms have been crushed and utilized as a fertilizer on ground, as they are quite rich in calcium and nitrogenous contents. For the same reason they are used as food and lime supply for poultry.

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TECHNIQUES FOR THE STUDY OF RODENT POPULATION

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Rodents are a great menace to mankind as they share its food, damage its property and act as reservoirs of several of its dreadful diseases. They are known to be serious pests in farms, food stores and residential houses. Some one has rightly said "They sow not, neither do they reap-yet these rats are better fed than many of us" How to control these pests is one of the major economic problems, at present, confronting the nation. For effective control of these rodents, more and more bio-ecological studies, especially an idea of their population is essential. Although an exact estimate of the population of rodents in a large country like ours is a difficult job, yet a sample survey in different ecological niches would provide useful data for successful implementation of any control programme. Unfortunately, not much work has been done in our country on the population of rodents and we depend mainly on foreign sources for the techniques employed for such studies. Authors like Chitty (1942), Jackson (1939), Lincoln (1930), Leslie and Davis (1939), Burt (1940), Blair (1941), Dice (1941), Evans (1949), Hayne (1949), Manville (1949), Davis (1956), Andrewartha (1961), Louch (1965), Spillet (1966), Prakash (1971) have dealt with different aspects of population dynamics in small mammals. The present paper gives a brief review of the techniques employed for the study of rodent population.

The success of any ecological study largely depends on proper planning. Consequently, for the study of rodent population, selection of site, selection of right kind of trap and bait, a trapping routine, marking of animals etc. are some of the points which need special attention.

Selection of plot

A plot, in a relatively uniform area of a single ecological niche is selected for trapping. The plot must be a typical representative of the whole population. Any given species that occurs in two or more ecological niches is apt to behave differently in each. Therefore, if more than one habitat type is included in a trapping area, the results from each type should be evaluated separately.

Normally, a plot of less than two hectares is regarded as too small for an accurate determination of population density of small mammals. However, if the study area is surrounded by another ecological habitat that may act as a barrier to the species under investigation, the size of the plot is not so important, as for example for an arboreal species, a woodland surrounded by a grass land or for a fossorial species a plot of land surrounded by water. Where there is no barrier, a plot should be from 10 to 20 times the expected size of the home range of the species.

Traps and trapping

The kind of trap and the quality of the bait to be used are selected with care depending on the animals sought. Traps should neither be too small nor too large for the anticipated catch. Traps are broadly categorized into two types (Fig. 1) (i) Break-back type—This type of trap is unsuitable for population studies as it kills the animal. (ii) Live traps—This, in turn, may be of two types—(a) Multiple catch 'Wonder' traps having counter balanced entrances: When an animal enters the trap, its weight makes it fall into the cage below. The counter balance on the trap door brings it back into place. This type of trap can catch more than one animal at a setting, but is only good for commensal forms.

(b) Single catch trap having remote triggered door: This type of trap rarely catches more than one animal at a setting but is much more effective than the previous one especially for field rodents which are generally trap shy. Various designs of traps have been suggested by Hatt (1925), Chitty (1938), Scheffer (1934), Blair (1941), Horn & Henry (1946), Fitzwater (1966) etc.

While proper placement is the main key to trap success, its effectiveness is enhanced with good bait. Attractive baits for commensal rodents are bread with butter, nuts, fried fish or pakora, meat scraps, banana etc. For field rats fried pakora, nuts, cheese, fried fish etc. are more effective. The baits must be changed often and different materials tried. Only token amount of bait is sprinkled around the trap, putting the bulk deep inside. A trap in which a rat has been caught should not be washed before resetting. The odour of the animal or its faeces and urine tends to draw more rats into the trap.

A wad of loose cotton or jute is kept in each trap to provide nesting material for any species of rodent that may be caught. It will not only attract rodents who are in need of nesting material but will also protect them from excessive cold. With trap shy individuals it may sometimes be necessary to camouflage the trap with a layer of mud, grass or twigs. Even against commensal rodents it is not advisable to use new shiny traps.

