STUDIES ON SEA-CUCUMBERS OF MINICOY, LAKSHADWEEP

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DECLARATION

I hereby declare that this Thesis entitled "Studies on Sea-Cucumbers of Minicoy, Lakshadweep" is based on my own research and has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles or recognition.

Cochin 682 014,
November 1994.

(S. Kandan)

CERTIFICATE

This is to certify that the Thesis entitled "Studies on Sea-cucumbers of Minicoy, Lakshadweep" is a bonafide record of the work carried out by Shri. S. Kandan under my guidance and supervision and that no part thereof has been presented for the award of any other Degree or Diploma.

Cochin 682 014,
November 1994.

(Dr. K. Rengarajan)
Senior Scientist
Central Marine Fisheries Research Institute

DEDICATED TO

MY LOVING PARENTS

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CONTENTS

PREFACE

PREFACE

The sea-cucumber ranks first among the non-conventional marine edible organisms and this is in great demand in Asian Countries very particularly in China. Many countries including India are nowadays fishing, processing and exporting to improve their country's foreign exchange. In recent years the sea-cucumbers have been indiscriminately fished in India, processed and exported including the undersized ones. This necessitated the Government of India to impose a ban on fishing small ones and to formulate the policies to rationaly exploit the sea-cucumbers.

Currently the fishing and processing are concentrated along the coasts of the Gulf of Mannar and the Palk Bay on the southeast coast of India. But certain pockets on the mainland and the entire Union Territories of Andaman & Nicobar Islands and Lakshadweep Islands are still having virgin grounds for sea-cucumbers for judicial exploitation.

Though we have over 100 species known from Indian waters, only one species namely *Holothuria scabra* is commercially processed. Only very few aspects have been studied on *Holothuria scabra* and no information is available on many of the aspects. The other species are poorly known and studied and even basic knowledge on these species are still wanted.

The Minicoy Islands with its lagoon habitat and coral reef flat is one of the largest islands among the Lakshadweep groups and these two ecosystems provide a good niche for the thriving of holothurians in the island. Hence this island has been selected as an important place to investigate on the sea-cucumbers available and as there is at present no proper fishing, processing and exporting from this island groups. In addition to this above the lagoon and the reef flat ecosystem may definitely provide a good locality for ranching of sea-cucumber seeds and culture them in the protected areas in the lagoon provided proper planning and management are planned, and hatcheries are set up as the one now at the Central Marine Fisheries Research Institute, Tuticorin. This may provide employment avenues to the islanders to improve the economy.

In view of the above in mind, the candidate selected to study all the species available from Minicoy Island for their taxonomy, anatomy and distribution, and biology, fishery and seasonal abundance of these species with special reference to H. nobilis and A. mauritiana which are economically important for processing and commonly available in the Minicoy Island.

The candidate stayed in Minicoy Island continuously for two years from January 1990 to December 1991. He located twelve stations - 9 in the Minicoy Lagoon and 3 in the Coral Reef Flat. Fortnightly sampling of sea-cucumbers, water, sediment and other associated fauna and flora have been regularly collected for two years for taxonomy, anatomy, biology, seasonal and quantitative abundance of sea-cucumbers. The water samples were analysed for salinity and dissolved oxygen. Temperature was taken at the sampling site itself. The sediments were analysed for fauna and flora and organic content in the laboratory. Quardrate sampling was carried out from twelve study areas for quantitative and seasonal abundance of sea-cucumbers. Some of the sea-cucumbers are processed in the laboratory at Minicoy to test the quality. The data have been systematically arranged in Tables, analysed statistically, results presented and discussed elaborately.

Significant results and conclusions drawn are presented in the following six chapters, preceded by an "Introduction", "Review of Literature" and "Materials and Methods". The Chapters are :

Chapter I : Taxonomy and anatomy of sea-cucumbers from Minicoy Island and their geographical distribution.

Chapter II : Morphometry and biometry of *Holothuria nobilis* and *Actinopyga mauritiana*.

Chapter III : Biology of *Holothuria nobilis* and *Actinopyga mauritiana*.

Chapter IV : Sea-cucumber fishery in Minicoy Island.

Chapter V : Quantitative and seasonal abundance of sea-cucumbers from Minicoy Island.

Chapter VI : Ecology of *Holothuria nobilis* and *Actinopyga mauritiana*.

Some of the salient and significant findings by the candidate from the studies are briefly listed below :

Chapter I

1. Sixteen species of sea-cucumbers belonging to Holothuroidae, stichopodidae and Synaptidae are described morphologically and anatomically with illustrations for the first time from the study area.

Chapter II

2. The total length range of *H. nobilis* is between 20.0 to 39.0 cm and the same of *A. mauritiana* is 6.0 to 30.0 cm.

3. The size frequency distribution from morphometry shows "one size class in one locality" for both the species.

4. Biometry indicates the allometric growth pattern between body length and body weight of these two species.

Chapter III

5. The feeding biology indicates that the food intaking is by mechanical process in H. nobilis, while the same is by chemical process due to adhesive secretion of nodules in A. mauritiana.

6. The gut morphology shows that H. nobilis and A. mauritiana are surface sediment feeders. The gut length and total body length show very fair positive relationship, since 'b' value is 3. There is no feeding ceasation at any time in these two species.

7. Micro-fauna and flora are the main food items found in the gut, but these two species are not digesting any of the food items, instead they absorb the organic carbon from the sediment.

8. H. nobilis is not a selective feeder and A. mauritiana is a selective particle feeder.

9. The organic carbon and assimilation efficiency is more in the foregut region than in other regions of the gut in both the species.

10. H. nobilis assimilates nearly 40% of organic carbon, while A. mauritiana assimilates nearly 30%.

11. The average digestion time in H. nobilis is 12 hours and it consumes 17.5 gm of dry sediment per day and

18.33 kg per year. The above for A. mauritiana are 14 hours, 6.8 gm of dry sediment per day and 2.28 kg per year respectively.

12. H. nobilis reproduces by sexual means with 6 reproductive stages and one reproductive cycle in an year. 100% matured animals are found in July and August. The spawning takes place in September. The oocytes at the time of spawning are measured between 180 um to 190 um.

13. The length of H. nobilis at the time of first maturity is between 24.0 - 25.9 cm.

14. An average fecundity is estimated as 9,31,071 eggs.

15. The average age of H. nobilis at first maturity is 2.8 years and age at maximum size was 4 years.

16. The temperature and salinity are found to influence the reproduction in H. nobilis. Lower salinity and temperature influence spawning.

17. A. mauritiana reproduces asexually by fission. High temperature and salinity trigger the fission.

18. The age at minimum size of A. mauritiana is 0.6 years and maximum size 2.9 years.

Chapter IV

19. The processed H. nobilis gives a I grade Beche-de-mer, while A. mauritiana only gives III grade.

20. While processing H. nobilis looses its body weight by 85% and A. mauritiana by 90%.

Chapter V

21. It is found that H. atra in the lagoon and A. mauritiana in the reef flat area are abundant in the Minicoy Island. H. atra is not economically important due its shrinkage and its thin body wall.

Chapter VI

22. The temperature, salinity, depth, grain size of the sediment and _ater current are having positive relationship with the abundance of H. nobilis at certain stations in the lagoon and A. mauritiana in the reef flat area.

The Thesis concludes with a 'Summary', highlighting the significant findings by the candidate followed by a list of literature consulted under 'References'.

It is hoped that the results obtained, the significant findings and the conclusions drawn from this study would definitely and appreciably enhance the knowledge available on this subjects.

With great pleasure, I record my deep sense of gratitude to Dr. K. Rengarajan, my supervising teacher and Senior Scientist, Central Marine Fisheries Research Institute, Cochin-14 for providing able guidance, constant help, continuous encouragement and constructive criticism throughout the investigation and the preparation of this thesis.

I am very much indebted to Dr. P.S.B.R. James, Former Director, CMFRI and Dr. P. Vedavyasa Rao, Director, CMFRI, Cochin for providing me all the facilities for the study both at Minicoy and at Cochin.

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INTRODUCTION

INTRODUCTION

"I also here salute the echinoderms as a noble group of animals especially designed to puzzle the Zoologists"

- Libbie Henrietta Hyman

Yes, this is what the naturalists found echinoderms as morphologically and anatomically different traits of animals such as Sea-stars, Sea-urchins, Sea-dollors, Sea-lilies and Sea-cucumbers belong to Phylum Echinodermata. They defined that these are enigmatic echinoderms.

Nichols (1976) states "All animal Phyla are unique, but some are more unique than others". This statement is not a wonder when researchers found that all these echinoderms are having a unique place in natural science and modern research, for example sea-lilies in evolutionary research (Hyman, 1955), sea-stars and sea-urchins in embryological research (Leigh, 1990), sea-cucumbers in biomedical (Bakus, 1973) and ecological research (Dubinsky, 1990). However among the echinoderms only sea-cucumber is more abundantly, directly and economically important to man than the other echinoderms.

IMPORTANCE OF SEA-CUCUMBER

A source of protein food

In fact Chinese are real "Initiators" who made sea-cucumbers a delicacy in their menu. When the world was looking at the sea for protein food, the Chinese were able to collect sea-cucumbers which served as protein food with some medicinal values to cure some diseases. They believed that sea-cucumbers are aphrodisiac and having curative properties for ailments such as blood pressure and muscular disorders (Joseph and Shakeel, 1991). This is the reason that it became Chinese delicacy and even now this is one of the auspicious items in important functions and festivals in China. Recent researches on biochemical and nutritional composition of sea-cucumbers proved that they are highly nutritious and it has 43% of protein with low fat content (Krishnasamy, 1991). Tanikawa (1955) reported that Stichopus japonicus is having chiefly insoluble protein collagen which is a tough muscle protein.

A source of income

Due to more demand in China, countries bordering the Indo-Pacific where these animals are abundant and form a traditional fishery, had trade with China. Presently the sea-cucumber fishery has become an artisanal fishery and source of income to the poor coastal fisher-folk, while their products are attractive and lucrative for many developing countries in their export industry especially in Indo-Pacific region. The world export reached 7,286 tonnes in 1991 valued at US \$ 29,940 x 10^3 million and imports 11,497 tonnes in 1991, valued at US \$ 53,204 x 10^3 million (INFOFISH, 1992).

A source of medicine

Researches on Pharmaceuticals and drugs showed outstanding results and that the sea-cucumbers are having abundant source of biomedical compounds. As an example, a highly active antifungal steroid glycoside has been isolated from the sea-cucumbers (Bakus, 1973). Geronimo and Domantay (1974) detected a tumor-inhibiting potency in the tissues of sea-cucumbers. Some anticancer properties have been identified from Actinopyga mauritiana and Holothuria hilla by Allen et al. (1986). Sarma et al. (1987) isolated triterpene glycosides and aglycones from Holothuria atra and H. scabra. Antifungal property from sea-cucumbers has been demonstrated as a cure for superficial dermatophytosis by Shimada (1969). Besides these investigations, the Cuvierian tubules of certain species of sea-cucumbers have been traditionally used by fisherman in Cebu and Maldives as a plaster for minor wounds and sprain (Joseph and Shakeel, 1991).

A source of toxin

The sea-cucumbers are containing toxic substances such as Saponin (Burnell and Apsimon, 1983) in their skin and other internal organs. The holothurin a steroid saponin is helping holothurians to protect from predators. Some toxic substances from the body of sea-cucumbers when applied in water, render fishes weak and less active. Native of Guam use this as a fishing method (Frey, 1951). H. vagabunda is also used as fish poison in the Tokara Islands (Yamanouchi, 1955).

Ecological importance

In coral reef ecosystem, the holothurians are playing an important role as determinators and regenerators of ammonium in ammonification, which is an important step in nitrogen cycle in the ecosystem (Webb et al., 1977). These animals are also controlling the bacterial production in the ecosystem. Moriarty et al. (1985 b) found that bacterial production and algal-mat formation in coral reef ecosystem declined when holothurian grazing was permitted. Hence holothurians are considered as benthic bacteriovores. Holothurians are also considered as important bioturbators of soft sediments of reefs (P.A. Tyler, Per.Comm.).

A BRIEF DESCRIPTION OF SEA-CUCUMBER

The sea-cucumber is otherwise known as holothurian. The name sea-cucumber derived from Pliny's term Cucumis marinus that he applied to a true holothurian (Hyman, 1955). These animals are spiky-skinned animals of the Sub-Phylum Echinozoa and the Class

Holothuroidea. These animals are both sessile and sedentary. Some of their salient characters are given below.

External characters

Sea-cucumbers are usually elongated in the oral and aboral axis with bilateral symmetry. Colour of the animals differ from species to species. They are mainly black, yellow, grey, white and combination of these colours depending upon environmental condition. The general body surface is thick, leathery and slimy in most sea-cucumbers and more or less covered with warts, tubercles or papillae. Endoskeleton reduced to microscopic spicules or plates, are embedded in the body wall and make them soft. These spicules are made up of magnesium rich calcite and help in the identification of the species. Mouth is surrounded by tentacles which vary from species to species and help to trap the food. The tentacles are greatly modified according to their mode of feeding. Sea-cucumbers are generally deposit feeders, but there are filter feeders, detritus feeders and plankton feeders too. In some species the anus is surrounded with five calcareous anal teeth, which is also an identifying character. Tube-feet are arranged ventrally or dorsoventrally to make the animals to move.

Internal characters

The water vascular system of these animals is distinct and characteristic to this Phylum. The water vascular system is helped by a pore or cluster of pores termed madreporite to communicate with the external medium. Respiratory trees are responsible for gas exchange. Haemal, digestive and nervous systems are well developed. In most of the species sexes are dioecious *e.g. Holothuria scabra* and *Holothuria nobilis*, a few species show hermaphroditism *e.g. Parariza pallens*, a few species reproduces by asexual reproduction by transverse fission *e.g. Holothuria atra* and brooding behaviour e.g. Cucumaria lubrica. In general the sexes cannot be distinguished externally. The gonad usually consists of numerous tubules united basally into one or two tufts attached to either side of the dorsal mesentery. The animal in its development undergoes a series of larval stages such as Auricularia, Doliolaria and Pentactula. Some species of Sea-cucumbers are having Cuvierian tubules which are very sticky and it is helping them to escape from the enemy. Holothurians have remarkable capacity of evisceration and regeneration.

Habitat

The sea-cucumbers are exclusively marine and distributed all over the world. These animals are found in shallow-water neritic zone, deep water zone and oceanic coral islands. But higher diversity being found in tropical areas of the Indian, Pacific and Atlantic Oceans. Higher density being found in tropical shallow water mainly in Indo-South Pacific which is predominate in coral ecosystem. Hence, these systems are highly diverse and productive marine ecosystem in the world.

PRESENT STATUS OF SEA-CUCUMBER RESOURCE IN INDIA

Total number of species so far known from the world ocean is 1200, while in Indian waters less than 100 species only so far known. Considering the importance of echinoderms, especially sea-cucumbers as food and gaining foreign exchange through export, it is surprising that other than taxonomic and distributional study no attempt was made to assess its resources and initiate research on biological aspects from India, until the beginning of the present century. This may be attributed to (i) the interest shown by us to fish, crustacean and molluscan resources, (ii) unfamiliarity on the food and economic value of these animals, and (iii) to the fact that the unattractive appearance of these animals created a wrong impression in our minds that these animals are harmful to human beings. However, due to the continued growth of the world population, increasing pressure for food and economy, sea-cucumber which forms an annually renewable resources, has become main aspects in Indian research from middle of this century. Now concerted efforts are made in India, particularly in the Central Marine Fisheries Research Institute's (CMFRI) Laboratory at Tuticorin to breed sea-cucumbers at the controlled laboratory conditions, hatch them, rear them upto a particular size and ranch them at suitable water bodies for culture and raise them for export market.

Availability in India

Though India has a coastal-line of about 7,000 km including its Union Territories of Andaman & Nicobar Islands and Lakshadweep, the holothurians are confined to particular habitats such as coral reefs, rockey coasts, sandy shores, muddy flats and algal flats. These animals were reported common along with other echinoderms from mainland coasts of Jamnagar, Bombay, Ratnagiri, Karwar, Cochin, Vizhinjam, Tuticorin, Mandapam, Madras, Machilipatnam, Kakinada, Waltair, Gulf of Mannar and Palk Bay and Andaman & Nicobar Islands and Lakshadweep group of Islands. Among these places the Gulf of Mannar, Palk Bay, Lakshadweep Islands and Andaman & Nicobar Islands are very important places as they, in large quantity and size, go into preparation of high quality of *Beche-de-mer*. For the last 100 years the sea-cucumber fishery was only confined to the Gulf of Mannar and Palk Bay area and that too only on one species *Holothuria scabra*. The total sea-cucumber export from India is estimated approximately as 50 tonnes dry weight/year (Gurumani and Krishnamurthy, 1989). But the recent export quantity is 38 tonnes and value are 92.00 lakhs for 1991-1992 (MPEDA, 1993). The resource of sea-cucumber in Andaman & Nicobar Islands was estimated by James (1987) and he reported 52 species of holothurians from this island ecosystem and only half a dozen species are of commercial value particularly *Holothuria scabra*, the most important species because of its numerical abundance. Lakshadweep resource was estimated by James (1989) and reported 3000 to 5000 tonnes of H. nobilis and B. argus could be collected when we take whole islands into consideration. But from the exploitation point of view these are untapped potential so far.

Although these sea-cucumbers are source of food, income, medicine and toxin, it is directly involving in socio-economic development of human being through exports of their product Beche-de-mer. The major Beche-de-mer producing countries are Philippines, New Caledonia, Malaysia, Fiji, Maldives, India, East African countries, the Republic of Korea and Japan. A sudden upsurge in international trade is noted both imports and exports from 1985 and have been stable since then (Krishnasamy, 1991).

But Indian fishery statistics showed some decline particularly in 1982-83 with product export for the past 10 years declining to 28 tonnes from 56 tonnes. This economic damage was brought to attention of Marine Products Export Development Authority (MPEDA). It was noticed that this decline was on sea-cucumber fishing particularly the small sized ones due to government's ban. Moreover indiscriminate fishing of juveniles from the Gulf of Mannar to meet the foreign market demand compelled the Government to promulgate the ban to avoid over exploitation including the juveniles which is not suitable for foreign market grade. In 1987 Government of India through its Ministry of Agriculture constituted a committee of experts with Director, CMFRI as Chairman to exam the ban. This committee found that the ban is justifiable and pointed out that the holothurians from nonexploited area can be fished to avoid the serious economic damage (Sakthivel and Swamy, 1989).

Based on the recommendations and as there was lack of informations on the sea-cucumber, the CMFRI which is responsible for the assessment of marine living resources of the country initiated a preliminary survey to assess the living resources of Lakshadweep Islands during January to March 1987. As the CMFRI conducted only a preliminary survey and as there is still want of informations on holothurian of the Lakshadweep Islands, the candidate has taken up an intensive and detailed studies on the taxonomy and distribution of all available sea-cucumbers, their biology and ecology, and economic important of commercially valuable species and selected the topic "Studies on sea-cucumbers of Minicoy, Lakshadweep" for his Doctoral Thesis.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

It is imperative in any field of research to gather information on the field and aspects from the past and understand the information, literature and knowledge available. Accordingly all information on sea-cucumber from throughout the world and particularly from the mainland of India and the Union Territories of Lakshadweep and Andaman & Nicobar Islands.

Compared to other parts of the world, information on sea-cucumbers from India is very less and specifically from Union Territory of Lakshadweep, it is extremely poor except a few passing remarks on a few species of sea-cucumbers of the Lakshadweep. It may be said that there is no systematic investigation on sea-cucumber of the Lakshadweep area.

Taxonomy

Scientific studies on holothurians started only in the later half of the 16th century, although they had been known for a long time before. But still the systematic study has not yet been completed and makes it difficult due to structural complexities, frequent (body) structural changes, asexual reproduction and faunal composition. Their abundance in many areas is imperfectly known.

As the taxonomy is elaborately reviewed and discussed under section 1 of chapter I, only a brief reviewing is carried out here.

The synthesis of literature shows advances in the knowledge of holothurians, which have come chiefly from various expeditions especially by H.M.S. Challenger. Based on the collections from the expedition, Ludwig (1875, 1889-1892) and Theel (1882, 1886) published an exhaustive historical account on Holothuroidea. Ludwig

(1894), Edwards (1907) and Deichmann (1937, 1938 a, 1941) have described the species of sea-cucumbers of the Pacific Coast, while Deichmann (1930) monographed holothurians of the Atlantic Coast of America from Capecod to Brazil. On the basis of the holothurian collections at the British Museum and existing literature, Semper (1868), Pearson (1914), Clark (1922, 1924), Panning (1929-35) and Deichmann (1958) made primary investigations of holothurian fauna collected from all over the world.

Domantay (1949-1950) classified sea-cucumbers of Eastern Pacific from Coastal America to the Northern parts North America from Hawaii, the West Pacific around the Marianas Islands, Guam and a small Atlantic collection from Florida. Again Domantay (1961) described taxonomic characters of 25 species of littoral Holothuroidea of Hundred Island of Philippines. Pawson and Fell (1965) revised classification of the Dendrochirote holothurians which is most important in evolutionary trends. The deep water holothurians comprised of 24 species in which 10 new records to science were reported from New Zealand region by Pawson (1965). In 1968 Pawson reported some holothurians from Macquaire Islands in which Pseudocnus laevigatus is a new record for the islands.

Clark and Rowe (1971) in their monograph on "Shallow-water echinoderm of Indo-Pacific area" gave a Table of references to each species by geographical area while Rowe and Doty (1977) reported thirty species of holothurians from shallow water of Guam in which six were new records. Pawson (1978) reported echinoderm fauna from Ascension Islands of South Atlantic Ocean in which one new species Holothuria (Halodeima) manningi was new to science and also noted the absence of members of the Order Aspidochirotida from this region.

Tan Tiu (1981) collected, identified taxonomically and described twentyseven species from Central Philippines with three new species namely Actinopyga caroliniana, Holothuria mactanensis and Holothuria canaliculata. The recent review by Pawson (1982) on Holothuroidea has given an upto date classification, geographical distribution and total number of holothurian available all over the world.

With reference to Indian Ocean, holothurian had received major attention only from 1868 onwards. The pioneering works and classic references on taxonomy of sea-cucumbers of the Indian Ocean are by Semper (1868), Ludwig (1875, 1899), Bell (1884, 1886), Lampert (1895), Pearson (1903, 1910) Koehler and Vaney (1905, 1910), Clark, H.L. (1914, 1923) and Gravely (1927). Monograph of Bell (1884) on 'Alert' material, Theel (1886) on "Challenger" material, Ludwig and Heding (1935) on "Valdivia" material added considerably to our knowledge on this aberrant group. In the middle of this century many investigations were started on holothurians from different regions of the Indian Ocean. Clark, H.L. (1938, 1946) from Australia, Heding (1937), John (1939), Cherbonnier (1952, 1953, 1954 a), Panning (1941), Deichmann (1944,1948) from South Africa, Heding (1940) from Iran region, Tortense (1947, 1960), Clark, A.M. (1951, 1952), Cherbonnier (1954 b, 1955) from Red Sea region, Nair (1946), Gopalakrishnan (1967), Daniel and Halder (1974), James (1965, 1968, 1969, 1971, 1973, 1978, 1980, 1981, 1982, 1983, 1985, 1986) from Indian region.

Morphology

Colour : The holothurians have different colours. This colouration serves as an adaptive feature and vital for species identification. But no attempt has been made to study the adaptive advantages of colour in coral reef holothurians (Bakus, 1973). Yonge (1931) found that black and brown colour is predominate on the Great Barrier Reef holothurians as it is typical of many Indo-Pacific reefs. Clark (1945) observed brown or grey colour for most of the holothurians. Hyman (1955) has stated that holothurians are mostly with dull coloration, occur in shades of grey, brown and olive upto black. The Elasipoda which are mostly residents at deep water, present the purple-maroon or violet shades common to animals of abyssal zone. Millott (1950, 1953) remarked that the brown and black shades are probably of melanistic nature chemically. Stichopus japonicus occurs in three colour phases and is distributed along the entire coast of Japan. A green form lives in sand or mud near bays, while red form lives on reefs and bebble or gravel beds on an exposed shorelines (Choe and Ohshima, 1961; Choe, 1963). Nichols (1964) found the reason for colouration that amoebocytes (pigments) are responsible on Holothuria forskali as in other echinoderms. Cherbonnier (1980) recorded very great variability in the colouration of Holothuria scabra and Holothuria versicolar. Black, speckled and beige colour of Holothuria scabra from Pacific Islands were reported by Conand (1990).

Size : The holothurians are mostly moderate in size, but vary within wide limits. Very small forms are of a few centimetre in length occur among the Elasipoda and Dendrochirota and in the genus Leptosynapta among the Apoda. Moderate size prevails among the Molpadonia. The Aspidochirota are mostly of moderate to large size and the largest holothurians that retain the cucumber shape occur in the aspidochirote genera Holothuria, Actinopyga and Stichopus often 30 to 50cm in length (Hyman, 1955). Stichopus variegatus from the Philippines was reported by Semper (1868) to reach a length of a metre with a diameter of 21cm. Crozier (1918) reported that in Bermuda Island, the holothurian Stichopus moebii showed same size through the reef flat and it may be due to reproduction by transverse fission. Bakus (1968) measured Synapta maculata from 1.8 to 2.4m in length from Eniwetok, Marshall Islands. Macnae and Kalk (1962) have found Holothuria arnicola and Holothuria pervicax with a size about 50 cm in length at Inhaca Islands, Mozambique. Bonham and Held (1963) recorded Holothuria atra between 2 to 60cm in length at Rongelap Atoll, Marshall Islands. The other pioneering works on the morphometric character and size distribution of various sea-cucumbers at various geographical areas are by Choe (1963), Fish (1967), Rutherford (1973), Gentle (1979), Harriot (1980), Cherbonnier (1980), Shelley (1985), Conand (1981, 1982), Tyler and Gage (1983), Tyler and Billett (1987). Conand (1990) worked on different aspects on Holothuria scabra, Holothuria versicolor, Holothuria nobilis, Holothuria fuscogilva, Actinopyga echinites, Thelenota ananas and Holothuria atra from the Pacific Island countries.

General anatomy

From the avilable literature, it appears that Selenka (1867) was the first to work on the anatomy of Stichopus chloronotus. Semper (1868) worked on the anatomy of different holothurians of Philippines. Sivickis and Domantay (1928) worked on the morphology of Stichopus chloronotus from Philippines and they have clearly reported gross and the microscopic anatomy of this animal. Hyman (1955) reviewed very clearly the anatomy of Thyone briaereus, digestive and haemal system of Stichopus spp. digestive and haemal system of Paracaudina sp. Pawson (1982) has given detailed anatomy of dendrochirotid holothurian.

Food and feeding biology

During the past sixty years there have been several investigation onto various aspects of holothurian feeding and their importance in sediment turnover in the tropics. Based on the tentacular nature and feeding habits, Hyman (1955), Pawson (1966 and 1982) Clark and Rowe (1971) have described various types of tentacles in different Orders of the groups as Pinnate type and Digitate type in Apodida, Peltate type in Aspidochirotida, Dendritic type in Dendrochirotida and Digitate type in Molpadiida. The method of food collection by various holothurians and tentacular mechanism have been reported by Anderson (1966), Fish (1967) and Binyan (1972). Chia and Buchanan (1969) have reported the presence of Papillae on the tips of the tentacles from the Pentacula larvae of Cucumaria *elongata* and stated that these are out-growths of acid mucopolysaccharide cells that produce mucous secretion important in both feeding and locomotion.

Fankboner (1978) observed the tentacle's papillae of *Psolus chitinoides*, to which an adhesive function was attributed, while Roberts (1979) observed the tentacle structures of twelve different species from Thousand Islands through scanning electron microscopy. His reports shows that the texture of tentacles are different and based on an apparent relationship with the mean particles size of sediments. Sediments and detritus adhere to the "knobby surface" of the digits on the feeding tentacles of young *Chiridota rotifera* was reported by Engstrom (1980). Roberts and Bryce (1982) examined the tentacles of several tropical holothurians at light microscopy level and observed that secretory cells of epithelia produce an adhesive material which is helping them to collect the food materials from substratum. Levin (1982) has stated that in *Stichopus japonicus* the tentacle functions as an adhesive process. Cameron and Fankboner (1984) studied the tentacle structure and function in the pentacula larvae, juvenile and adult life-stages of *Parastichopus californicus*.

As per literature available, as early as 1884, Hamann gave detailed accounts of the gut histology of holothurian *Leptosynapta* and *Holothuria* sp. Hyman (1955) reviewed various type of gut morphology, their histology and functional relation to various orders and species belong to Holothuroidea. Stott (1957) has studied alimentary canal and associated structure of *Holothuria forskali*. Tanaka (1958) described the feeding and digestive process of *Stichopus japonicus*. Trefz (1958) remodified the nomenclature of gut of *Holothuria atra* and added new information on gut morphology. Choe (1963) has given an account of gut structure and digestive enzymes found in *Stichopus japonicus* and Kawaguti (1964) studied by electron microscopy on the intestinal wall of the sea-cucumber *Stichopus japonicus* with special attention to its muscle and nerve plexus.

Fish (1967 a) described the gut nomenclature and morphology of Cucumaria elongata and found that the presence of glandular cells in the intestine involving in secretion of digestive enzymes. Massin and Jangoux (1976) observed the alimentary behaviour of Holothuria tubulosa using colour sand and estimated the time between the ingestion and the egestion of sands. Structure and functional peculiarities of the digestive system of Cucumaria frondosa described by Filimonova and Tokin (1980) and their results show that intestinal epithelium are intended to carry out various functions.

However, majority of literature available on types of food consumed by holothurians are concerned with micro-organisms and on the organic content of sand, mud, ooze and detritus. A few tropical species reportedly feed on plankton, organic matter on rocks, micro-crustaceans, polychaetes and foraminiferans (Kent, 1893; Finckh, 1904; Crozier, 1915 a; Frizzell and Exline, 1955; Macnae and Kalk, 1957). Yamanouti (1939) observed that Holothuria lecanorva and an unidentified black sea-cucumber feed on ooze from 'sea plants'. Hyman (1955) reviewed the early studies and listed food items found in the gut of sea-cucumber principally meiofauna and diatoms. Trefz (1958) analysed gut contents of Holothuria atra and reported diatom, trochophore larvae, copepods, small cymatium and morula (gastropods) are frequently ingested since they were often observed in faeces. Choe (1963) reported that young individuals of Stichopus japonicus feed on micro-algae and detritus and adults are non-selective feeder. Bakus (1968) reported that bacteria and foraminifers may be major sources of food for atoll holothurians. The production of bacterio-plankton in tropical water is thought to be a major food source for filter-feeder (Sorokin, 1971; Roberts, 1979).

With available literature, Crozier (1918) estimated the amount of bottom material ingested by holothurian Stichopus, while Yamanouti (1939) studied the total amount of sand eaten in a year, range of daily wandering, the time from the ingestion to the egestion, daily rhythm and feeding habits of various species of sea-cucumbers at Palao Islands. Tanaka (1958) measured the period of feeding in Stichopus japonicus and noticed that it feeds from 1.5 to 5 hours and passes food in 30 hours. Trefz's (1958) research on digestive physiology of Holothuria atra shows that this species utilizes approximately 50% of the nitrogen in sand and consumes sediments both day and night. Choe (1963) reported that Stichopus japonicus digested 51-57% organic carbon from the sediments and usually undergone eastivation during summer period. Fish (1967 a) noticed that eastivation also occurs in the temperate species Cucumaria elongata and the effect of temperature on the feeding behaviour. Fish (1967 b) also analysed various types of digestive enzymes in Sea-cucumber Cucumaria elongata. Bakus (1968) observed in Holothuria difficilis about 2% of the dry weight of sediment consumed. The ash free dry weight or approximate organic content of this sediment is 4-10%.

Investigation on the nutrition and the role of holothurians on th- coral ecosystem have been described by Townsley and Townsley (1973) and Bakus (1973). Yingst (1976) investigated the utilization of organic matter and constituent food items in shallow marine sediments by Parastichopus parvimensis as epibenthic feeding holothurians. Hauksson's (1979) results show that the assimilation efficiency of organic matter in Stichopus tremulus is normally 30%, but it is lower by 17% during the spawning period. Organic carbon, nitrogen and bacterial biomass from the sediments and gut contents of Holothuria atra and Stichopus chloronotus on the Great Barrier Reef, have been analysed by Moriarty (1982). Deming and Colwell (1982) identified the boraphilic bacteria associated with digestive tracts of abyssal holothurians. Yingst (1982) examined the rate of sediment ingestion and organic matter uptake by Parastichopus parvimensis in relation to intraspecific patterns of age-size distribution. Concentration of organic carbon, nitrogen, ATP and total plant pigments from gut contents of the deposit feeder aspidochirote holothuroids Isostichopus badionotus have been analysed by Hammond (1983).

Since the holothurians are bottom dwellers, the feeding selectively is an important aspect which links feeding behaviour to food sources. Some species selectively feed on specific sizes. Others are non-selective feeders on bulk sediments. Most of the critical investigations carried out on the food particle selection of sea-cucumbers are by Crozier (1918), Yamanouti (1939), Trefz (1958), Bonham and Held (1963). Glynn (1965) found that the gut of Astichopus multifidus filled with fine grained (medium 212 μm) calcareous bioclastics and there is no linear relationship between grain size and the cube root of dry tissue weight. Fish (1967) analysed sediments from the gut of Cucumaria elongata and substratum and reported that this species is taking selective particles hence it is a suspension feeder. Bakus (1968) reported Holothuria difficilis consumes particles of which about 80% are $>$ 25 μm in diameter, the remaining calcareous fragments measure upto 2 mm. Bakus (1973) reviewed many papers on digestion of holothurians and concluded that detritus feeder predominate in the finest sediments and deposits and filter feeders are predominate in intermediate grades. Roberts (1979) reported that distributional and gut content analysis showed that species partitioning is on the basis of substratum and particle size preference.

Reproductive biology

An overall review of literature on reproductive biology and allied aspects of sea-cucumbers shows that the early information concerning reproductivity of holothurian became available through the collection and studies designed primarily for embryological information. When later studies on systematics yielded data on reproduction including information on spawning, gonadal condition and brooding behaviour (Clark, 1898, 1910; Mitsukuri, 1903; Reimers, 1912; Mortenson, 1937, 1938).

In general, Hyman (1955) reviewed various works on the reproductive biology and has described various type of reproduction (sexual, asexual, brooding and hermaphroditic) and the functional morphology of reproductive organs of various orders belong to class Holothuroidea. Colwin (1948) reported the reproductive cycle and spawning of sea-cucumebr Thyone briareus. The studies of Tanaka (1958) and Choe (1963) on Stichopus japonicus are the most detailed accounts of holothuroid reproductive biology such as reproductive cycle, gonado-somatic index, spawning behaviours. Boolootian (1966) reviewed the studies so far have been made on holothuroid reproduction in relation to geographical area such as Red Sea, the Mediterranean, the New England Coast, Puget Sound and Japan region by various investigators. Pearse (1968) conducted research on patterns of reproductive periodicities in four species of Indo-Pacific echinoderms in which Holothuria atra showed a synchronous development of gametogenesis among individuals and same individuals spawns at different times during the spawning period. Krishnan and Dale (1975) attempted to made a complete picture of the testis of the holothurian Cucumaria frondosa using light microscopy, scanning and transmission electron microscopy in addition to histochemical spot test, while similar study has been made by Fontaine and Lambert (1976) on fine structure of the mature sperm of the holothurian Cucumaria miniata with particular reference to the acrosomes. Green (1978) studied the annual reproductive cycle of an apodus holothurian Leptosynapta tenuis and found that these animals are spawning twice in a year. Reproductive cycle of Holothuria floridana, Holothuria mexicana and their hybrids in Southern Florida, U.S.A. have been reported by Engstrom (1980).

In New Caledonia, Conand (1981, 1982) studied the sexual cycles of various economically important sea-cucumbers, while Harriot (1982, 1985) carried out similar studies on reproductive cycles of commercially important sea-cucumbers at Heron Reef, Australia. Engstrom (1982) focused attention on behaviour and ecological adaptation of reproductive biology of a brooding dendrochirote holothurians

Cucumaria lubrica. Smiley and Cloney (1985) described the ovulation and the fine structure of the *Stichopus californicus* ovarian tubules and their architectural simplicity. Costelloe (1985) reported an investigation of the gonadal cycle in *Aslia lefevrei* using histological techniques and gonad indices against a background of hydrographic data from the Black Rock Reef in Galway Bay. Cameron and Frankboner (1986) examined the reproductive periodicity and spawning behaviour of *Parastichopus californicus*. Spawning occurred in the late spring through summer. Reproductive biology of deep sea holothurians from Atlantic Ocean and other region by Tyler and Gage (1982), Tyler *et al*. (1985, 1985 b, 1987) are giving valuable information on their gametogenesis strategies, reproductive cycles and ecological adaptation to their reproductive behaviour at abyssal zone.

McEuen (1988) investigated the reproductive behaviour of twelve species of Northeast Pacific holothurians living in water surrounding the Juan Archipelago, Washington. Pearse *et al*. (1988) noticed spawning behaviour of *Parastichopus californicus*, while observing the simultaneous spawning behaviour of six species of echinoderms from British Colombia. Smiley (1988) studied the morphological, anatomical and major cytological stages of oogenesis in the holothurian *Stichopus californicus*. Sewell (1990) noticed the variability in the reproductive cycle of *Stichopus mollis* comparing the gonado-somatic index to environmental parameters, while Conand (1988, 1990) studied the reproductive biology of commercially valuable sea-cucumbers from South Pacific Islands.

Age and growth

For resource assessment, the studies on age and growth of the organisms are important. The work so far carried out on age and growth are very few. Edwards (1909) presented growth data for newly metamorphosed *Holothuria floridana*, but only upto size of 4mm and an age of 75 days under laboratory condition. Fish

(1967) and Buchanan (1967) discussed growth and mortality of Cucumaria elongata and calculated rates of growth based on size frequency distribution for many ages. Rutherford (1973) investigated growth of newly recruited Cucumaria pseudocurata to an age of 1 year. Tetracycline tags of the calcareous rings of holothurian has been used by Ebert (1978) to estimate the growth of Holothuria atra and estimated maximum size as 32cm and 1352 grams. But annual loss was 50 to 70% of the total population based on the growth parameter and population size structure. However similar trials by Harriot (1980) in the same species were unsuccessful.

Franklin (1980) on Stichopus chloronotus from Heron Reef, Shelley (1981) on Actinopyga echinites from Papuan coastal lagoon, calculated age and growth based on changes in size distribution and the associated progression of the model using the monthly sample collection. Conand (1983) in New Caledonia studied growth in holothurians by tagging experiments and in 1988 and 1990 derived growth curve for commercially important sea-cucumbers by using the same tagging experiments from Pacific Islands.

Evisceration and autotomy

The power of evisceration as a defence mechanism and ecological adaptation in holothurian is termed autotomy by Fredericq (1883). The classic review on "fission and autotomy in echinoderms" by Emson and Wilkie (1980) reported that three types of autotomy occurred in holothurians viz. ejection of the internal organs through the anus, evisceration through the anterior end of the body and transverse division of the whole body into two or more pieces. Thyone ejects viscera (evisceration) through the body wall, while Holothuria atra, Holothuria sanguinolenta and Stichopus chloronotus eject the digestive tract and internal organs through the anus (Crozier, 1915 a; Domantay, 1931). Kille (1939) and Mosher (1956) reported this evisceration seldom occurs under natural condition in some holothurians, while Glynn (1965) claimed that this is a normal defence response. Bakus (1973) has reviewed elaborately the all available informations on evisceration in holothurians, particularly the areas or places of evisceration in the body.

The other investigators worked on the reasons or causes of evisceration and their root causes are by Pearse (1909) due to chemicals; Crozier (1914) due to direct sunlight; Domantay (1931) due to foul water; Kille (1936) due to electric shock and Russell (1965) during handling and temperature differences.

Sea-cucumber fishery

Holothurians are the economically important group among echinoderms. Almost all countries are now-a-days collecting, processing and exporting to other countries especially to China. Bakus (1973) have reviewed the whole work on the sea-cucumber fishery world over. The notable work on the fishery are by Koningsberger (1904) from Netherlands, Hornell (1917) from Indian region, Sella and Sella (1940) from eastern Africa. Panning (1944) discussed the 'trepang' fishery from main countries of the Indo-Pacific region and its trade around the world. Adithiya (1969) reported the Beche-de-mer industry of Sri Lanka and Ward (1972) from Pacific Islands with special reference to Fiji. Sachithananthan (1974) summarised the avialability of commercially valuable sea-cucumbers, collection and processing of Beche-de-mer in the Hand book on Beche-de-mer and published by FAO. There are so many publications on the method of processing and guidelines for Beche-de-mer among which notable are Parrish (1978) from Australia, Harriot (1985) from Great Barrier Reef, Joseph and Shakeel (1991) from Maldives. Sachithananthan et al. (1975) has introduced the improved method for processing. The status report on Beche-de-mer are provided by Roa (1987) for Philippines, by Krishnasamy (1991) on the International trade and Conand (1990) from Indo-Pacific countries.

The weight loss and shrinkage during processing of *Holothuria nobilis*, *Thelenota ananas* and *Actinopyga echinites* reported from New Caledonia by Conand (1979). A few notable studies on the nutritive value of meat of sea-cucumber particularly *Stichopus japonicus* are by Tanikawa (1955), Tanikawa and Ishiko (1955) and on the nutritional composition on the dried product by Nichols (1955), Sachithananthan (1974) and Krishnasamy (1991).

Ecology of Holothuria

Pearse (1908) reported that *Thyone* sp. can live for three weeks in slowly evaporating seawater and in sea water diluted one and half or more with fresh waters they could survive upto 24 hours. Heding (1928) observed significantly that *Opheodesma grisea* found in large numbers thrown on the beach at Pearl Harbour, Hawaii were almost completely dried out by the strong sunlight and became dried and during high tide and immersion in tidal water, they resumed their normal activity apparantly unharmed by their long exposure. Hyman (1955) reported that *Thyone* sp. may be found living at the mouth of rivers with one half of normal salinity and exposed for three hours to a temperature of 37°C. It was found that in the North Sea, *Thyonidium pellucidium* can tolerate salinities as low as 20 ppt (Ursin, 1960). A Philippine species *Protankyra similis* lives in a brackishwater habitat, in the mud of mangrove swamps (Pawson, 1966). Choe (1963) observed the green *Stichopus japonicus* has a preference to some what lower salinity and eventually find its favourite habitat on sand and muddy grounds, while the red species preferred the higher salinity mainly in the rock, bebble and gravel grounds. Bakus (1973) reported that aspidochirotes are more characteristic of ecological habits with clear tropical water and dendrochirotes are more characteristic of boreal latitudes. This phenomenon is related partially to the low standing crops of phytoplankton in tropical oceanic surface water and the highest plankton densities and numerous organic detritus, particles in boreal water. Deichmenn (1957) found that certain tropical shallow water forms are almost circumtropical range, while most of the modern forms are plankton feeding dendrochirotes and sandy mud eating apodus holothurian. Pawson (1976, 1978) observed Isostichopus badionotus is a common large epibenthic species widely distributed on shallow, muddy, sandy and sea-grass beds from America to West Africa and from Ascension to Bermuda Islands. On Suva Reef, Gentle (1979) observed fairly dense populations of Holothuria fuscogilva in sea-grass beds of Syringodium isoetifolium and Halophila ovalis at 10 m depth zone, subject to terrigenous influence as well as salinity variation due to the Rewa River out flow. Sibuet (1977) measured quantitive distribution of abyssal holothurians in relation to environmental parameters. Tyler et al. (1985) studied on the distribution of deep sea holothurian in relation to the sedimentological character. There are several other reports available on ecological parameters and their relation to holothurians (Crozier, 1918; Baker, 1929; Yamanouti, 1939; McNae and Kalk, 1962; Bonham and Held, 1963; Bakus, 1968; Taylor, 1973; Taylor and Lewis, 1970; Townsely and Townsely, 1973; Webb et al., 1977; Sloan and Bodungen, 1980; Massin and Doumen, 1986).

Quantitative abundance

The literatures available on the abundance of holothurians are mostly concerning to the commercially and economically important species for the estimation of their economic potential. But Hauksson (1979) stated that high abundance makes it a convenient study object for obtaining information about the biology and role of deposit feeding holothurians in the benthic ecosystem. Bakus (1973) and Webb et al. (1977) reported on the abundance of sea-cucumbers and indicated that they are important reworkers of sediments. Baker (1929) described the different zones of Gaua Island, New Hebrides where the density of 0.5/25 m^2 was recorded for Actinopyga mauritiana and 7/25 m^2 for Stichopus chloronotus. Fish (1967) reported Cucumaria elongata which is found in temperate sea in densities of $20/m^2$.

Salvat (1975) noticed in French Polynesia, the predominant species is Holothuria atra with a mean density of 2 to $8/m^2$ and maximum density that can reach $43/m^2$. Rowe and Doty (1977) found a population of Actinopyga echinites with a density of $0.8/m^2$ located behind the population of Actinopyga mauritiana which had a higher density of 1.2 to 1.5 specimens/m^2 area. Lawrence (1980) reported that Actinopyga mauritiana reached high densities of $12/m^2$ area on a windward reef flat of Eniwetak atoll.

In Yap Lagoon, Grosenbaugh (1981) found high densities of Actinopyga echinites (5 to 15 specimens/m^2 area) in Thalassia bed on the inner reef flat. Several others have estimated the abundance of holothurians in tropical water and their impacts on coral reef environment (Yamanouti, 1939; Kalk, 1959; Macnae and Kalk, 1962; Bonham and Held, 1963; Bakus, 1968; Townsley and Townsley, 1973; Sloan and Bodungen, 1980 and Hammond et al., 1985). In Pacific Islands, Conand (1990) estimated the abundance of various species and divided into three categories based on their commercial value. The first category species which is most economically important accounted for 25% of the total and are dominated by Actinopyga miliaris. The second category accounted for 56% dominated by Holothuria atra with 33%, while third categories are less abundant.

REVIEW OF LITERATURE FROM THE INDIAN REGION

The available literature show that the works so far carried out in Indian region are generally on all echinoderms, not particularly with holothurians. A review by James (1983) on "Research on Indian echinoderms" and who is the pioneer worker on echinoderms from Indian seas from 1967 onwards reported that Bell (1888, 1889, 1902), Wood Mason and Alcock (1891 a, 1891 b), Alcock (1893 a, 1893 b, 1894 a, 1894 b, 1895), Koehler and Vaney (1905,1908) and Koehler (1914, 1923, 1927) have paid considerable attention on taxonomic study of sea-cucumbers in the Indian region.

In recent years, Nair (1946) described a new species of holothurian Chondrocloea varians from Madras Harbour, while James (1967, 1968 b) recorded new species Phyllophorus parvipedes and Stolus buccalis from Indian seas. In 1974 Daniel and Halder collected 32 species of holothurians from Andaman and Nicobar Islands and listed.

James (1978 a) redescribed the two little known holothurians with a note on an early juvenile of Holothuria scabra. There are some scattered informations on systematics of some shallow water asteroidea ophiuroidea and holothuroidea from Indian seas. Soota et al. (1983) made a taxonomic description of 19 species of holothurians from Andaman and Nicobar Islands, while James (1986 e, f) reported two species namely Holothuria pyxis, Phyrella fragilis from Andaman.

Most of the works on India sea-cucumbers related only to taxonomy with little information on their biology, ecology and other aspects. James (1967, 1968 b) has given the gross anatomy of Phyllophorus parvipedes and Stolus buccalis. In 1968 Rao has given the anatomy of Psammothuria ganapatii found in the interstitial sands of Waltair. Mary Bai and Ramanathan (1977) have published the internal anatomy of Holothuria cinerascens collected from Kanyakumari Coast. In 1980, Mary Bai has published a monograph on Holothuria scabra with anatomy and histology. Baskaran and Sathyamoorthy (1989) observed morphological characters and abundance of Holothuria atra from the lagoon of Krusadi Island.

In India, little attention has been made on the reproductive biology and physiology of echinoderms. With reference to sea-cucumbers, Krishnaswamy and Krishnan (1967) have worked on the reproductive cycles of Holothuria scabra and found that it breeds twice in an year - one in July and again in October. Histochemical studies on reproduction and nutritional cycles of Holothuria scabra shows that protein and lipids were found to be important storage material for utilization during development (Krishnan, 1968). Biochemical and cytochemical observations of the nucleic acids in the gonads of Holothuria scabra have been estimated by Krishnan (1976). Jayasree and Bhavanarayana (1989) worked on the reproduction in Holothuria leucospilota from Anjuna, Goa. Baskar (1989) studied morphology, food and feeding, reproductive biology and growth of Holothuria scabra from the Gulf of Mannar.