Traps are placed either perpendicular to the runways (Break-back type) or along the runways (live traps) commonly used by rodents. These paths

can be determined by accumulation of droppings, tracks in the dust and grass land or greese left by the animal as it runs along the wall. In the field the base of the break back trap is sunk in the mud so that the top is in level with the ground. The trap is tied to a nearby bush to prevent its loss. Live traps are set firmly on the ground so that these do not wiggle when animals start to enter.

The success of a trapping operation is directly proportional to the number of traps used. Therefore plenty of traps should be placed in such a way that at least one trap falls within the minimum home range of the individual. This distance varies from species to species. In the case of house mouse, *Mus musculus*, it is less than three metres. A gap of 15 metres between the traps was found satisfactory for Wood Mouse (Burt, 1940) and of 20 metres for rodents in Blue Grass association of Michigan (Blair, 1941). But a gap of 15 metres was found to be unsatisfactory in case of Five Striped Squirrel, *Funambulus pennanti* (Louch et al, 1965). To study the outdoor population of rodents, setting up of traps in a rectangular grid pattern is desirable, as it insures even distribution of traps over the plot and simplifies the calculation of the size of home range. When the place is irregular no geometrical system is followed and the traps are scattered evenly over the area (Louch, 1965; Schwartz, 1941). To study the indoor population of rodents, for example of rats, mice (Evans, 1949) or bandicoots (Spillet, 1966), the traps are set inside the godown, in question. Additional traps are also placed outside the building to see the outward and inward movements of animals. The traps, if possible, are set in a grid fashion, otherwise are placed 'strategically' where capture is thought most likely.

Trapping is done intensively in an area normally for three to six days, and then all the traps are removed. But a trap once set continues to be there until removed at the end of a trapping period.

Mortality in the traps is avoided as far as possible whether it is due to heat, cold, predators or mishandling.

The traps are, generally, visited once, daily, in the morning or evening in case of nocturnal and diurnal species respectively. But to avoid the chances of death due to heat or cold, it should be visited twice. In this way no animal will have to remain in the trap and exposed to rigors of nature for a long period. For nocturnal rodents, traps are set sufficiently late in the afternoon. These are visited once at midnight when all the trapped animals are released after taking the data etc., and then the next morning. For diurnal species, the traps are set as early in the morning as possible and left up to the evening. Here also, the traps are checked once at noon and then in the evening, and if there is any animal, it is examined and released. Finally, the traps are set off for the day or night as the case may be.