With reference to Beche-de-mer industry, Hornell (1917) traced the history and revival of the Beche-de-mer industry in India. James (1973 a) has estimated commercial value of sea-cucumbers and feasibility for improving this product from Indian regions. Jacob (1973) has given a description of Holothuria scabra which support the Beche-de-mer industry of India. The Beche-de-mer fishery, seasons, collection centres, curing practices, proximate composition, percentage loss in curing, export trade and quality inspection was also described by many authors (Shenoy, 1977; Durairaj, 1982; Durairaj et al., 1984; James, 1994). An account of availability of commercial grade species and present status of Beche-de-mer industry of Andaman and Nicobar Islands have been reported by James (1983, 1994) and Soota et al. (1983). James (1986 a) has described methods for the improvement of the quality of Beche-de-mer. A National workshop on Beche-de-mer was conducted in February 1989 and papers on various aspects were presented. In fact the literature available on the ecology of holothurians are very few. Rao (1968, 1973) has given an account of autoecology of the holothurians Psammothuria ganapatii and Patinapta ooplax from Waltair and Andamans respectively. Daniel and Halder (1974) reported that the prevailing ocean currents also influence the dispersal of sea-cucumber to some extent in India sea.

REVIEW OF LITERATURE FROM LAKSHADWEEP

The Lakshadweep consisting of a number of islands, islets and submerged coral reef lie scattered in the Arabian Sea on the west of India. Since these islands are geographically isolated, there have been lot of living resources in and around the islands which is holding great potential for exploitation. But from a resource point of view, the Lakshadweep Archipelago has not yet been surveyed systematically till now.

The Cambridge University Expedition under the leadership of Prof. J. Stanley Gardiner was a significant event in the marine biological and oceanographic research and the results were reported in two volumes of "Fauna and geography of the Maldive and Laccadive Archipelagoes (1903-1906)". These two volumes are giving some general accounts of holothurian fauna. Koehler and Vaney (1905, 1908, 1910) reported 18 species from deep sea, 8 species from shallow water in which Actinopyga mauritiana is only economically important species. Based on the Gardiner's collection Pearson (1913, 1914) reported the holothurian component from Lakshadweep. Burton (1940) observed several species of holothurians in every pool in Chetlat Island, while Holothuria atra, Holothuria scabra, Actinopyga mauritiana and Actinopyga echinites are most abundant species in Minicoy Island. Later, James (1969) recorded about 40 species from various islands of Lakshadweep, while Nagabhushanam and Rao (1972) gave a list of 13 species from various ecological niches of the Minicoy Island. Recently Daniel and Halder (1974) dealt twenty three species of shallow-water holothurian from Lakshadweep. Mukhopadhyay and Samantha (1983) enumerated taxonomical characters of twelve species of holothurian from the islands of Androth, Kalpeni and Minicoy. Rao and Misra (1985) recorded the holothurian Leptosynapta species from Lakshadweep. The CMFRI Bulletin 43 by James (1989) on "Echinoderms of Lakshadweep and their zoogeography" is giving compact information on taxonomic characters, key for identification, abundance and distribution of 26 species of sea-cucumbers available at Lakshadweep Islands.

However, little information is available on Beche-de-mer industry in Lakshadweep. Hornell (1917) reported that when he visited Kiltan Island in 1908 he saw small quanitities of Beche-de-mer being processed from three species *Holothuria nobilis*, *Bohadschia argus* and *Actinopyga mauritiana*. He also noticed that the method of curing was different compared to that of Palk Bay. Ayyangar (1922) noted that the Beche-de-mer industry which was a success for some times in Androth, had been abandoned due to an epidemic of cholera. James (1973, 1986) pointed out that the Lakshadweep Islands possess highly potential and commercially valuable sea-cucumbers.

The present investigation by the candidate deals with Taxonomy, Morphometry, Biometry, Food and Feeding, Reproductive Biology, Age and growth, Seasonal abundance and Ecology of sea-cucumbers of the Minicoy Island and Beche-de-mer industry.

MATERIALS AND METHODS

MATERIALS AND METHODS

Period of Study

The present work was carried out for two years from January 1990 to December 1991 at the Minicoy Island, Union Territory of Lakshadweep, stationing at the Minicoy Research Centre of CMFRI.

Geographical Location of Study Area

The Lakshadweep otherwise known as "Coral Paradise" of India consists of 36 islands and lies between 08°00 - 12°30' N and 70°00' and 74°00' E in the Arabian Sea (Jones and Kumaran, 1980; Jones, 1986; James, 1989) (Fig. 1). Among these islands, 27 islands are irregular with scattered reefs and 9 of them are atoll. These all islands cover a total geographical area of 32 sq.km. Out of these only ten islands are inhabitated (Jones, 1986). Among all islands, Minicoy atoll is the southern most situated at 08°15'30" - 08°20'N and 73°00' - 73°05'E (Admirality Chart 2006, 1962).

The Minicoy Island is semi-circular and the approximate length between two extreme points in a straight line is 8.536 km with 0.990 km width at the broadest point (Admirality Chart 2006, 1962). The lagoon is 9.45 km long and 4.57 km wide with an average depth of approximately 1.55 m and maximum tidal amplitude of 1.57m (Untawale and Jagtap, 1984). The southeast region of Minicoy Atoll is rocky and subjected to strong wave action that have formed gullies. The northeast region is rich in branching corals and protected from strong wave action by harder reef. Boat channel NERUMAGU CHANNEL of this island giving safe access and anchorage to vessels of about 3 m depth (Fig. 2). Hundred years old light house is landmark of this island while many of the Central Government Offices including Research Centre of Central Marine Fisheries Research Institute and

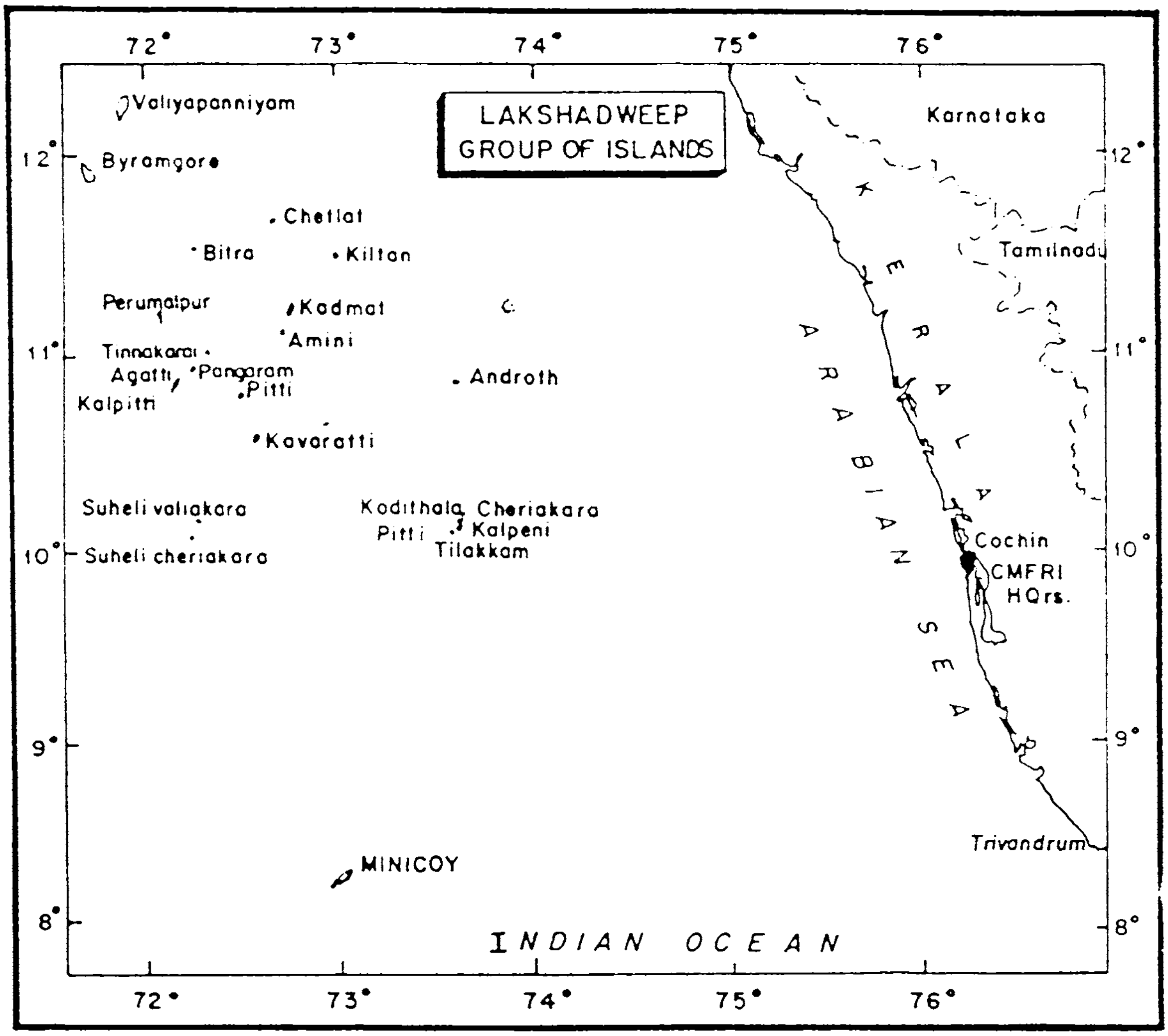


Fig.1. Distribution of Lakshadweep group of Islands in the Laccadive Sea.

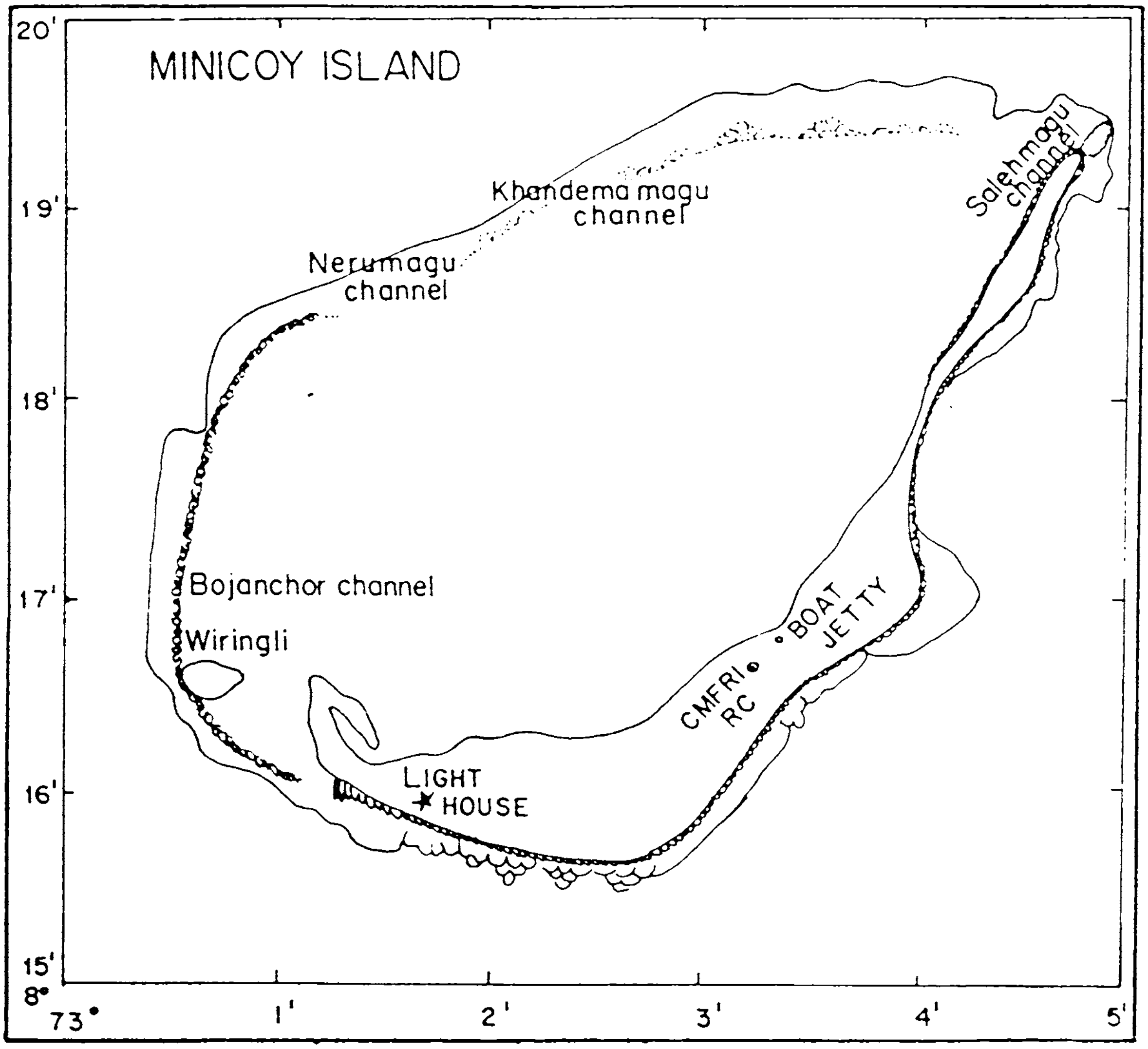


Fig.2. Topography and geography of the Minicoy Island.

Navodaya Vidhyalaya Sangathan is contributing major service to this island people. The two most important items coming under the flora and fauna of the island are the coconut and fishes which form the mainstay of the people of this island. The nearest city on the mainland is Cochin which is covering a distance of 398 km from Minicoy with frequent transport and shipping facilities.

Preliminary General Survey

On reaching in January 1990, a preliminary general survey was undertaken to record the visually distinct benthic species, levels and cover of corals and algae, the nature of the reef substrate and the aesthetic appeal of the area as suggested by Kenchington et al. (1988), particularly for sea-cucumber to assess their distribution and abundance in relation to their habitat and for the selection of species of holothurians for biological studies. In the lagoon, tow method is prevailing in the island and popular to collect live-baits for tuna fishing (Plate I A) was adapted for sampling of holothurians. In this method, the divers holding the rope behind the boat with accessary equipments such as mask, snorkle, etc., survey the area whether the specimens are avialable (Plate I B). In reef area, simply walked along the reef flat and collected all visibly available specimens.

Sampling Stations

Based on the general survey conducted in the reef and lagoon, 12 sampling stations were fixed (Fig. 3), of which 9 stations from the lagoon and 3 from reef flat for collecting biological and hydrological samples. The plastic floats with aluminium paints and nylon rope were anchored in each station for easy identification and regular collections throughout the study period. All the 12 stations are briefly described here. The location of stations are mainly based on the bottom topography, nature of bottom and floral and

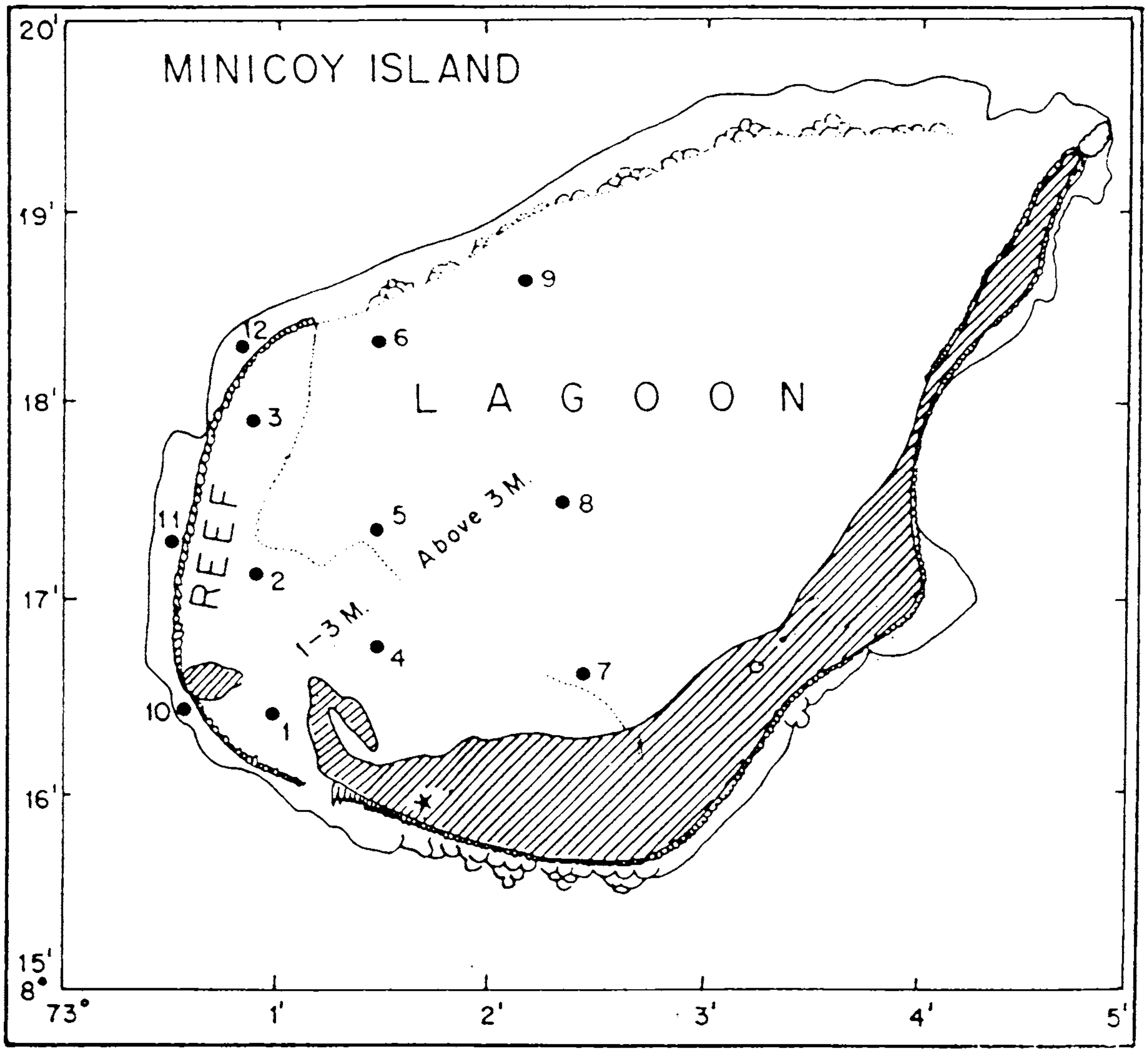


Fig.3. Sampling stations for present work at Minicoy Island.

PLATE I A. Live-bait collection in the lagoon of Minicoy Island by fisherman community using tow method.

PLATE I B. Sea-cucumber collection and survey in the lagoon of Minicoy Island by the cadidate using tow method.

faunastic composition as suggested by Bakus (1989). The situation or peculiarity of each station are also provided and are called as Mangrove point, Dead Coral point, Reef point, Artificial Reef point, Seaweed point, Nerumagu Channel point, Sea-grass point, Light-buoy point, Khandema Magu Channel point, Wrinkle point, Linckia point and Anchor point (Plate II A, B).

Station 1 - Mangrove point : This station is fixed at the southwest corner in the lagoon 1.5 km from shore between Wrinkle Island and Helipad point. Substratum is sandy-rocky with scattered boulders. Mostly water is shallow with approximate depth of 0.5 m in low tide and 2.5 m in high tide. This station is with full of Mangrove plants, hence it is called Mangrove point. The most abundant algae in this station belong to Turbinaria spp. and Padina spp.

Station 2 - Dead Coral point : This station is near the Bojanchor Channel with a distance of 1.5 km from station 1. Substratum is rocky and sandy and this area is fully covered with dead corals. This station is densely populated with seaweeds such as Chetomorpha spp., Turbinaria spp. and Padina spp. Depth at this station is same as station 1.

Station 3 - Reef point : This station is situated 1.5 km north of station 2. Substratum is similar to that at station 2 and with full of coralline boulders. In this area, starfish Linckia spp. and algae Turbinaria spp. are abundant. The depth is 1 m in low tide and 3.5 m in high tide.

Station 4 - Artificial Reef point : This station is located northeast to station 1 and southeast of station 2 with a distance 2 km from station 1. In this station the bottom is totally exposed during low tide and muddy. CMFRI is growing the corals artificially providing some artificial substratum.

PLATE II A. Showing major collection sites for Holothuria nobilis at Minicoy Lagoon.

PLATE II B. Showing major collection sites for Actinopyga mauritiana at Minicoy Reef Flat.

Station 5 - Seaweed point : This station is 1 km north of station 4 and just opposite to Bojanchor Channel. In this station always water current and tidal fluctuation are prevailing. Substratum is sandy-muddy with several coral formation. A thick cushion of seaweeds mainly Padina spp. Acanthophora spp. and Gracilaria spp. is seen in this area. Depth at this station is 2 m in low tide and 5 m in high tide.

Station 6 - Nerumagu Channel point : This station is 1.5 km north of station 5 and nearer to Nerumagu Channel. Substratum is sandy and rocky with dead corals and occasionally with new coral formation. Starfish Linckia sp., bivalve Tridacana sp. and seaweed Turbinaria sp. are abundant in this station. Depth is 1 m in low tide and 3.5 m in high tide.

Station 7 - Sea-grass point : This station is situated exactly east of station 4 at a distance 2.5 km and north of widest point of the land area of Minicoy Island. Substratum is muddy to sandy. The vegetation consists mainly of seagrass Thalassia hemprichii, Halodule uninervis and Halophila ovalis and green and brown algae forming a thick cushion like structure.

Station 8 - Light-buoy point : This station is almost centre of the lagoon and is north of station 7 at a distance of 1.5 km. Substratum is sandy forming a sand-bar and changing to sandy-rocky with few corals. Vegetation is less compared to other stations. Depth at the station is 3 m during low tide and more than 5 m during high tide.

Station 9 - Khandema Magu Channel point : This station is near to Khandema Magu Channel with a distance of approximately 2 km from station 8. Substratum mostly composed of sand changing to sandy-rocky with few coral formation. Sargassam sp. and Turbinaria sp. are abundant in this area.

Station 10 - Wrinkle point : This station is on the reef side near the Wrinkle Island exactly west of station 1. This station is characterised with lot of coral boulders. Dense population of *Turbinaria* sp. in this area was noticed. During low tide, this area is exposed for more than 3 hours.

Station 11 - Linckia point : This station is near to Bojanchor Channel. Distance from station 10 is 2 km. This area is covered with high densities of small to medium boulders. This area always submerged in water. Exposure time during low tide 1 hour. Starfish *Linckia* sp. are dominant in this area and seaweeds are sparsely populated.

Station 12 - Anchor point : This station is 3 km from station 11 with full of small, medium and big coralline boulders. The substratum was sandy at times. Less vegetation was noticed compared to the other two reef stations.

Sampling Frequencies

Collection of holothurians and water samples were made during day and night preferably during low tide, but at times during high tide also. Immediately on collection at the site, species identification was made by natural colours and other external morphology of tentacles, tubercles, pedicels, tube-feet, etc. and the same was confirmed at the laboratory by detailed studies. The samples were measured for morphometry and dissected for biological analysis and preserved for future references. The water samples were fixed at the site with reagents for O_2 estimation by Winkler method at the laboratory. Salinity was also analysed at the laboratory. Temperature recorded by a centigrade Thermometer at the sampling site. Sediments were collected for analysis of sand particle size, organic carbon and faunastic composition at the laboratory. *Holothuria nobilis* and *Actinopyga mauritiana* only were studied in detail for biology and ecology as they are abundant and major species of Minicoy Island.

The sampling was done once in a fortnight from all the 12 stations from January 1990 to 1991 for taxonomy, biology and ecology. For quantitative and seasonal abundance of major species of holothurians were sampled by quadrate method once in three months from all 12 sites viz. 6 sectors in the lagoon and 6 sectors on the reef flat shown in Fig. 4. The species were identified and enumerated. For sampling most of the time CMFRI fibre glass boat 'NILAMAGI' fitted with Yamaha 15 HP out-board engine, was used and sometimes private boat was also engaged for collecting the samples especially in deeper area.

Sample Collection

Specimens from the lagoon were collected by skin diving, burrowing forms were taken out with the help of a shovel and iron rods, and the rest free living animals were easily hand picked.

Preservation : To preserve the holothurian, a method by Rowe and Doty (1977) was adopted. Based on this, animals were carefully brought to the laboratory from the field and relaxed them in 50 litres aquarium tank for 30 minutes. Magnesium chloride was added in the seawater as required by its size to anaesthetise the animals. The time and the amount of anaesthetic needed for stupefying this animais depends upon the size of the live-specimen. Extreme care was taken while handling the live specimens for narcotization, which render the observation of the gross anatomy difficult. After narcotization the animals were injected with 95 % denatured alcohol and submerged the whole animal in the alchohol. After about a week the specimens were transferred into 70 % denatured alcohol for permanent storage and labelled with proper notes. Formalin was never used for preservation since this preservative dissolves tiny spicules, which are vital parts for species identification to the generic and species level.

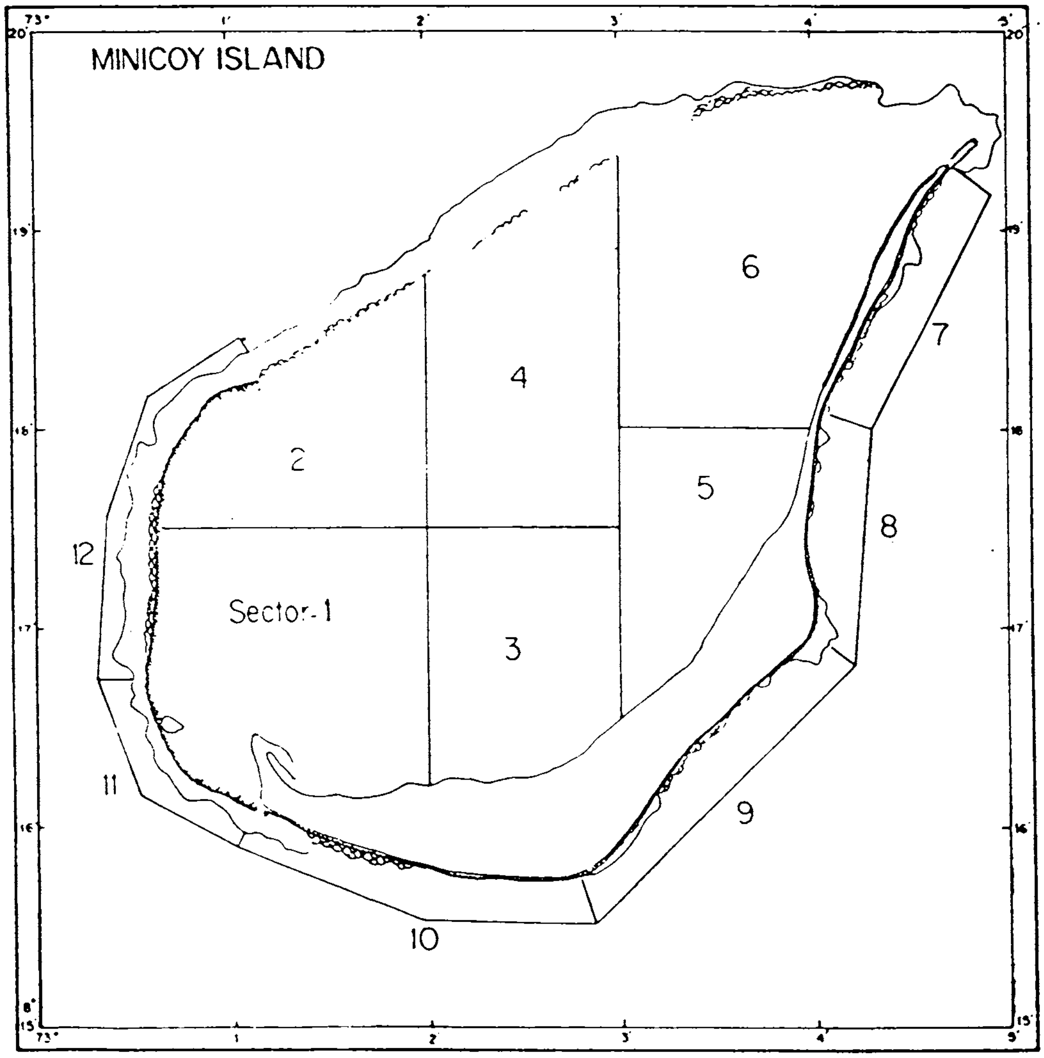


Fig. 4. Sampling sectors for quantitative and seasonal abundance of available species of holothurians at Minicoy Island.

Identification

For identification of holothurians, various features including the natural colour at the sampling site and external morphological characters, number of tentacles, distribution of tube-feet and papillae, presence or absence of respiratory trees and Cuvierian organs, calcarious spicules found in various parts of the body were considered (Rowe and Doty, 1977). For analysis of spicules, a small piece of body-wall from mid-dorsal and mid-ventral region was cut and put in Embryo-cup with a drop of 10 % sodium hypochloride to dissolve the tissues. After the tissue was dissolved, washed twice with distilled water and spicules were transferred by a dropper to a microslide and covered with a cover glass for observation under microscope with 40 x objective lens and 10 x eyepiece magnification. Ocular micrometer was used to calibrate the measurement of the spicules. Spicules of all the sixteen species of sea-cucumbers were observed and necessary clear drawings were made and presented.

For internal features, the specimens were opened by a longitudinal incision from anterior to posterior end. The flaps were than pinned down to expose all the organs and noticed the internal anatomy of the animals.

The different techniques adapted for biology, ecology and seasonal quantitative abundance, etc. and statistical formula and methodology are described under respective chapters in the Thesis.

CHAPTER 1

CHAPTER I : TAXONOMY AND ANATOMY OF SEA-CUCUMBERS FROM MINICOY ISLAND AND GEOGRAPHICAL DISTRIBUTION

Before directly entering into the description of species, it is essential to review and discuss briefly the classification of Holothuria followed by different workers to evolve and adopt the most correct and suitable classification here.

Jacob Klein (1734) applied the name Echinodermata to only echinoids. In 1771, Bruguiere recognised echinoderms as a distinct group of invertebrates and separated from Mollusca as it was followed by Linnaeus (1758). In 1801, while Lamark greatly improved the classification of all invertebrates, he included the echinoderms under the Class Radiata and continued the echinoderms under one of the two orders in coelenterates till 1822. Cuvier (1817) made a modification in the classification of Animal Kingdom and recognised only four Classes namely Vertebrata, Mollusca, Articulata and Radiata, the last one consisting of echinoderms. Leuckart (1954) suggested that "the echinoderms must be regarded as a separate division of the Animal Kingdom, since their grade of structure is obviously higher than that of the coelenterates" and it was followed till the middle of nineteenth century. A fine historical account on the classification of echinoderms has been given by Hyman (1955) in her book "The invertebrates : Echinodermata".

According to available literature, Aristotle gave the name Cucumaria for holothurians and it was considered as animals belong to Class Echinodermata by Lamark (1801), which was previously under the various classes of animal group. Based on the available knowledge and information, Oken (1815) classified holothurians based on body shape. But Lamark (1816-1822) used the tentacles for identifying the various species. Brandt (1835) divided the holothurians into two family as Pedata (with podia) and Apodus (without podia). Afterwards Grube (1840) followed Oken and Lamark and separated the holothurian into two families based on tentacle structure as Aspidochirotae with peltate tentacles and Dendrochirotae with arborescent tentacles. In 1867, Selenka divided the holothurian into two separate orders based on anatomical characters and on the presence or absence of respiratory tree viz. Pneumophora (with respiratory tree) and Apneumona (without respiratory tree). Later Theel (1882, 1886) divided into two orders like Apoda and Pedata based on the presence or absence of tube-feet.

In fact, Ludwig (1889,1892) was able to classify the holothurians upto 6 families belong to two orders in the first time of holothurian taxonomy, based on the presence or absence of podia or of respiratory trees as follows:

Order 1. Actinopoda - Radial canals supplying tentacles and podia.

- A. with respiratory trees
  - (a) with podia
  - (b) without podia

    Family: Holothuriidae
    Cucumariidae
    Molpadiidae
- B. without respiratory trees
  - (a) with podia
  - (b) without podia

    Family: Elpidiidae
    Pelagothuriidae

Order 2. Paractinopoda - Neither radial canals nor podia, Tentacles supplied from circular canal.

Family: Synaptiidae

After this classification, Bather (1900) classified the Phylum Echinodermata into two Sub-phyla viz. Pelmatozoa and Eleutherozoa. In these Sub-phyla former one mainly consisted of fossil echinoderms, while the latter is mainly consisted of living echinoderms. Further, he also modified a little of Ludwig's (1889-1892) classification based on holothurian Phylogeny and family Synapatiidae of Ludwig belong to order Paractinopoda seems to be common with Molpadiidae of order Actinopoda and as follows:

Order 1. Actinopoda

Group 1. Family:	holothuriidae Elpidiidae Pelagothuriidae	Tentacles are more or less peltate and calcareous ring is radially symmetrical and of simple structure.
Group 2. Family:	Cucumariidae Molpadiidae	Tentacles are simple or branched, never peltate.

During the beginning to middle of this century the above mentioned classification has undergone dramatic changes by various taxonomist (Clark, 1907, 1922, 1924; Panning, 1929, 1935; Heding, 1928; Heding and Panning, 1954). In 1955, Hyman reviewed thoroughly and compiled all the earlier reports on taxonomy and she has given comprehensive classification based on the presence or absence of podia, tentacles and respiratory trees which is as follows:

Phylum : Echinodermata
Sub-phylum : Eleutherozoa
Class : Holothuroidea
Order : Aspidochirota
Family : Holothuriidae
Stichopodiidae
Order : Dendrochirota
Family : Cucumariidae
Phyllophoriidae
Order : Molpadonia
Family : Molpadiidae
Order : Apoda
Family : Synaptiidae
Chiridotiidae

However, later on, Hyman's classification also reviewed by various taxonomist particularly by Deichmann (1958), Pawson and Fell (1965) and Rowe (1969) following the new entry of some species in their collection and modified the classification upto sub-genus level.

In 1971, Clark and Rowe prepared a monograph of the shallow water Indo-West Pacific echinoderms. In this, they have thoroughly reviewed and compiled all the previous taxonomy of holothurians and presented compact classification which contain class, sub-class, order, family, genus, sub-genus and species for all available holothurians in these region till now. It seems this work is very useful and adoptable by the biginners who want to know basic knowledge of echinoderms especially holothurians.

In 1977, Rowe and Doty published a paper on shallow water holothurians of Guam with natural colour photos and also contain the general methodology for collection, preservation and identification of holothurian, key to the identification and systematic account of some holothurians. This information is readily assisting to the non-taxonomist to understand particularly about shallow-water species, in which economically important species of holothurians are available. Recently Pawson (1982) made upto-date taxonomy of holothurian of the world, based on his own work as well as from various reports. He mentioned that Class Holothuroidea comprises of 3 sub-classes viz. Dendrochirotacea, Aspidochirotacea and Apodacea; 6 orders viz. Dendrochirotida, Dactylochirotida, Aspidochirotida, Elasipodida, Apodida and Molpadiida; 25 families and more than 1200 species.

However, in the present study, the classification of Rowe and Doty (1977) is adopted, which mainly deals with shallow water holothurians and provides information collection, preservation, identification, etc. with excellent keys for identification. This helped very much to identify the holothurians of Minicoy Island.

MATERIALS AND METHODS

During the present study from January 1990 to December 1991 sixteen species of holothurians were collected from different habitats of lagoon and reef flat of Minicoy Island.

Various morphological characters such as body shape, colour, colour pattern, tentacle structure, presence of pedicels and anatomical characters viz. presence of calcareous ring, stone canal, haemal system, reproductive system and size and forms of microscopic spicules embedded in the body wall were used to identify all genera and species of holothurians.

CLASSIFIED LIST OF HOLOTHURIANS COLLECTED FROM MINICOY ISLAND

Class : HOLOTHUROIDEA De Blainville, 1834

Sub class : ASPIDOCHIROTACEA Grube, 1840

Order : ASPIDOCHIROTIDA Grube, 1840

Family : HOLOTHURIIDAE Ludwig, 1894

Genus : HOLOTHURIA Linnaeus, 1767

Sub genus: Halodeima Pearson, 1914

1. Holothuria (Halodeima) atra Jaeger, 1833

Sub genus: Microthele Brandt, 1835

2. Holothuria (Microthele) nobilis (Selenka, 1867)

Sub genus: Thymiosycia Pearson, 1914

3. Holothuria (Thymiosycia) hilla Lesson, 1830
4. Holothuria (Thymiosycia) impatiens (Forsskal,1775)

Sub genus: Semperothuria Deichmann, 1958

5. Holothuria (Semperothuria) cinerascens (Brandt, 1835)

Sub genus: Mertensiothuria Deichmann, 1958

6. Holothuria (Mertensiothuria) leucospilota (Brandt, 1835)

Sub genus: Cystipus Haacke, 1880

7. Holothuria (Cystipus) rigida (Selenka, 1867)

Genus: ACTINOPYGA Bronn, 1860

8. Actinopyga mauritiana (Quoy and Gaimard,1833)

9. Actinopyga miliaris (Quoy and Gaimard,1833)

Genus: BOHADSCHIA Jaeger, 1833

10. Bohadschia marmorata Jaeger, 1833

11. Bohadschia argus Jaeger, 1833

Family: STICHOPODIDAE Haeckel, 1896

Genus: THELENOTA Clark, 1921

12. Thelenota ananas (Jaeger, 1833)

Genus: STICHOPUS Brandt, 1835

13. Stichopus chloronotus Brandt, 1835

14. Stichopus variegatus Semper, 1868

Order: APODIDA Brandt, 1835

Family: SYNAPTIDAE Brumeister, 1837

Genus: SYNAPTA Eschscholtz, 1898

15. Synapta maculata (Chamisso and Eysenhardt,1821)

Genus: Euapta Ostergreu, 1898

16. Euapta godeffroyi (Semper, 1868)

DESCRIPTION OF THE SPECIES

Holothuria (Halodeima) atra Jaeger, 1833
(PL. III A & B, Fig. 5)

Holothuria atra Jaeger, 1833 : p. 22; Fisher, 1907 : p. 657; Deichmann, 1926 : p. 148; Domantay, 1954 : p. 339.

Holothuria (Halodeima) atra Pearson, 1914 : p. 170; Rowe, 1969 : p. 137; Geronimo, 1970 : p. 63; Clark and Rowe, 1971 : p. 176; Rowe and Doty, 1977 : p. 230; Mukhopadhyay and Samantha, 1983 : p. 302; Wainiya, 1988 : p. 101; James, 1980 : p. 124.

Holothuria (Holothuria) atra Panning, 1934 : p. 30.

Halodeima atra Panning, 1944 : p. 61; Cherbonnier, 1955 a: p. 77.

Ludwigothuria atra Deichmann, 1958 : p. 312; Acosta, 1969: p. 104.

Type locality : East Indies.

Materials : 44 animals examined - 24 males and 16 females. In four specimens no sex organs. Length 5.0 to 30.0 cm and weight 15 to 1200 gram.

Habitat : Found exposed on sandy areas of reef flats, sea-grass beds and lagoon at 3 m depth. Body always covering with sand particles.

PLATE III A. Holothuria (Halodeima) atra in natural habitat.

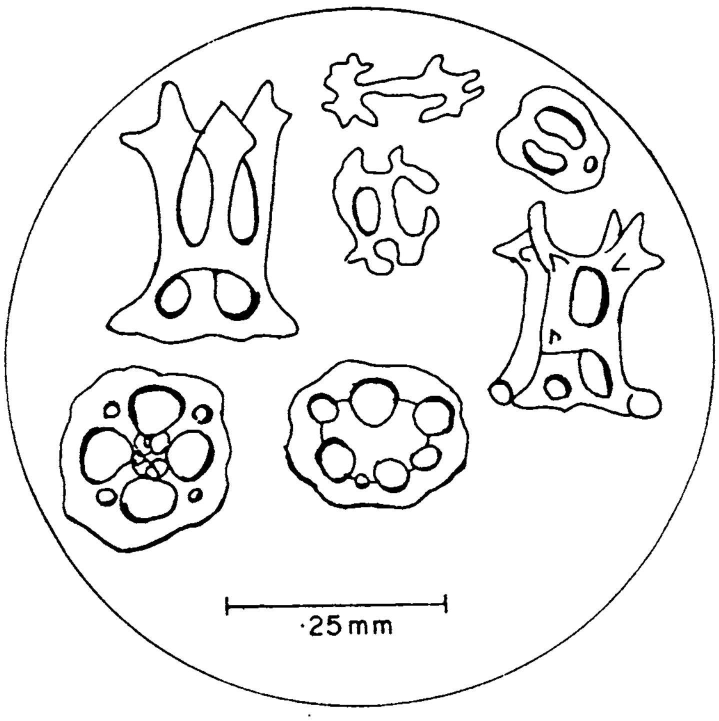


PLATE III B. Spicules of Holothuria (Halodeima) atra

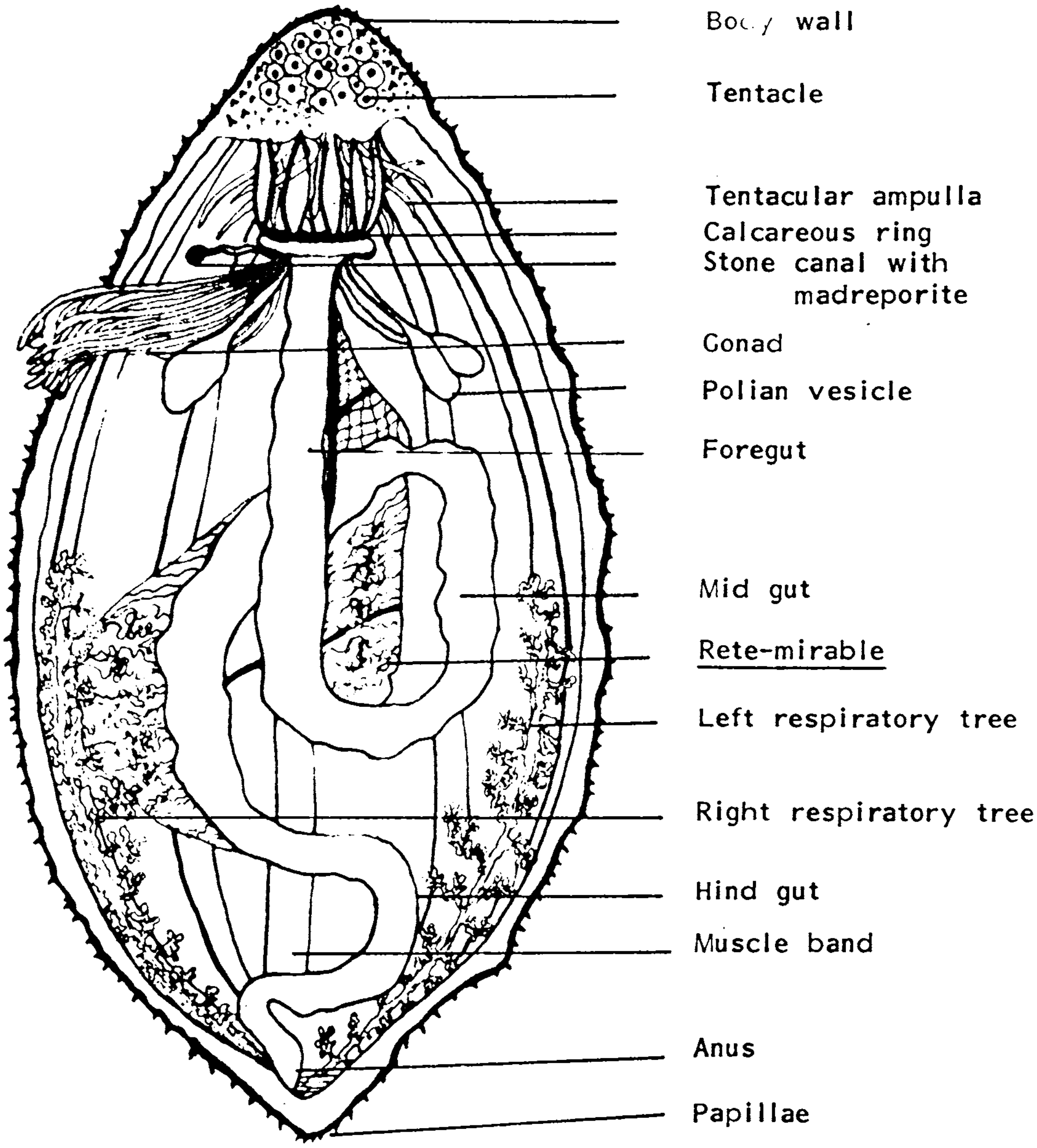


Fig.5. Anatomy of <u>Holothuria (Halodeima) atra</u>.

Morphology (Pl. III A) : Body cylindrical gently tapering on both ends, soft and thick body wall in normal condition and surface smooth and becomes spongy, when the specimen is contracted, colour uniformly black in adult and purplish black in younger ones on dorsal and ventral side slightly reddish tinge; dorsal side with a few prominent, widely spaced papillae; ventral surface covered with numerous podia with yellowish tips; black, peltate type tentacles twenty, arranged in double rows.

Spicules (Pl. III B) : Consisted of tables with reduced disc, spire of moderate hight depend upon animal size, button and rod absent.

Anatomy (Fig. 5) : Body wall approximately 0.5 cm thick; five calcareous rings; polian vesicles three; single madreporite; intestine extents from mouth to anus with three loops and it is semi transparent, foregut and midgut closely adhered with complex haemal vessels; respiratory trees one each on both sides extends upto middle of body. Rete mirable consists of complex entanglement of hundreds of tiny tubules on respiratory trees; gonad in a single tuft and thread-like. Animals undergo asexual reproduction by fission when they do not have favourable conditions. They are also known for sexual reproduction.

Distribution : Indo-West Pacific area and the Indian Ocean. The Gulf of Mannar, Palk Bay, Andaman & Nicobar Islands and Lakshadweep Islands in India.

Remarks : This species is not a commercially valuable due to its remarkable weight loss during processing.

Holothuria (Microthele) nobilis (Selenka, 1867)
(PL. IV A & B, Fig. 6)

Muelleria nobilis Selenka, 1867 : p. 313.

Actinopyga nobilis Fisher, 1907 : p. 647.

Microthele nobilis Domantay, 1953 b : p. 122; Clark and Davies, 1966 : p. 600; James, 1969 : p. 61; Nagabhushanam and Rao, 1972 : p. 291.

Holothuria (Microthele) nobilis Panning, 1929 : p. 131; Clark, 1946 : p. 302 ; Clark, 1952 : p. 203-214; Cherbonnier, 1963 : p. 80 ; Rowe, 1969 : p. 162; Clark and Rowe, 1971: p. 178; Clark and Davies, 1971 : p. 89-92; Geronimo, 1976 : p. 53; Rowe and Doty, 1977 : p. 231 ; Mukhopadhyay and Samanta, 1983 : p. 311; Clark, 1984 : p. 83-103; James, 1986 : p. 585; 1989 : p. 128.

Type locality : Zanzibar, Sandwich Islands.

Materials : 30 animals examined - 14 males and 16 females. Length 20.0 cm to 38.0 cm and weight 550 gram to 2200 gram.

Habitat : Found in the lagoon at 3 to 6 m depth. Body always covered with sand.

Morphology (Pl. IV A) : Body barrel shaped with arched dorsal and flat ventral sides; body wall thick, tough and massive; colour blackish brown mottled with white blotch; dorsal papillae not discernible or very minute, ventrally distinct sole with crowded pedicels; peltate tentacles twenty and grey in colour with black spot. The most distinguishing external feature is the presence of about six lateral teat-like projection known as papillae and hence the animal is called Teat-fish.