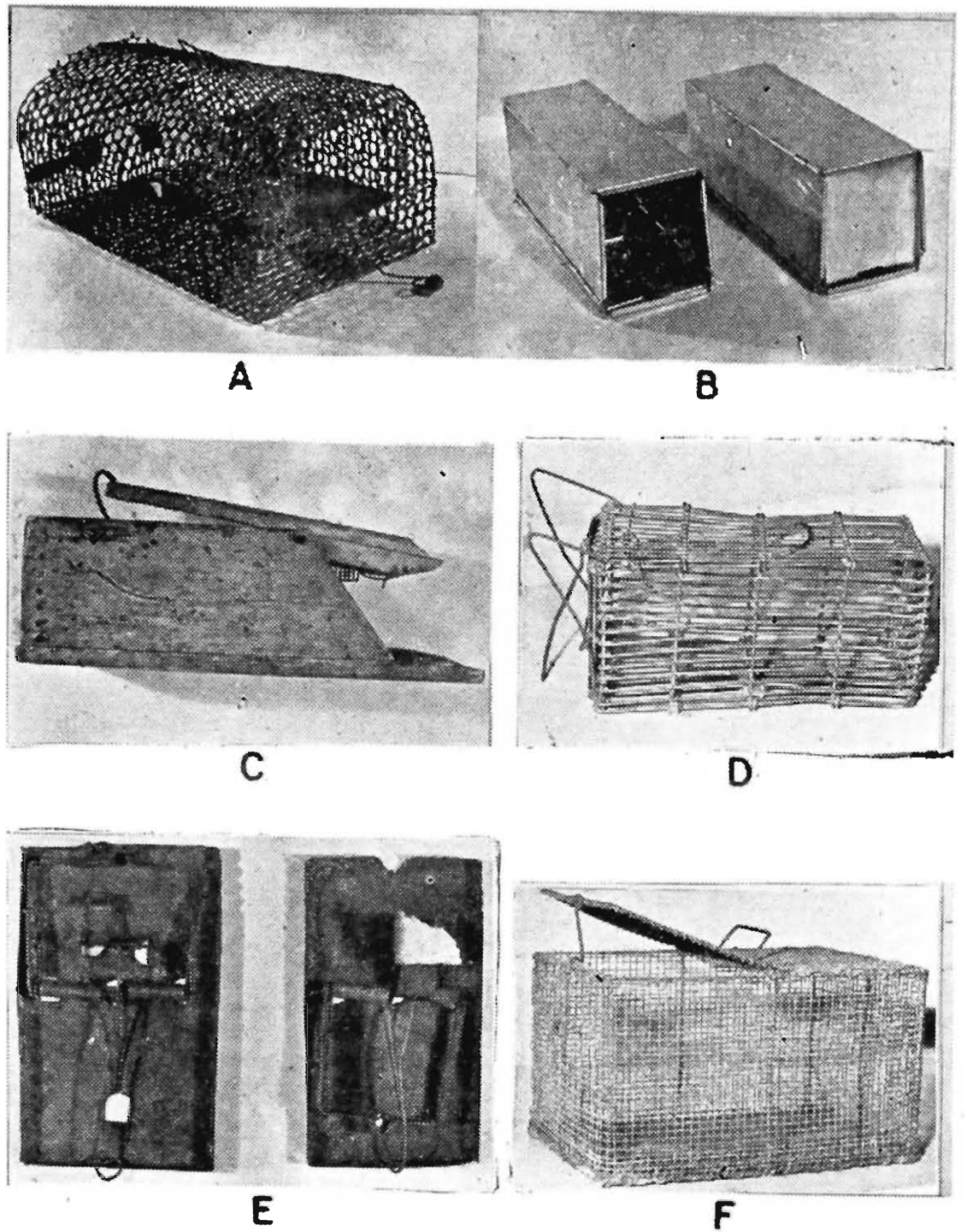


Fig. 1. Different kinds of rat traps: A—Multiple catch “Wonder” trap, B—‘Sherman’ trap, C & D—Single catch traps having remote triggered door, E—Break-back or Neck-break trap, F—Cage for keeping live rats.

Care must be taken at the time of removal of animals from the trap, so that neither they should run away nor die. Small rodents like mice etc. may be caught by grasping the nape between thumb and fore finger. But larger rodents which usually bite, should first be transferred to a small sack and then grasped by hand.

Marking of rodents

Each animal is marked, the first time it is caught, so that it can subsequently be recognized. The method of marking should be such as to be quickly and easily applied, conspicuous, permanent and humane. Chitty (1937) used zinc and nickel rings just above the ankle for marking *Apodemus* sp. Numbered ear-tags have successfully been used by Eidy and Joyce (1944) on *Peromyscus* and by Spillet (1968) on *Bandicota*. Ground squirrels are marked by trimming off the tips of grey hairs in various designs, thus exposing the dark base of the pelage. But such markings last only up to the next moult. Dyes and paints have also been used for marking animals by Fitzwater (1943) Gordon (1939) etc., but in all cases it remained up to the next moult. Various types of mutilations have been employed for marking rodents by Johnson (1926), Burt (1940), Louch (1965), etc. These are relatively permanent and useful for long term study. Rodents may easily be marked by punching holes at designated places in the ears and by clipping off fore-or hind toes. Both of these, in proper combinations, enables one to mark the animals serially into thousands.

Trapping record

Two types of records are maintained on crossed ruled paper. The first contains the details of animals trapped in each plot, for each day of a trapping period. On this sheet there are columns for recording trap number, name of the species trapped, sex, weight, breeding condition (condition of mammae, testis, pregnancy etc.), details of parasites collected, marking given etc. Another relates to the record of each individual. It contains the name of the species, collection number, sex, date of first capture, weight, size, number of the trap in which first caught, number of the trap/traps in which it was subsequently caught, date of subsequent capture/s, plot number, if any, etc.

Estimation of population

The population of rodents in a particular area may be estimated by (i) the direct count method in which every animal in a given area is counted and (ii) the capture, marking and release method which is especially useful where home range and population both have to be studied.

1. *Direct count method* :

This method is especially useful for those species of rodents which are very trap shy, such as the Indian Desert Gerbil, *Meriones hurrianae* occurring in India in Rajasthan and Gujarat.

In this method every animal in a quadrat, is counted. Here the quadrat means a small plot chosen randomly in a larger area which contains the whole population. The only condition is that the proportion of the quadrat in relation to the whole area must be accurately known. The accuracy of the estimate made from counting the animals depends on how representative the quadrat is of the whole area, and how close one gets to see all the animals in it. The latter question is a matter of technique and differs from species to species. The task becomes easier if one knows the habit of the animal. As for example, the Indian Desert Gerbil is diurnal and fossorial in habit. It comes out of its burrow in the morning and before doing any other work, starts feeding. Prakash *et al.* (1971) estimated its population like this. In a given area all the burrow openings of the gerbil were sealed in the early morning. After giving them sufficient time to come out of the burrow, the burrow openings were counted. This gave an estimate of their population in that area. The same was repeated on three consecutive days and the mean was taken.

2. *Method of capture, marking and release* :

In this method the animals are captured alive, marked and then released into the population from where they were collected. Eventually, with no replacement of animals, and with a trapping programme of great intensity, all animals in the population might be marked and the population determined from the total number of individuals marked.

But, in nature, it is not possible to mark all the individuals of a population. Therefore, different methods have been evolved for estimating the population-size by marking only some of the animals.

A. *Lincoln Index Method* :

One such method in use is known as 'Lincoln Index Method' In this method some of the animals in a population are marked. Subsequently samples are captured to observe the proportion marked individuals in the entire population, which now consists of a known number of marked animals along with an unknown number of unmarked. An estimate of the total number is computed by dividing the total number of marked individuals in the population by the proportion of previously, marked individuals in the subsequent samples. The estimates which are computed in this manner refers to the number of animals present during the period of marking. Estimates are calculated thus :

$$N = t + \frac{s}{n} = \frac{t \times n}{s}$$

- Where
- N is the estimated total population,
 - t denotes the number of marked animals in the population at the time of sampling.
 - n denotes the total number of animals in each sample (both marked and unmarked).
 - s denotes the number of previously marked individuals present in the n sample.

This approach to the estimation of population is based on a number of assumption.

1. The marked animals when released into the population are distributed homogenously in respect to the unmarked ones. For this it is suggested that the animals after being marked should be released at the same place where these were trapped.

2. Recapturing is done immediately after the release or atleast before marked individuals die or are replaced by new entrants.

In practice, it is seen that there is rapid turn over in a rodent population and the individuals are constantly replaced from adjacent areas. Under such condition the lengthy separation of preliminary marking period from the subsequent ones results in an over estimation of the size of population. To minimize the above mentioned error, it is suggested that a population estimate by this method may be computed based on the data of two consecutive days.

Keeping in view the above mentioned probable errors, several modifications have been suggested by Jackson (1939), Hayne (1949), etc., in the Lincoln Index formula, which may be helpful in minimizing the errors in the estimation of population.

B. *Krumbolz Method* :

A slightly modified method has been adapted by Spillet (1968) for estimating the population of *Bandicota bengalensis*. It is known as Schnabel formula (Schnabel, 1938) or Krumbolz method. It is essentially the same as the Lincoln Index, except that it uses cumulative data rather than a single recapture sample. It is denoted by

$$N = \frac{\sum n^1 t^1}{\sum s^1}$$

Here the first two nights of each trap period are considered to be the marking period and the third night as the sampling period.

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