PLATE IV A. Holothuria (Microthele) nobilis

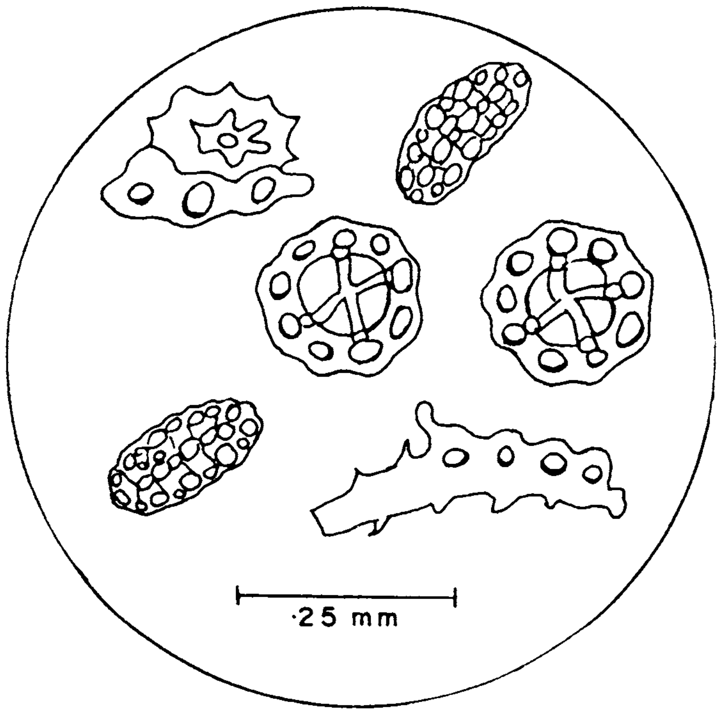


PLATE IV B. Spicules of Holothuria (Microthele) nobilis

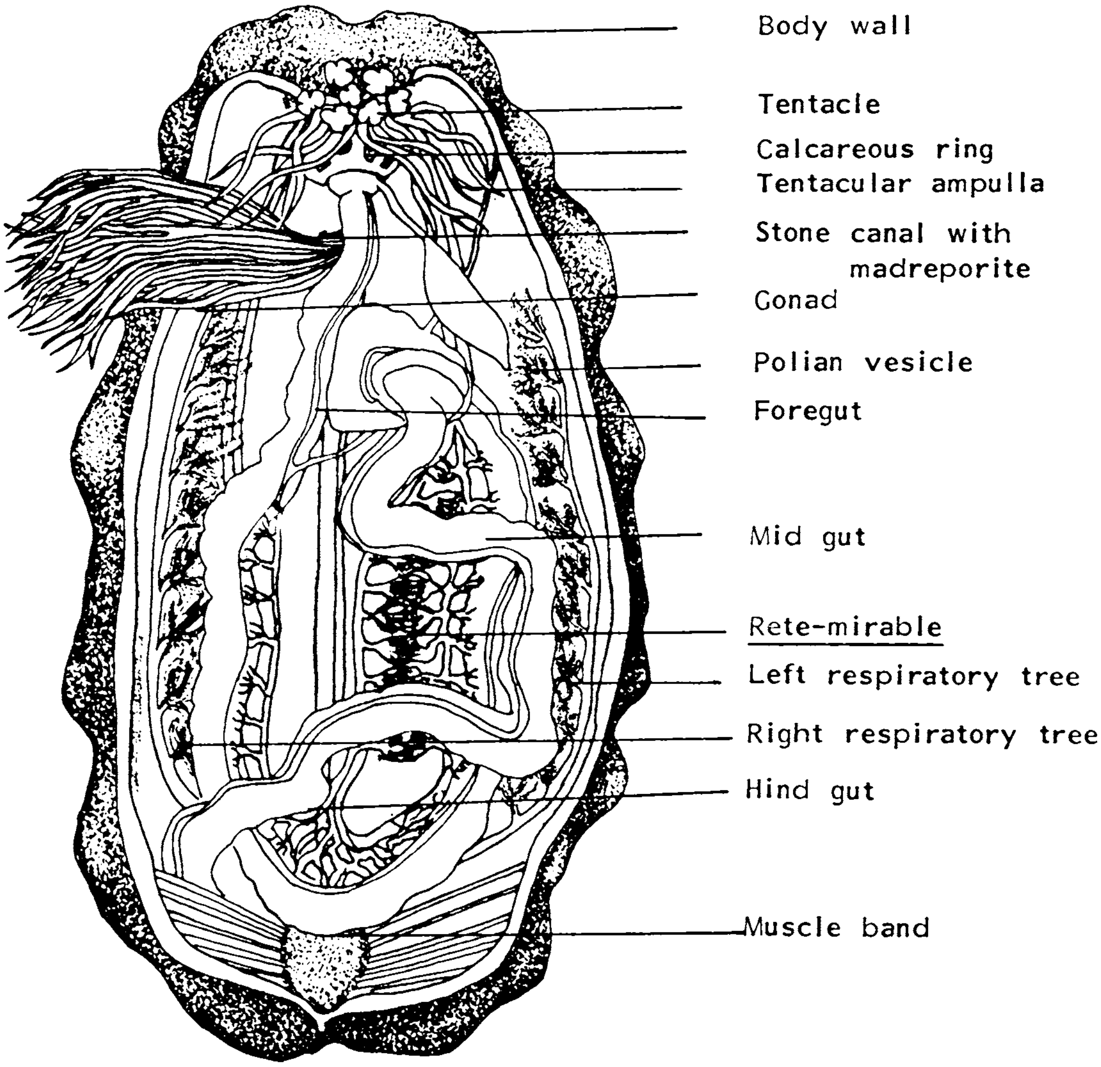


Fig.6. Anatomy of Holothuria (Microthele) nobilis

Spicules (Pl. IV B) : Spicules consisted of tables with smooth rim and top spire crowded with small tubules.

Anatomy (Fig. 6) : Body wall 0.5 to 1.0 cm thick and tough; five bulbous calcareous rings attached with five longitudinal muscular bands. Single polian vesicle with black spot all over the portion, stone canal single with madreporite; intestine very long with three loops, whitish in colour when filled with sand, light yellowish when empty; respiratory trees one each on both sides extends upto 2/3 of body upward and arises from cloaca, left respiratory tree is interlaced with the haemal system which is attached to the forward loop of the intestine; sexes are separate, gonad consists of single tuft of about 25 tubules and attached to the dorsal mesentery through which the gonoduct passes; strong muscle fibres present around cloacal chamber.

Distribution : Throughout the tropical Indo-West Pacific area and the Indian Ocean, where the coral reef islands like Lakshadweep and Maldives are situated.

Remarks : Since the body wall is thick and tough, this species is having good export market.

Holothuria nobilis could be identified easily by its 'teat'-like lateral dermal projection which is characteristic feature of this species.

Conand (1990) reported two groups - one with Black colour and the another white in colour. Cherbonnier (1980) stated that the species with fully black colour tegument with Cuvierian tubule is Holothuria nobilis, while the other with white to grey colour tegument and without any Cuvierian tubule is Holothuria fuscogilva. This morphological identification slightly varies in the present observation. Fresh H. nobilis observed in the present study shows black and brown batches and without any Cuvierian tubules and not with fully black tegument. This variation may probably be related to localities from where they were obtained. Sivickis and Domantay (1923) found that the species obtained from different environmental condition effect the colour of the animal. Bakus (1973) reported that the natural colouration of certain sea-cucumber may be altered by their habit of covering the body with foreign objects such as sand or algae and it is interesting to study the adaptive advantages of colour in coral reef holothurians. The other body form of this species generally agree with the observations of Tan Tiu (1981), James (1989) and Conand (1990).

Holothuria (Thymiosycia) hilla Lesson, 1830

(PL. V A & B, Fig. 7)

Holothuria hilla Lesson, 1830 : p. 226; Cherbonnier, 1951 : p. 532; Clark and Rowe, 1971 : p. 126-128.

Holothuria monacaria Koehler and Vaney, 1908 : p. 11; Panning, 1934 : p. 69; Clark and Davies, 1966 : p. 603.

Holothuria gyrifer Domantay, 1954 : p. 343.

Brandtothuria gyrifer Deichmann, 1958 : p. 291.

Holothuria (Thymiosycia) hilla Rowe, 1969 : p. 147; Clark and Rowe, 1971 : p. 178; Rowe and Doty, 1977 : p. 232; Mukhopadhyay and Samanta, 1983 : p. 307; James, 1986 : p. 585; 1989 : p. 126.

Type locality : South Pacific Islands.

Materials : 20 animals examined - 12 males and 8 females. Length 8.0 to 16.0 cm and weight 12 to 45 gram.

PLATE V A. <u>Holothuria</u> <u>(Thymiosycia)</u> <u>hilla</u>

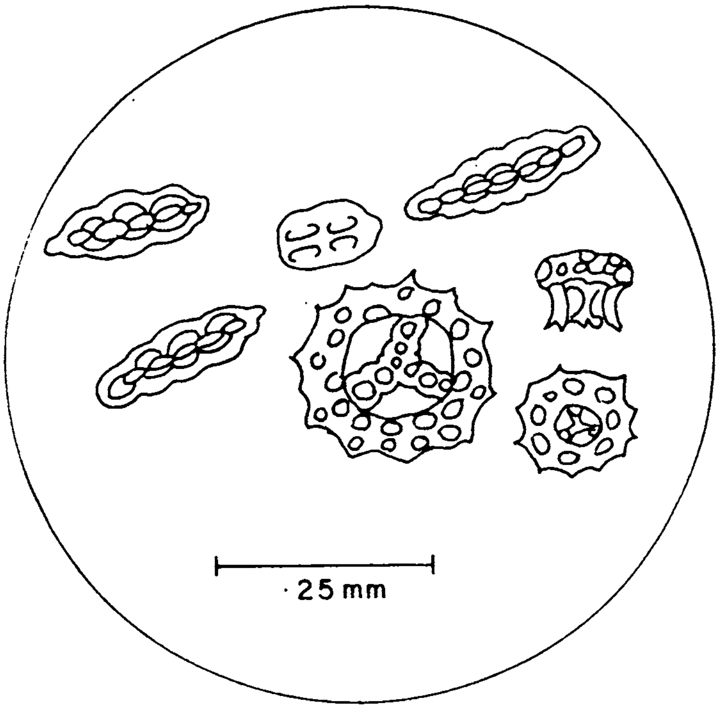


PLATE V B. Spicules of <u>Holothuria</u> <u>(Thymiosycia)</u> <u>hilla</u>

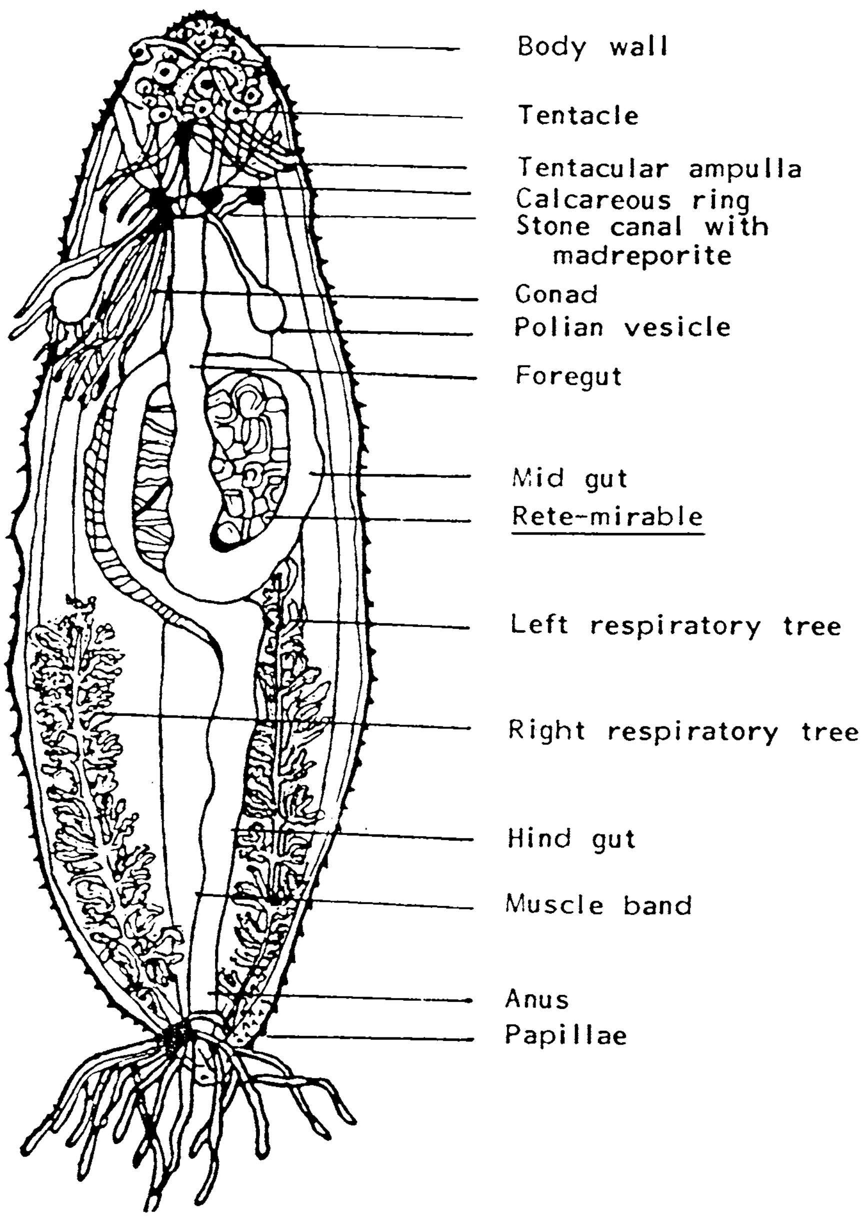


Fig.7. Anatomy of *Holothuria (Thymiosycia) hilla*.

Habitat : Found under coralline rocks and boulders at reef flat.

Morphology (Pl. V A) : Body vermiform, neither thick nor soft and gritty; tapering equally towards each extremity; colour generally rich brown and with light green in environmental water. Sometimes dorsal side more darker than ventral; papillae and pedicles yellow in colour arranged irregularly on whole body and they cluster near oral tentacles and anus region; eighteen tentacles, peltate, light greenish in colour.

Spicules (Pl. V B) : Spicules with tables and buttons with 3 to 5 pairs of holes.

Anatomy (Fig. 7) : Body wall 0.2 cm thick; five calcareous rings; two polian vesicles one on either side, single dorsal stone canal present; intestine comparatively thin, transparent and extends to anus with two loops, intestine filled with fine sediment particles; respiratory trees one each on both sides; haemal vessels attached with ventral side of midportion of intestine; sexes separate, single tuft of gonads freely lying in the body cavity; presence of Cuvierian organ characteristic.

Distribution : Throughout the tropical Indo-Pacific area and the Indian Ocean. Andaman & Nicobar Islands, Gulf of Mannar, Palk Bay and Lakshadweep Islands.

Remarks : Since the body wall is very thin, this species is not of commercially important.

Holothuria (Thymiosycia) impatiens (Forskal, 1775)
(PL. VI A & B, Fig. 8)

Fistularia impatiens Forsskal, 1775 : p. 121.

Holothuria (Holothuria) impatiens Panning, 1935 : p. 86.

PLATE VI A. <u>Holothuria (Thymiosycia) impatiens</u>

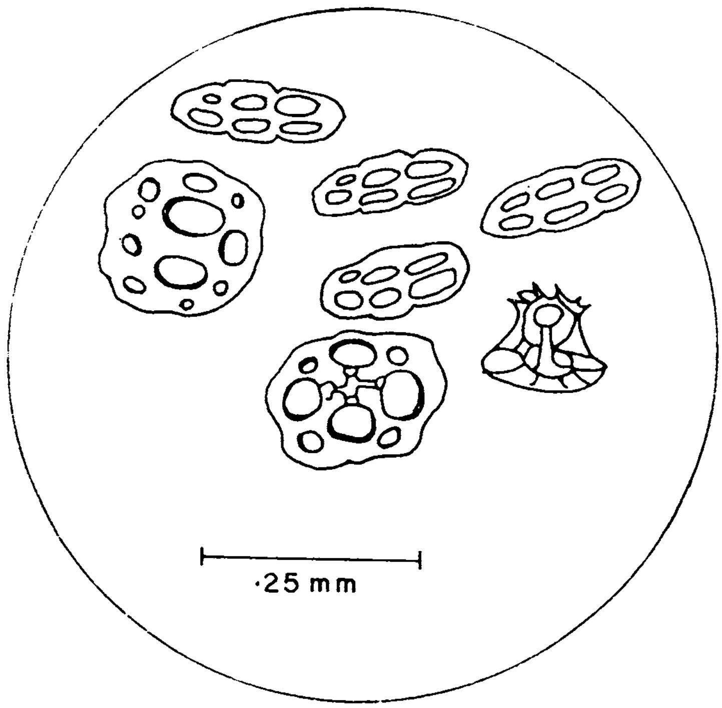


PLATE VI B. Spicules of <u>Holothuria (Thymiosycia) impatiens</u>

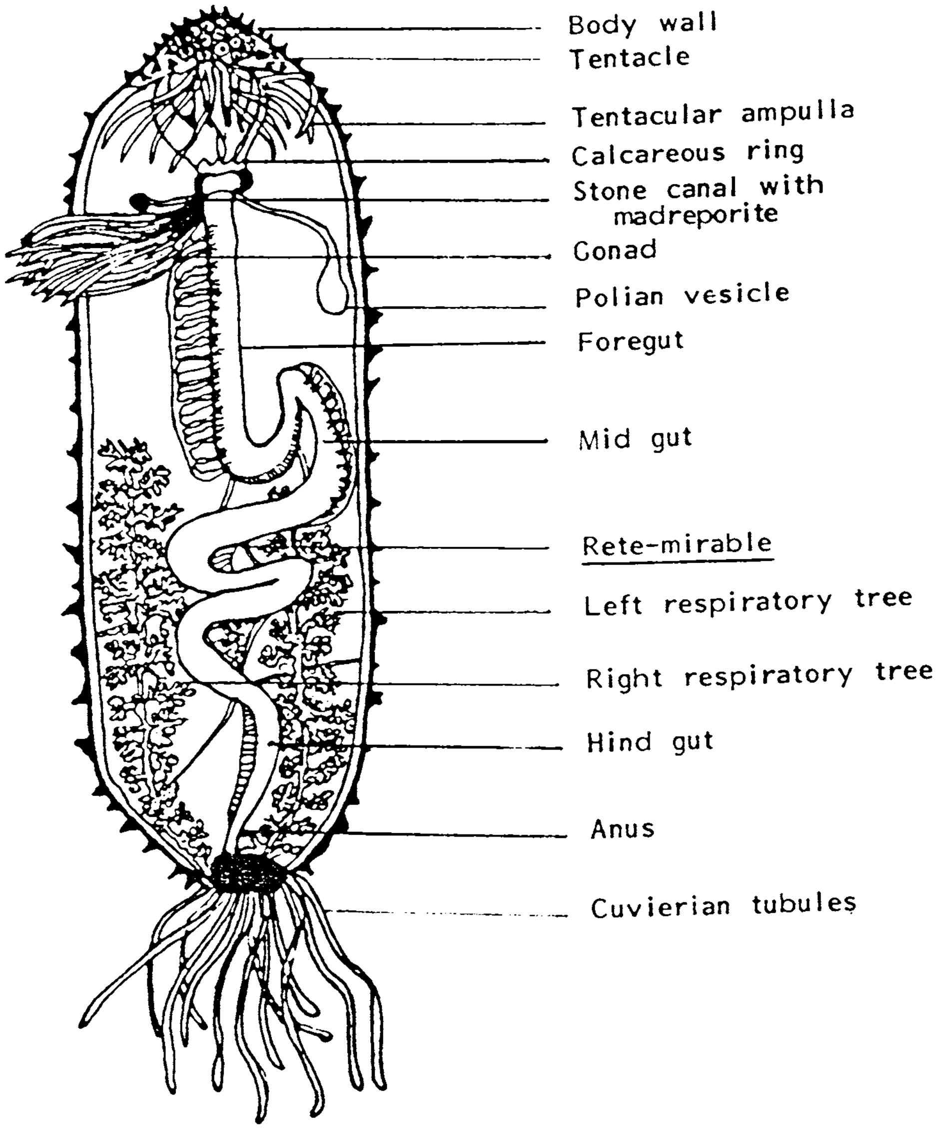


Fig.8. Anatomy of Holothuria (Thymiosycia) impatiens.

Holothuria impatiens Domantay, 1954 : p. 344; James, 1969 : p. 61; Nagabhushanam and Rao, 1972 : p. 290.

Holothuria (Thymiosycia) impatients Pearson, 1914 : p. 171; Boone, 1933 : p. 155-156; Rowe, 1969 : p. 145; Clark and Rowe, 1971 : p. 178; Ceronimo, 1976 : p. 46; Rowe and Doty, 1977 : p. 233; Elanganayagam, Ganesalingam and Sachithananantham, 1981 : p. 44 ; Mukhopadhyay and Samanta, 1983 : p. 307; Soota, Mukhopadhyay and Samanta, 1983 : p. 514; James, 1989 : p. 125-126.

Type locality : Red Sea.

Materials : 20 animals - 7 males and 13 females were examined. Length 4.0 to 13.0 cm and weight 8 to 120 gram.

Habitat : Found under coral rocks and water pools covered with brown algae (Turbinaria sp.)

Morphology (Pl. VI A) : Body cylindrical and gritty to touch; colour light to dark brown with white papillae irregularly scattered over the dorsal and ventral surface of the body; tentacles twenty, peltate type, light brown colour; papillae more around tentacular collar region; anus guarded by a circle of anal papillae.

Spicules (Pl. VI B) : Spicules consisted of tables, buttons and rods. Tables with six smooth holes, rods 3 to 4 lobed at ends.

Anatomy (Fig. 8) : Body wall 0.2 cm thin; five hard calcareous rings, single polian vesicle with bulbous end and single stone canal; intestine with two loops and filled with coral sand; haemal systems well developed; respiratory tree well developed one each on both sides and extends upto middle of body; sexes separate, single tuft of gonad on left side of the dorsal mesentery. Cuvierian tubules present, unbranched and in a bundle.

Distribution : Throughout the Indo-Pacific, Atlantic Ocean and Indian Ocean. Andaman & Nicobar Islands and Lakshadweep Islands.

Remarks : Not commercially important.

Holothuria (Semperothuria) cinerascens (Brandt, 1835)
(PL. VII A & B, Fig. 9)

Stichopus (Cymnochirota) cinerascens Brandt, 1835 : p. 51.

Holothuria cinerascens Pearson, 1913 : p. 64; Panning, 1934 : p. 37; Domantay, 1954 : p. 340; James, 1969 : p. 61.

Holothuria (Semperothuria) cinerascens Rowe, 1969 : p. 135; Clark and Rowe, 1971 : p. 178; Rowe and Doty, 1977 : p. 230; Mukhopadhyay and Samanta, 1983 : p. 302; James, 1986 : p. 583; 1989 : p. 124.

Type locality : Japan Coast.

Materials : 28 animals examined - 16 males and 12 females. Length 4.0 to 18.0 cm and weight 8 to 40 gram.

Habitat : Found under rocks near to wave breaking zone. Body buried with tentacles exposed.

Morphology (Pl. VII A) : Body thick and elongately cylindrical, both ends not very much tapering, dark brown or mottled black with orange red longitudinally elongated stripes in adult specimens, young specimens do not have longitudinal stripes; few papillae scattered

PLATE VII A. Holothuria (Semperothuria) cinerascens

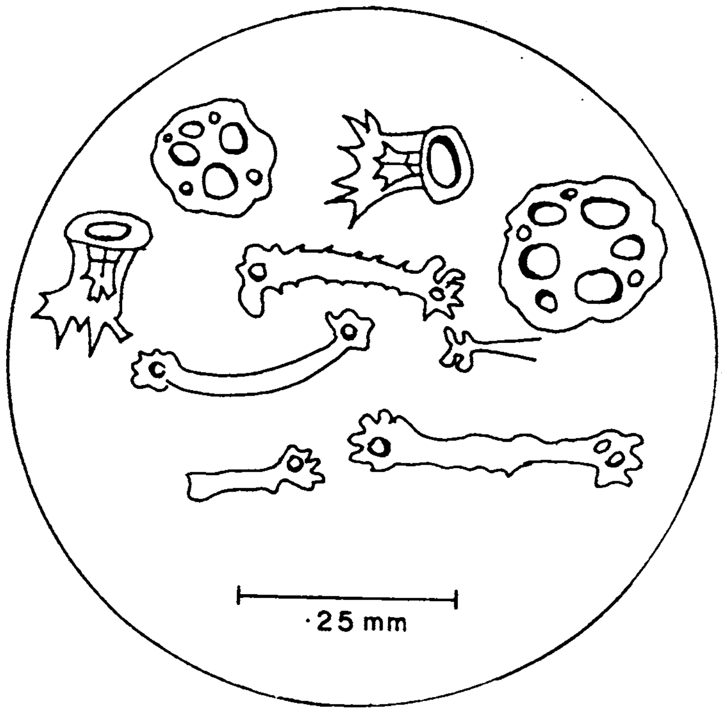


PLATE VII B. Spicules of Holothuria (Semperothuria) cinerascens

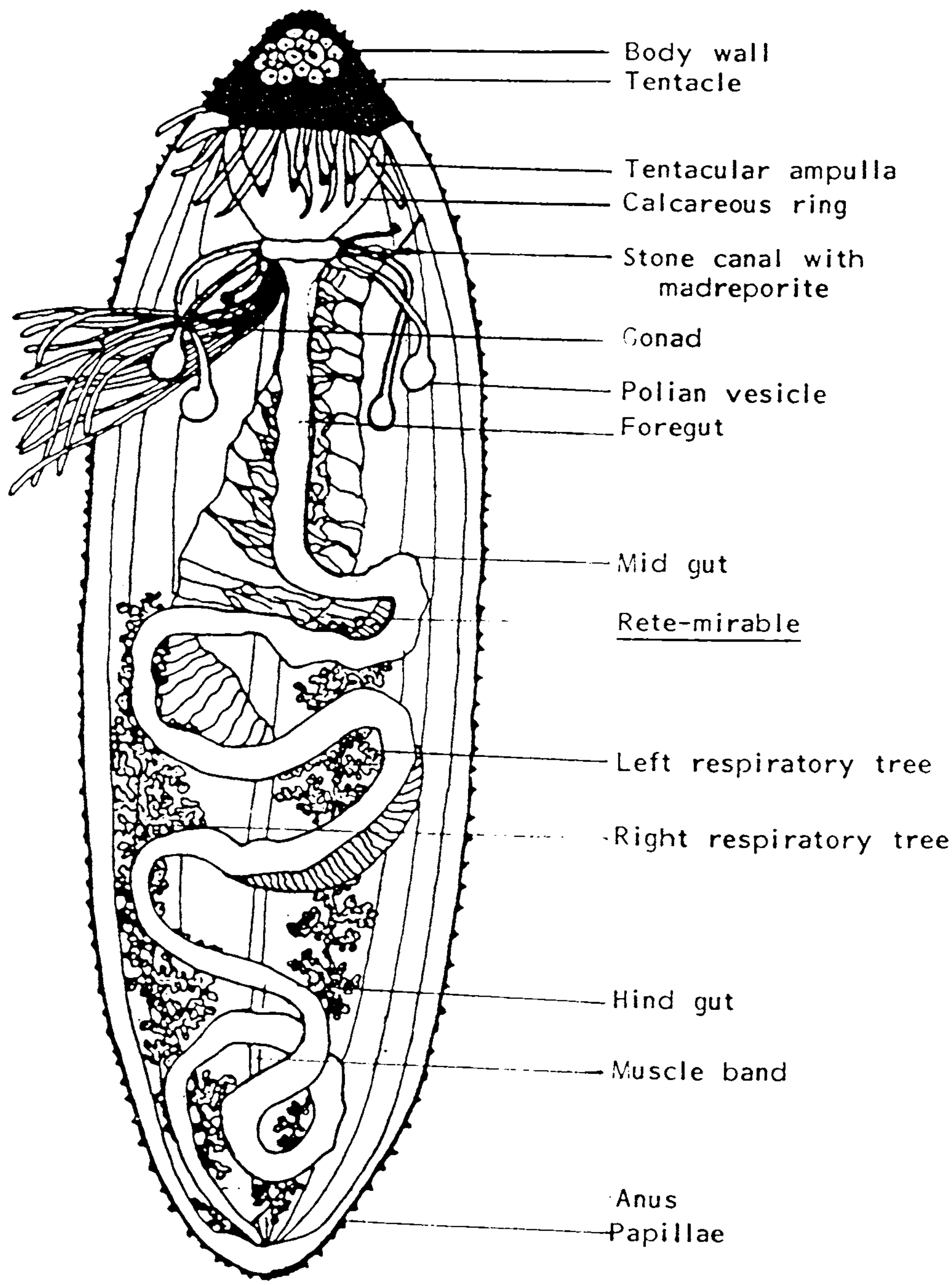


Fig.9. Anatomy of <u>Holothuria</u>(<u>Semperothuria</u>) <u>cinerascens</u>.

on dorsal side in light yellow colour, pedicels arranged closely on the ventral side, eighteen peltate type tentacles.

Spicules (Pl. VII B) : Spicules of spiny rods and smaller tables. Some rods broadly arched or curved, tables are slightly small with blunt protuberances on both ends. Cylindrical stem or body of the rod spicules with serrations.

Anatomy (Fig. 9) : Body wall 0.5 cm thick; 4 to 5 numbers of calcareous rings depending upon the size of animal and stiff; polian vesicle 4 to 8 with round bulbous terminal; stone canals four, intestine very long and folded into five loops, fine sediment from intestine visible, empty intestine appeared to be slightly red; respiratory trees one each on both sides extends upto middle of body in dissection and join with cloacal chamber; sexes separate, single tuft of gonad with 13 thread like tubules. Haemal vessels prominent at the anterior and middle of the intestine.

Distribution : Throughout the Indo-West Pacific and except Persian Gulf. Philippines, Mauritious, Andaman & Nicobar Islands, Gulf of Mannar and Lakshadweep Islands.

Remarks : Adult specimens are used for Beche-de-mer. But it is very difficult to collect from their habitat as they burrow inside sand.

Holothuria (Mertensiothuria) leucospilota (Brandt, 1835)
(PL. VIII A & B, Fig. 10)

Stichopus (Gymnochirota) leucospilota, Brandt, 1835 : p. 51.

Holothuria vagubunda Koehler and Vaney, 1908 : p. 17.

Mertensiothuria leucospilota Clark and Davies, 1966 : p. 603; James, 1969 : p. 62.

PLATE VIII A. Holothuria (Mertensiothuria) leucospilota

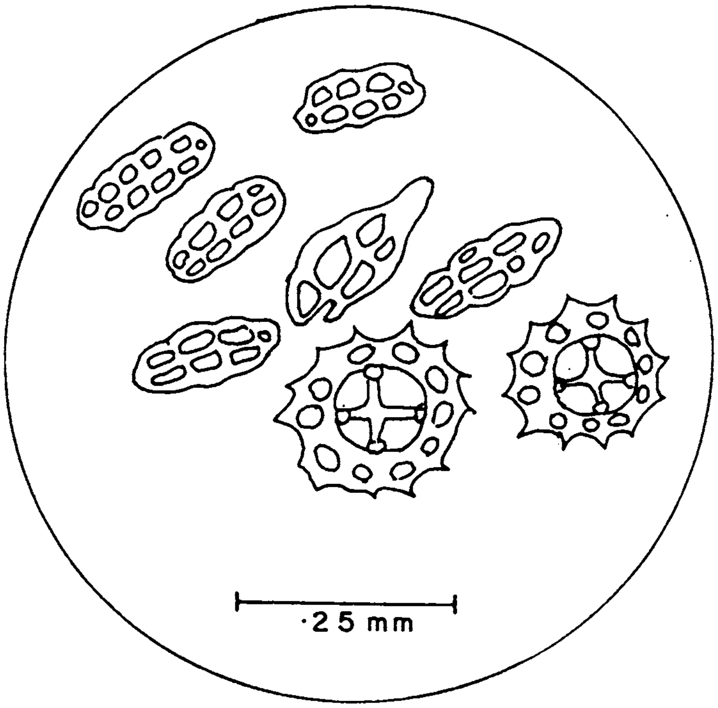


PLATE VIII B. Spicules of Holothuria (Mertensiothuria) leucospilota

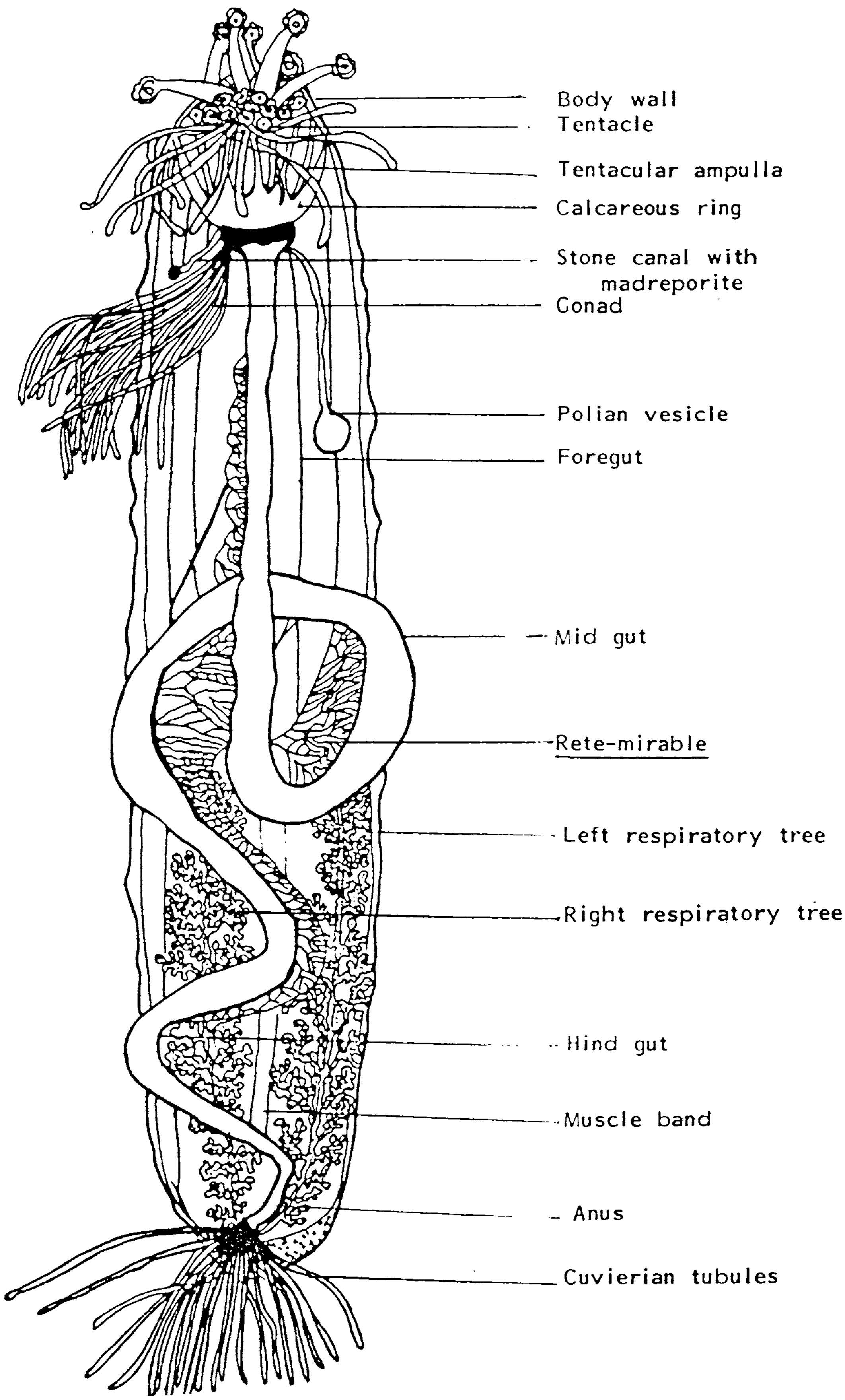


Fig. 10. Anatomy of Holothuria (Mertensiothuria) leucospilota.

Holothuria (Mertensiothuria) leucospilota Rowe, 1969 : p. 148; Rowe and Doty, 1977 : p. 233; James, 1986 : p. 585; 1989 : p. 126.

Type locality : South Pacific Islands.

Materials : 16 animals examined - 4 males and 12 females. Length 8.0 to 42.0 cm and weight 10 to 120 gram.

Habitat : Found among dead corals and water pools in reef flat.

Morphology (Pl. VIII A) : Body cylindrical, elongate, soft and fairly leathery; colour uniformly black or deep dark brown; papillae and pedicels irregularly scattered all over the body and both red in colour; peltate and pink tentacles twenty.

Spicules (Pl. VIII B) : Spicules are of tables and buttons. Table flat and smooth with irregular round margin and buttons usually with six holes.

Anatomy (Fig. 10) : Body wall thin; 5 to 8 calcareous rings, single polian vesicle with round free end and stone canal observed on left side; intestine very long with three loops, filled with medium size sediment particles; respiratory trees one each on both sides; haemal vessels attached with posterior portion of the intestine; rete mirable well developed and composed of small tiny tubules; sexes separate, gonad with single tuft of about 14 tubules; generally Cuvierian tubules prominent in larger individual.

Distribution : Indo-Pacific regions, Philippines, Andaman & Nicobar Islands, Gulf of Mannar and Lakshadweep Islands.

Remarks : Since the body wall is thin and comparatively larger Cuvierian tubules, in proportionate to its body makes this animal unsuitable for Beche-de-mer industry.

Holothuria (Cystipus) rigida (Selenka, 1867)
(PL. IX A & B, Fig. 11)

Stichopus rigida Selenka, 1867 : p. 317.

Holothuria rigida Semper, 1868 : p. 79; Clark, 1901 : p. 495.

Fossothuria rigida Deichmann, 1958 : p. 321.

Holothuria (Cystipus) rigida Rowe, 1969 : p. 155; Clark and Rowe, 1971 : p. 176; Rowe and Doty, 1977 : p. 233; James, 1986 : p. 585; 1989 : p. 127.

Type locality : Zanzibar, Hawaii.

Materials : Only two female animals collected from the study area. Length 15.0 and 22.0 cm and weight 20 and 30 gram.

Habitat : Buried under rocks and dead coral heads in reef flat.

Morphology (Pl. IX A) : Body uniformly cylindrical and soft; colour cream or yellow with small dark spots in longitudinal rows on dorsal side. Small light brown papillae in rows on dorsal side, while few pedicels irregularly arranged on ventral side; twenty peltate and yellow tentacles observed.

Spicules (Pl. IX B) : Spicules consisted of buttons usually with six holes and tough tables with spiny projections.

Anatomy (Fig. 11) : Body wall 0.2 cm thick; five calcareous rings; single polian vesicle lies on right side with round free terminal

PLATE IX A. Holothuria (Cystipus) rigida

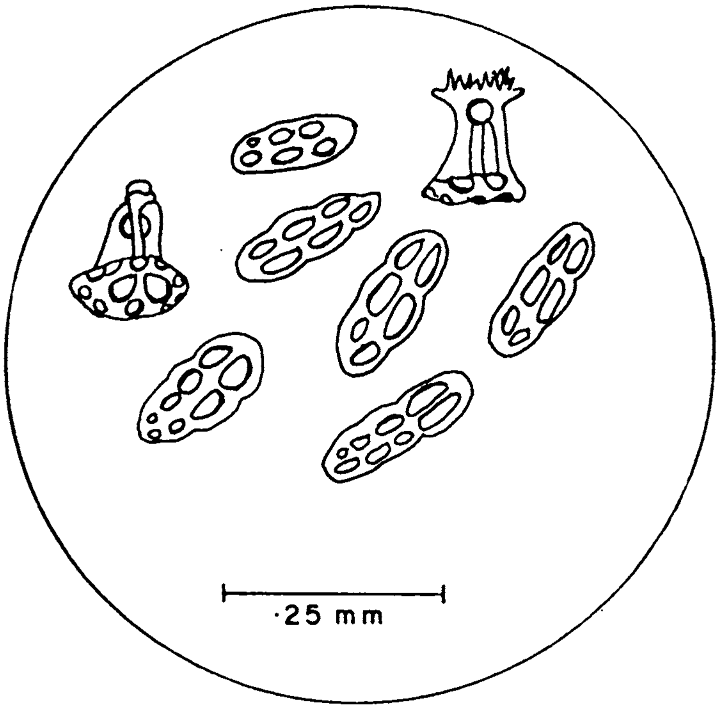


PLATE IX B. Spicules of Holothuria (Cystipus) rigida

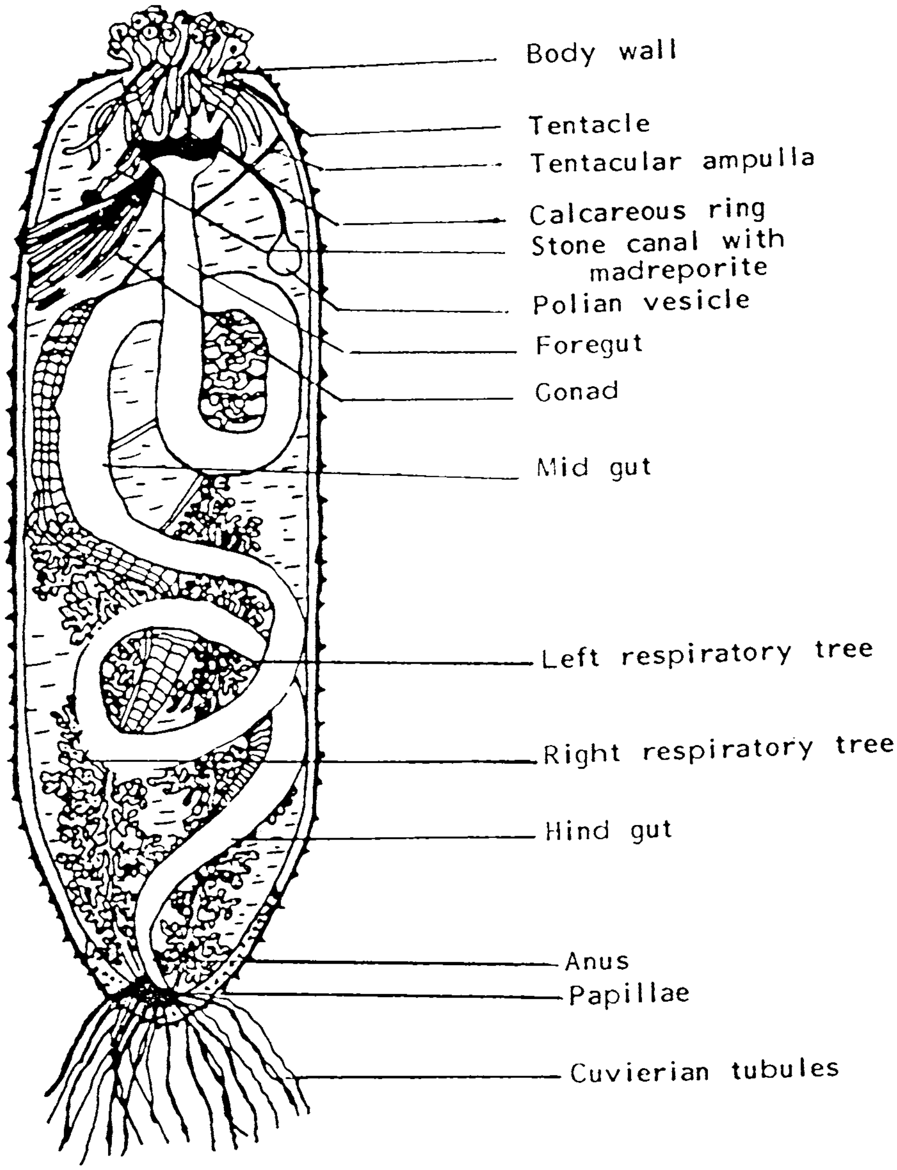


Fig.11. Anatomy of *Holothuria (Cystipus) rigida*.

and stone canal with madreporite on leftside; intestine with three loops and filled with calcareous coral and shell particles; respiratory trees very much branched, one each on both sides reached almost middle of body height from the aboral end; single tuft of gonad with 10 tubules in left side of dorsal mesentery; tubules very thin with fully matured ova observed; Cuvierian tubules 20 in number poorly developed.

Distribution : Throughout Indo-Pacific region and the Indian Ocean. Maldives and Lakshadweep Islands.

Actinopyga mauritiana (Quoy and Gaimard, 1833)

(PL. X A & B, Fig. 12)

Holothuria guamensis Quoy and Gaimard, 1833 : p. 137.

Holothuria mauritiana Quoy and Gaimard, 1833 : p. 138.

Microthele guamensis Cherbonnier, 1952 : p. 40.

Actinopyga mauritiana Bell, 1887 : p.653 ; Koehler and Vaney, 1908 : p. 22; Pearson, 1914 b : p.185 ; Panning, 1944 : p. 55; Cherbonnier, 1952 : p. 41; Domantay,1954 : p. 349; Clark and Davies, 1966 : p. 603; Rowe, 1969 : p. 131; Clark and Rowe, 1971 : p. 176; Nagabhushanam and Rao, 1972 : p. 290; Liao, 1975 : p.204 ; Rowe and Doty, 1977 : p. 228; Mukhopadhyay and Samanta, 1983 : p. 300; Soota, Mukhopadhyay and Samanta, 1983 : p. 507 ; James, 1989 : p. 128; Chao and Charw, 1989 : p. 127.

Type locality : Mauritius.

Materials : 40 animals examined. There is no male and female species. This species undergoes asexual reproduction. Length 4.0

PLATE X A. Actinopyga mauritiana

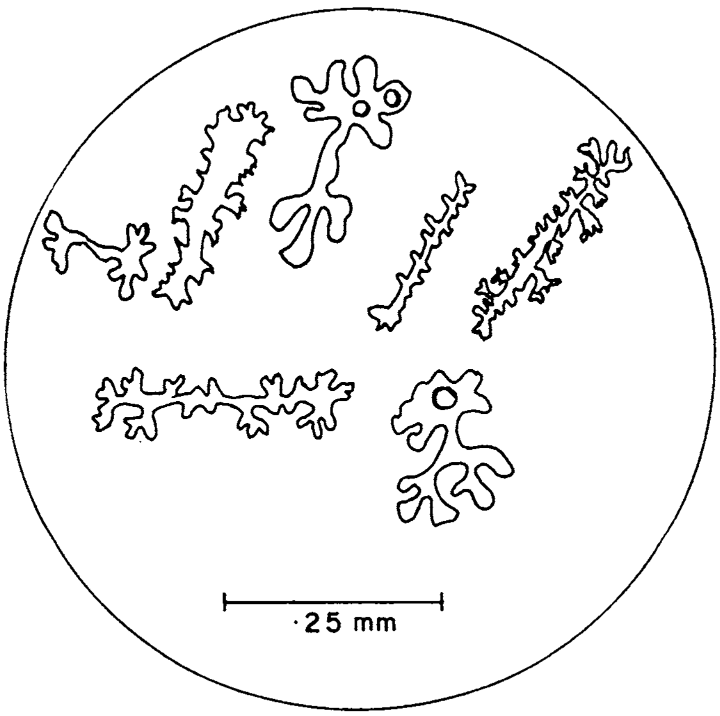


PLATE X B. Spicules of Actinopyga mauritiana

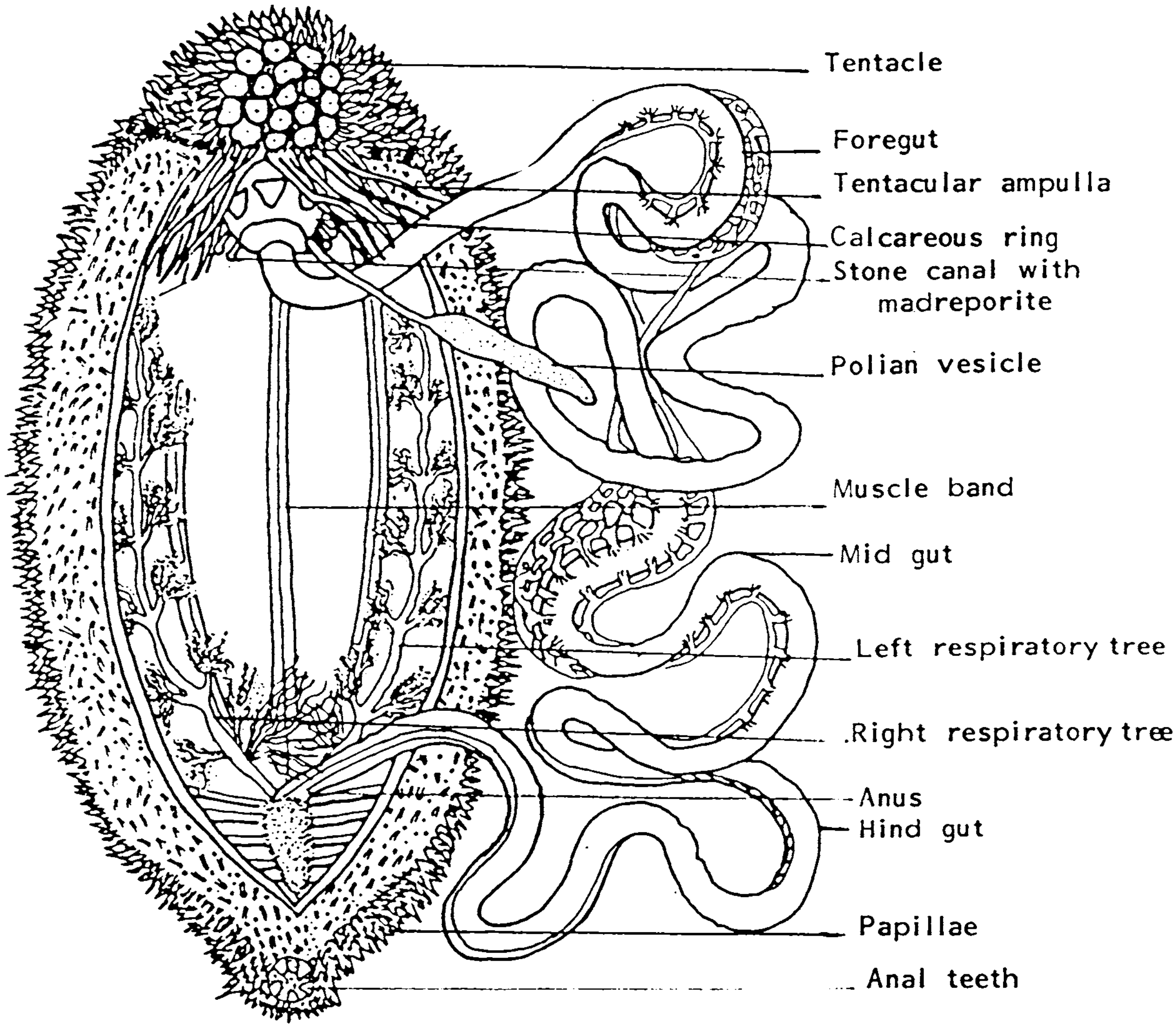


Fig.12. Anatomy of Actinopyga mauritiana.

to 28.0 cm and weight 5 to 1400 gram.

Habitat : Attached with dead coral, exposed on reef edge and coralline sand.

Morphology (Pl. X A) : Body not perfectly cylindrical and somewhat barrel-shaped with flat ventral side, middle portion bulged, very smooth to touch; colour brown or chocolate on dorsal side and white on ventral side, some animals have white and brown blotches; numerous papillae irregularly scattered on the dorsal side, while pedicels distributed ventrally, but it is not arranged in distinct series; tentacles twentyfive, peltate, brown; anus with five distinct calcified teeth is characteristic.

Spicules (Pl. X B) : Spicules consisted of elongate rods with lateral projection and rosettes with one or two holes. No tables or buttons.

Anatomy (Fig. 12) : Body wall muscular, very thick, 0.8 cm in adult; 5 to 8 calcareous rings, single prominent polian vesicle on left side with finger-like free end or in varying shapes with 1.5 cm long, 4 stone canals two on either side of the calcareous rings; intestine extremely long with many loops and packed with (green and brown) algae and fine sediment particles; haemal vessels well developed and attached on dorsal and ventral sides of intestine; respiratory trees one each on both sides almost reaches the oral end, no sex organs, it undergoes asexual reproduction. It is evident from all 800 specimen dissected and examined for biology and discussed in a latter chapter, which is an interesting and unique observation; Cuvierian tubules poorly developed, reddish colour.

Distribution : Throughout the tropical Indo-West Pacific area except Arabian Coast, the Persian Gulf. It is abundant in Andaman & Nicobar Islands and Lakshadweep Islands.

Remarks : Rowe and Doty (1977) have very elaborately discussed the taxonomic status of this species and "concluded that H. guamensis should be considered a synonym of A. mauritiana to prevent any confusion over revival of a little-used species name".

James et al. (1993) collected 3 males and one female for the first time from oceanic water of Andaman & Nicobar Islands and they were able to rear them in the aquarium of the FORV Sagar Sampada. Surprisingly a higher temperature at the aquarium water stimulated the male to spawn and released the sperms, which further stimulated the females to spawn. They were able to observe the fertilized and developed eggs upto four cell stage. The candidate has never come across any sexual animal of this species during the period of his stay at Minicoy where he studied reproductive biology elaborately of this species and examined over 800 animals. The observations of the candidate and James et al. (1993) are different and interesting. It needs further studies on this species particularly about their sexual reproduction.

Actinopyga miliaris (Quoy and Gaimard, 1833)
(PL. XI A & B, Fig. 13)

Holothuria miliaris Quoy and Gaimard, 1833 : p. 137.

Mulleria miliaris Brandt, 1835 : p. 127.

Actinopyga (Lacanora) miliaris Panning, 1944 : p. 50.

Actinopyga miliaris Ludwig, 1887 : p.144; Bell, 1887 : p.653; Pearson, 1914 : p. 181 ; Clark, 1946 : p. 110; Clark, 1932 : p. 120 ; James, 1969 : p. 61; 1989 : p. 129; Rowe, 1969 : p. 131; Clark and Rowe, 1971 : p. 176; Clark and Davies, 1966 : p. 120; Nagabhushanam and Rao, 1972 : p. 290; Liao, 1975 : p. 32 ; Mukhopadhyay and Samanta, 1983 : p. 311; Clark, 1984 : p. 102.

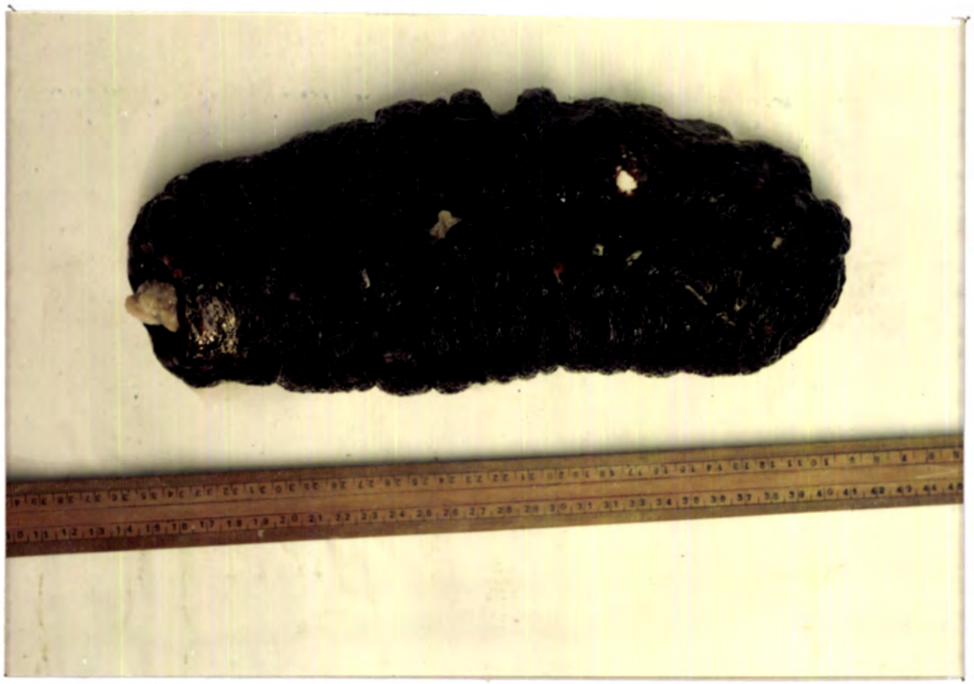


PLATE XI A. Actinopyga miliaris

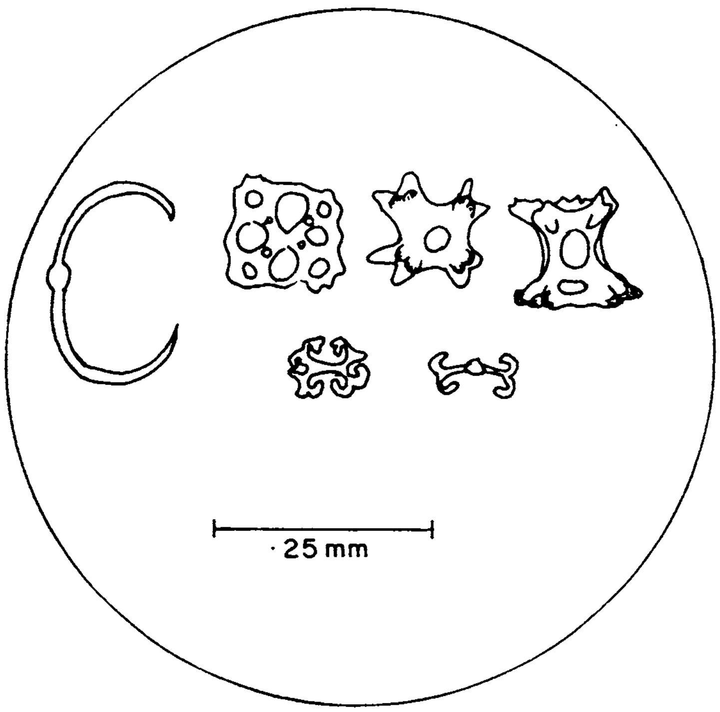


PLATE XI B. Spicules of Actinopyga miliaris

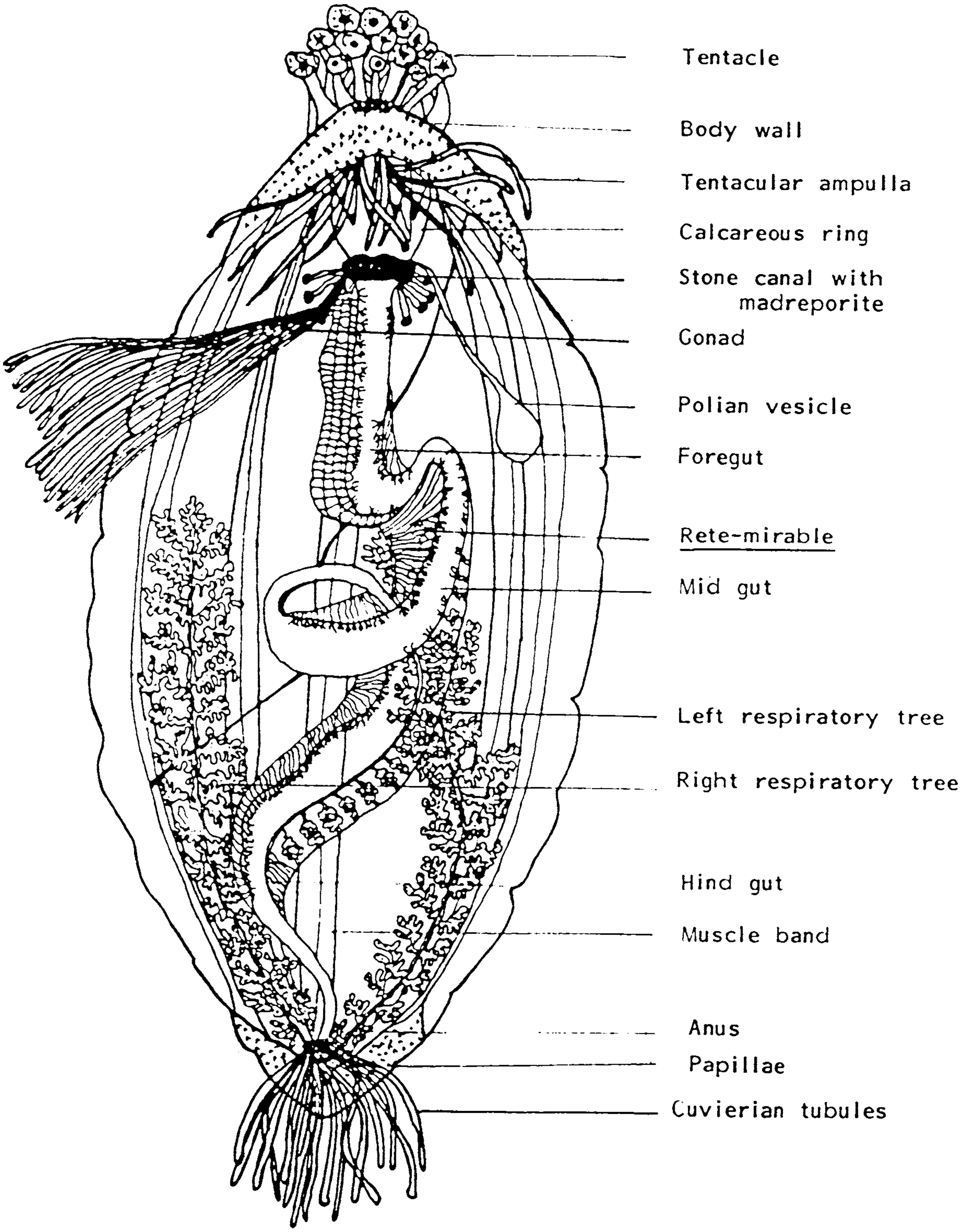


Fig.13. Anatomy of <u>Actinopyga</u> <u>milliaris</u>.

Type locality : East Indies.

Material : Only one female. Length 30.0 cm and weight 1400 gram.

Habitat : Found on dead coral bed covered with green algae.

Morphology (Pl. XI A) : Body elongate, cylindrical and massive slightly arched dorsally and flat ventrally; colour greenish black with orange or brown blotches on dorsal side and blotches distinct near anal region. When animal contracts, it appears black; papillae scattered irregularly on dorsal side; pedicels arranged in three distinct rows on ventral surface; twentyfour light brown peltate tentacles.

Spicules (Pl. XI B) : Rods 'C' shaped, squarish tables with holes and some with 'X' shaped corners and 'x' shaped rosettes.

Anatomy (Fig. 13) : Body wall very thick and over 1.0 cm; five calcareous rings, only one long polian vesicle with oval free end on left side of animal, 8 to 10 stone canals. Intestine long with three loops and packed with all types of sediments; respiratory trees one each on both sides extending 2/3 height of the total length of animal from anus; haemal systems well developed and attached to intestine almost throughout the intestine; longitudinal muscle bands observed; single tuft gonad with forked tips and fully matured ova observed; muscles fibres around cloaca well developed; Cuvierian tubules short and stumpy.

Distribution : Throughout Indo-Pacific region and the Indian Ocean. Andaman & Nicobar Islands and Lakshadweep Islands.

Remarks : Due to its massive size and very thick body wall, this is more suitable for Beche-de-mer. But their occurrence is very scanty.

Bohadschia marmorata Jaeger, 1833
(PL. XII A & B, Fig. 14)

Bohadschia marmorata Jaeger, 1833 : p. 18; Rowe, 1969 : p. 129; Clark and Rowe, 1971 : p. 176; Geronimo, 1976 : p. 95; Rowe and Doty, 1977 : p. 229; Nagabhushanam and Rao, 1972 : p. 301; James, 1986 : p. 585; 1989 : p. 129.

Holothuria (Bohadschia) vitiensis Panning, 1929 : p. 122; Domantay, 1933 : p. 76.

Bohadschia (Marmorata) marmorata Panning, 1944 : p. 10, 12.

Holothuria marmorata Domantay, 1953 b : p. 115; James, 1969 : p. 62; Nagabhushanam and Rao, 1972 p. 290.

Selenkothuria vitiensis Acosta, 1969 : p. 55.

Type locality : East Indies.

Materials : 12 males and 8 females - length 12.0 to 36.0 cm and weight 30 to 1200 gram.

Habitat : Found on soft sediment area and body covered with sand particles.

Morphology (Pl. XII A) : Body cylindrical, barrel-shaped and bulky, oral and aboral ends round, dorsal side arched and ventral flat; body thick and massive; small specimens cream in colour with chocolate and brown dots, while larger ones are dark orange or brown; papillae very minute and appears just like small dark brown spots on dorsal side, pedicels also small and seen as spots on ventral

PLATE XII A. Bohadschia marmorata

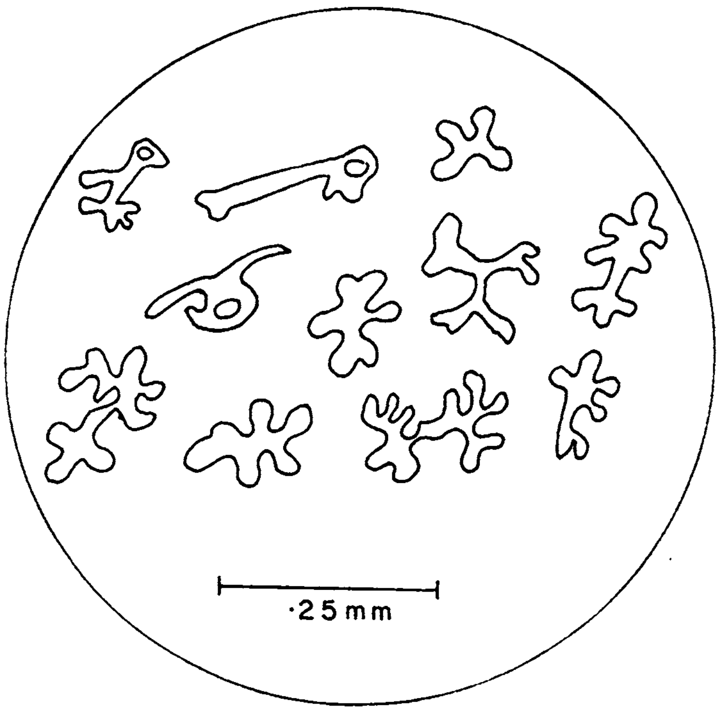


PLATE XII B. Spicules of Bohadschia marmorata

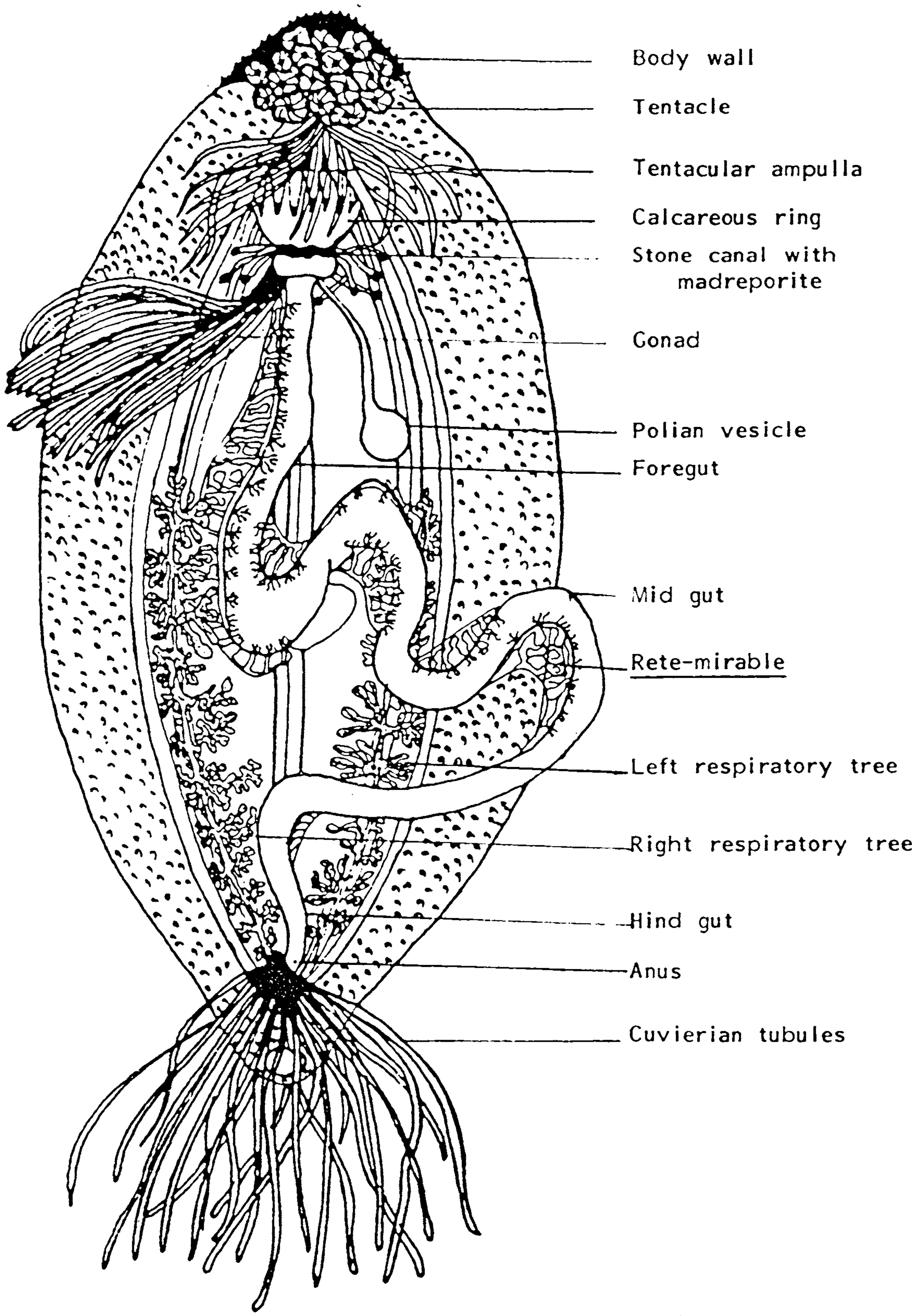


Fig.14. Anatomy of <u>Bohadschia marmorata</u>.

side, anus surrounded by five prominent papillae; twenty peltate and yellow tentacles.

Spicules (Pl. XII B) : Spicules from simple to complex branched rods only of varying sizes.

Anatomy (Fig. 14) : Body wall very thin, 0.2 cm in smaller specimens, 1.2 cm thick in adult and old specimens; calcareous rings eight, single polian vesicle with round free end on left side of the animal, ten stone canals around calcareous rings; intestine long with three loops and filled with calcareous particles and sediments; respiratory trees one each on both sides; haemal vessels well developed and prominent till 2/3 from oral end; sexes are separate; single tuft of gonad in smaller animal and in bigger animal two tufts of gonads observed; Cuvierian tubules extremely long and numerous and just like a lock of hairs; longitudinal muscle bands observed.

Distribution : Throughout Indo-West Pacific and the Indian Ocean. Andaman & Nicobar Islands, the Gulf of Mannar and Lakshadweep Islands in India.

Remarks : Due to the presence of long and massive Cuvierian tubules in bunches, this species is commercially less important.

Bohadschia argus Jaeger, 1833

(PL. XIII A & B, Fig. 15)

Bohadschia argus Jaeger, 1833 : p. 19; Panning, 1944 : p. 36; Rowe, 1969 : p. 130; Geronimo, 1970 : p. 72; Clark and Rowe, 1971 : p. 176; Rowe and Doty, 1977 : p. 229; Nagabhushanam and Rao, 1972 : p. 301; James, 1986 : p. 585, 1989 : p. 129; Chao and Charw, 1990 : p. 66 .

PLATE XIII A. Bohadschia argus

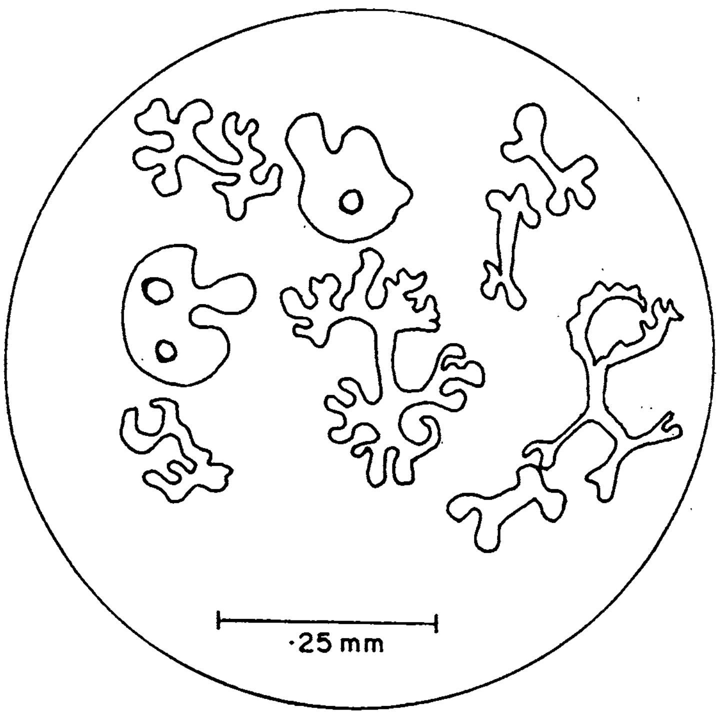


PLATE XIII B. Spicules of Bohadschia argus

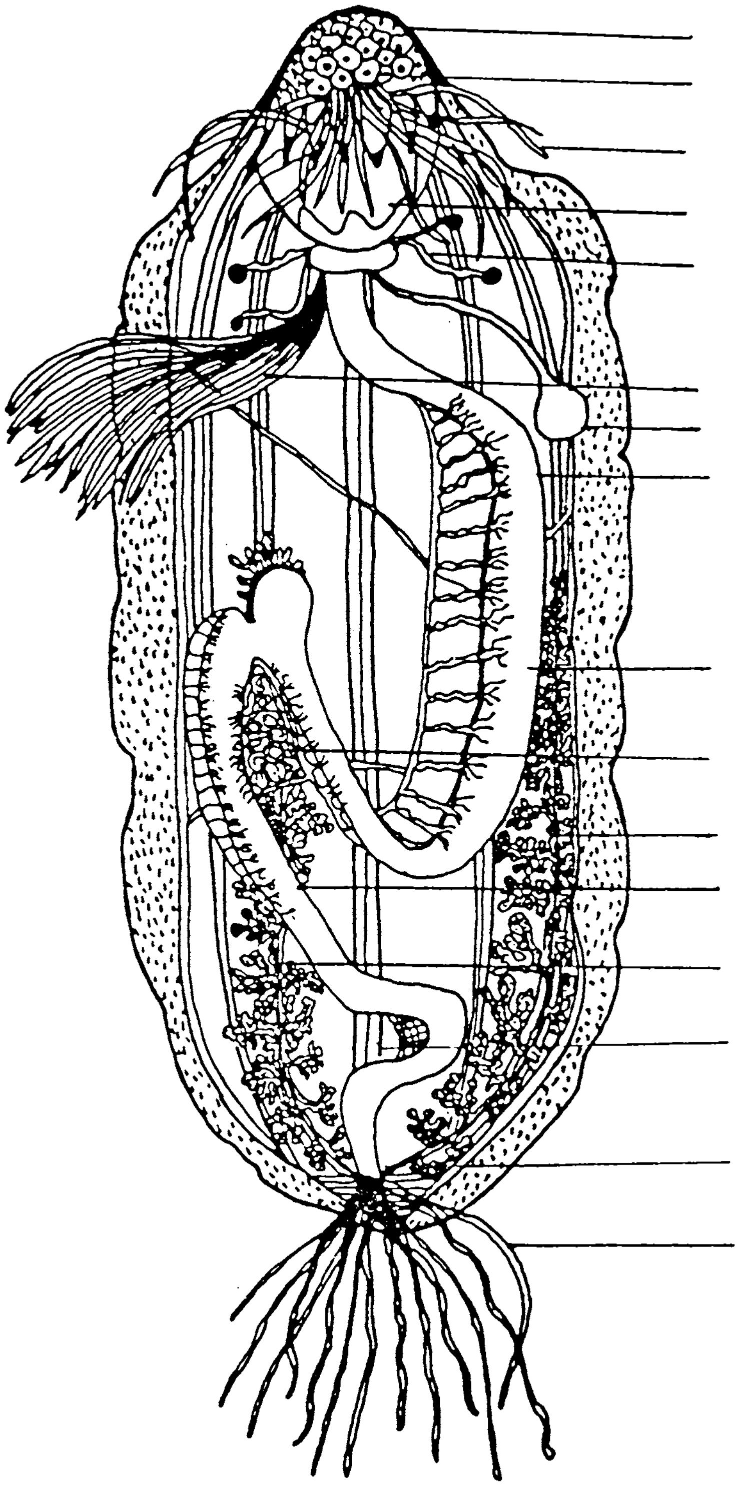


Fig.15. Anatomy of Bohadschia argus.

Holothuria argus Domantay, 1954 : p. 338; 1960 : p. 84.

Selenkothuria argus Acosta, 1969 : p. 107; James, 1969 : p. 62; Nagabhushanam and Rao, 1972 : p. 300.

Type locality : West Indies.

Materials : Only one female examined, length 33.0 cm and weight 1300 gram.

Habitat : Found in dead coral area, where brown algae are abundant.

Morphology (Pl. XIII A) : Body elongate, ovate and soft with rounded ends, colour from light brown to brown; papillae minute irregularly scattered on dorsal side, base of papillae encircled by a lighter brown ring; pedicels soft, black and numerous on ventral side; anal region darker brown compared to body colour with five prominent papillae on laterodorsal side; eighteen peltate, golden brown tentacles.

Spicules (Pl. XIII B) : Spicules from simple to complex rods and granules with one or two holes.

Anatomy (Fig. 15) : Body wall thick and massive (0.5 cm); calcareous rings eight; each side of calcareous rings two stone canals present; intestine long with three loops and packed with coral particles; respiratory trees present one each on both sides; haemal vessels well developed; Cuvierian tubules numerous, filamentous and long.

Distribution : Common in tropical Pacific and Western Indian Ocean. Sri Lanka and Bay of Bengal, Andaman & Nicobar Islands and Lakshadweep Islands in the Indian sea.

Thelenota ananas (Jaeger, 1833)
(PL. XIV A & B, Fig. 16)

Trepang ananas Jaeger, 1833 : p. 24.

Thelenota ananas Clark, 1921 : p. 184; Domantay, 1953 b : p. 81-88; Clark and Davies, 1966 : p. 603; James, 1969 : p. 60; 1986 : p. 586; 1989 : p. 130-131; Clark and Rowe, 1971 : p. 178; Geronimo, 1976 : p. 90-100; Rowe and Doty, 1977 : p. 227; Nagabhushanam and Rao, 1972 : p. 291; Mukhopadhyay and Samanta, 1983 : p. 309-310.

Type locality : East Indies.

Materials : Only two females were collected and examined - length 38.0 and 45.0 cm; weight 2000 and 2800 gram.

Habitat : Found in soft sediment beds and algal beds at 3 m depth of lagoon.

Morphology (Pl. XIV A) : Body sub-rectangular, elongated, ends blunt, dorsoventrally depressed; colour chocolate brown, speckled with darker brown spots on dorsal; papillae trilobed, large and crowded on dorsal side, pedicels on ventral side arranged irregularly; peltate reddish tentacles twenty.

Spicules (Pl. XIV B) : Spicules characteristic compared to other species, slender, varies from star-like to various shapes with many radiating pointed or branched rod. No tables and rosettes observed.

Anatomy (Fig. 16) : Body wall very tough and 1.0 cm thick; six hard calcareous rings; 1.5 cm long polian vesicle with spindle shaped free end, stone canals eight; intestine long with four loops and filled

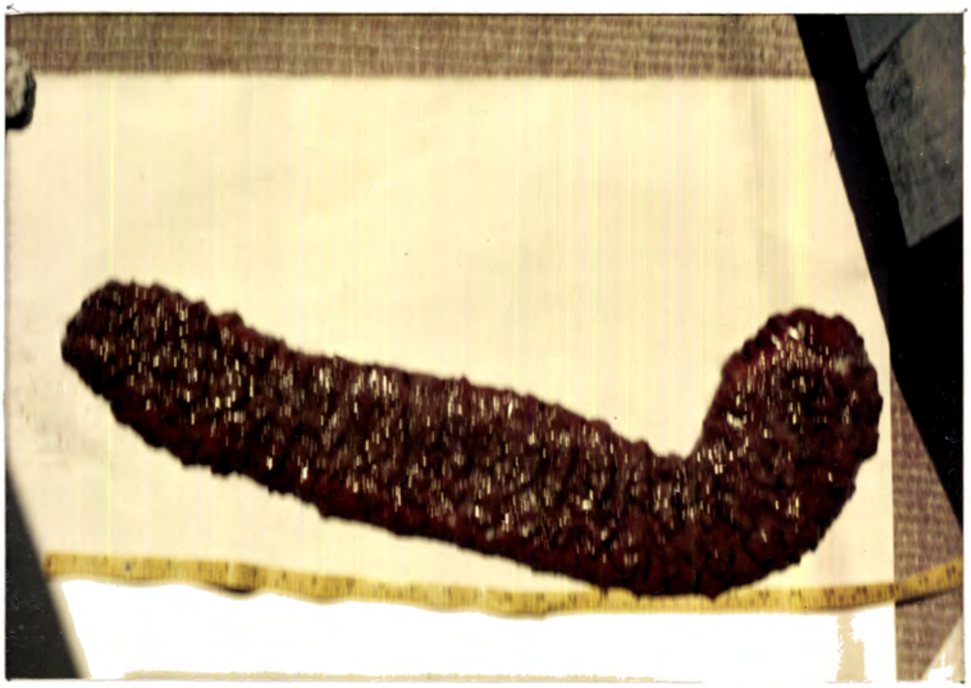


PLATE XIV A. <u>Thelenota ananas</u>

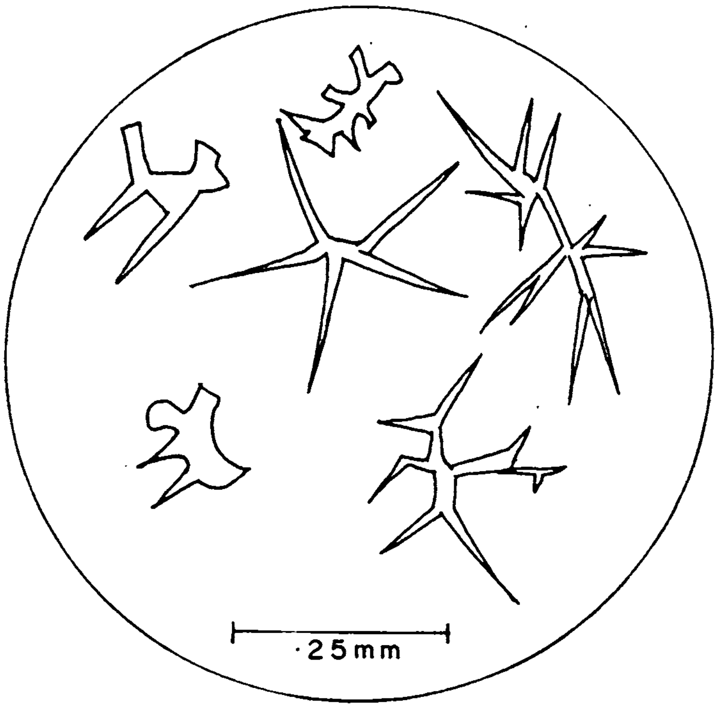


PLATE XIV B. Spicules of <u>Thelenota ananas</u>

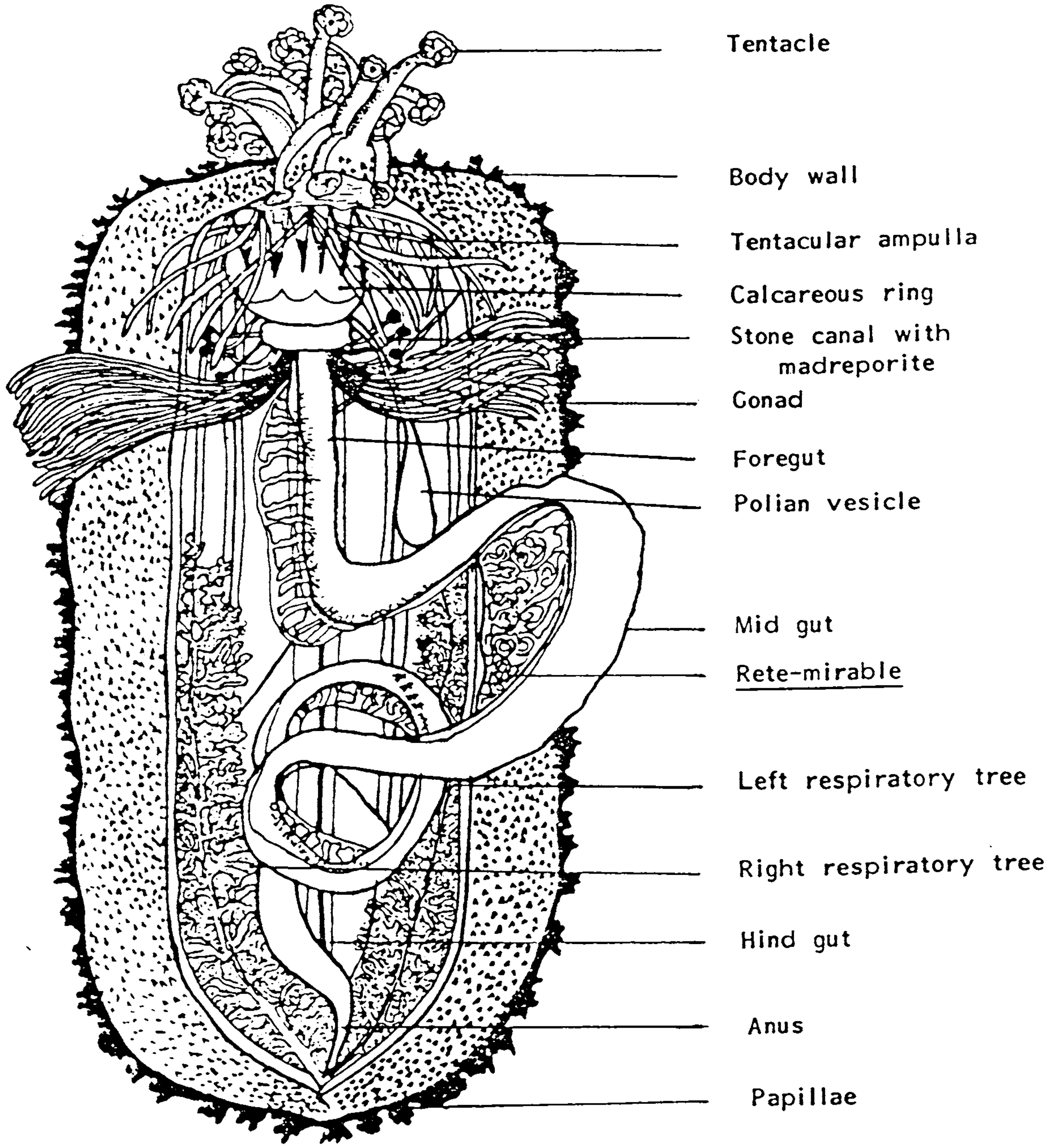


Fig.16. Anatomy of *Thelenota ananas*.

with sediment particles; respiratory trees well developed and extend with middle of body one each on both sides, branched, reddish; haemal system well developed, dorsal haemal vessel attached on the full length of the intestine, transverse haemal vessels prominently visible at the mid portion along the intestine; sexes separate, two tufts of gonad one each on both side, tubules long and branched.

Distribution : Islands in the Western Pacific, Australia, China, Japan, Maldives and Lakshadweep Islands in India.

Stichopus chlorontus Brandt, 1835
(PL. XV A & B, Fig. 17)

Stichopus (Perideris) chlorontos Brandt, 1935 : p. 50.

Stichopus chloronotus Clark, 1922 : p. 53; Domantay, 1954 : p. 351; Clark and Davies, 1966 : p. 600; Clark and Rowe, 1971 : p. 178; Rowe and Doty, 1977 : p. 227; Nagabhushanam and Rao, 1972 : p. 312; James, 1986 : p. 586; 1989 : p. 130.

Type locality : Fiji Islands.

Material : only one female was obtained - length 12.0 cm and weight 30 gram.

Habitat : Found on sea-grass bed.

Morphology (Pl. XV A) : Body rectangular and soft, colour dark green; papillae characteristically conical with red tips in two rows laterally and a median one on dorsal side; ventral pedicels numerous and in three rows - one row each on either sides and a ventral median row. The median row is twice the width of the lateral ones.

PLATE XV A. Stichopus chloronotus

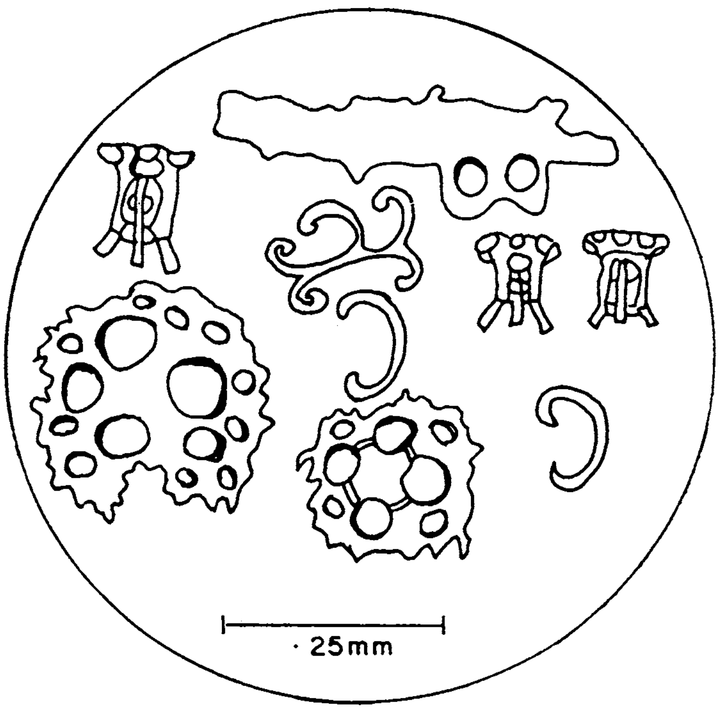


PLATE XV B. Spicules of Stichopus chloronotus

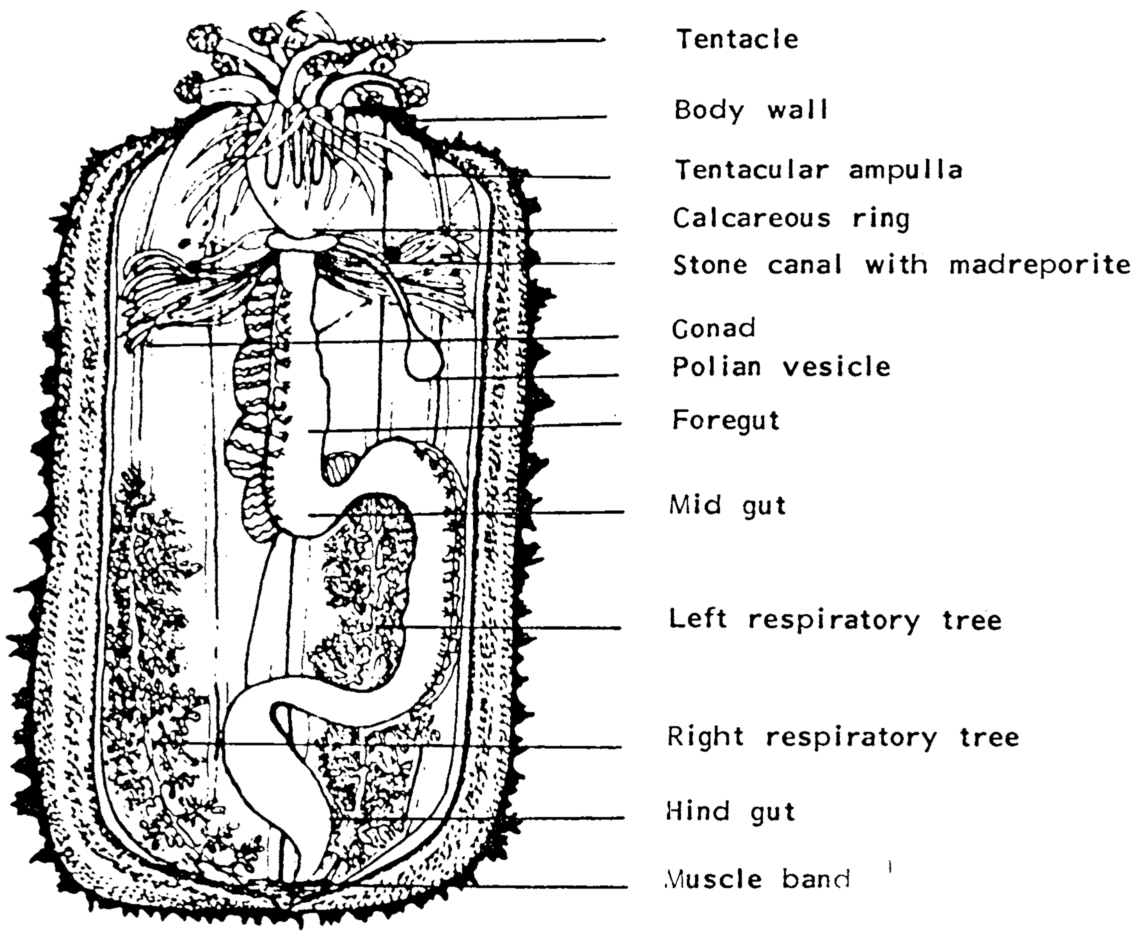


Fig.17. Anatomy of <u>Stichopus Chloronotus</u>

Tentacles twenty, peltate and yellow; mouth surrounded by a crown of papillae.

Spicules (Pl. XV B) : Rods 'C', 'x' and irregularly shaped with two holes. Tables moderately larger circles with about 10 holes and serrated rims. Rosettes not observed.

Anatomy (Fig. 17) : Body wall 0.5 cm thick; five calcareous rings, single polian vesicle with round end and three stone canals present with its madreporite body; very small intestine with single loope and filled with soft sediments and plant matters; respiratory trees pale yellow colour, comparatively short one each on both side; haemal vessels well developed and interlaced; sexes separate, two tufts of gonad present, fully packed with mature ova.

Distribution : Throughout the Indo-Pacific region and the Indian Ocean. Andaman & Nicobar Islands and Lakshadweep Islands.

Remarks : The only specimen was ascertained as female on observation of ova from gonad and it is a rare species and not found in large or even in normal numbers.

Stichopus variegatus Semper, 1868
(PL. XVI A & B, Fig. 18)

Stichopus variegatus Semper, 1868 : p. 73; Domantay, 1933 : p. 79-80; Clark and Rowe, 1971 : p. 178; Nagabhushanam and Rao, 1972 : p. 312; James, 1986 : p. 586, 1989 : p. 130.

Type locality : Philippines.

Material : Only one female was found and examined - length 13.0 cm and weight 40 gram.

PLATE XVI A. Stichopus variegatus

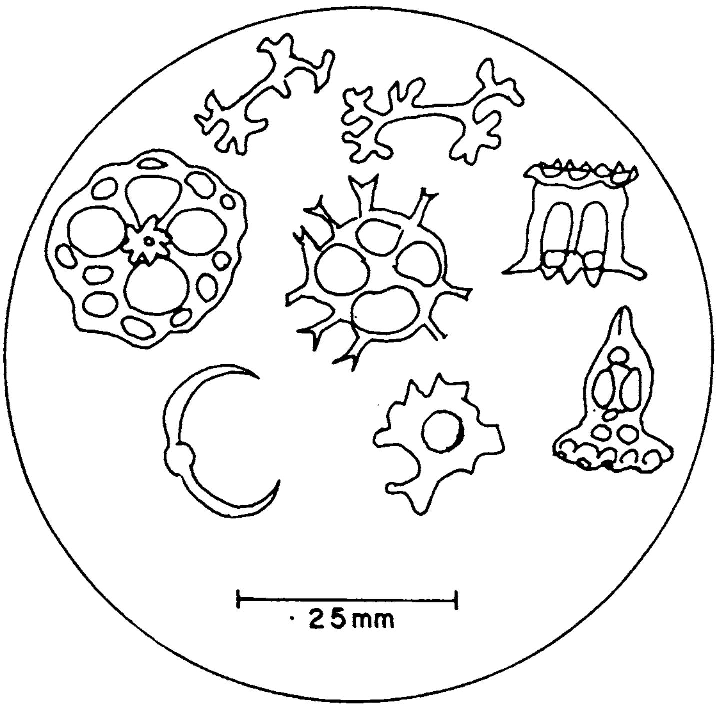


PLATE XVI B. Spicules of Stichopus variegatus

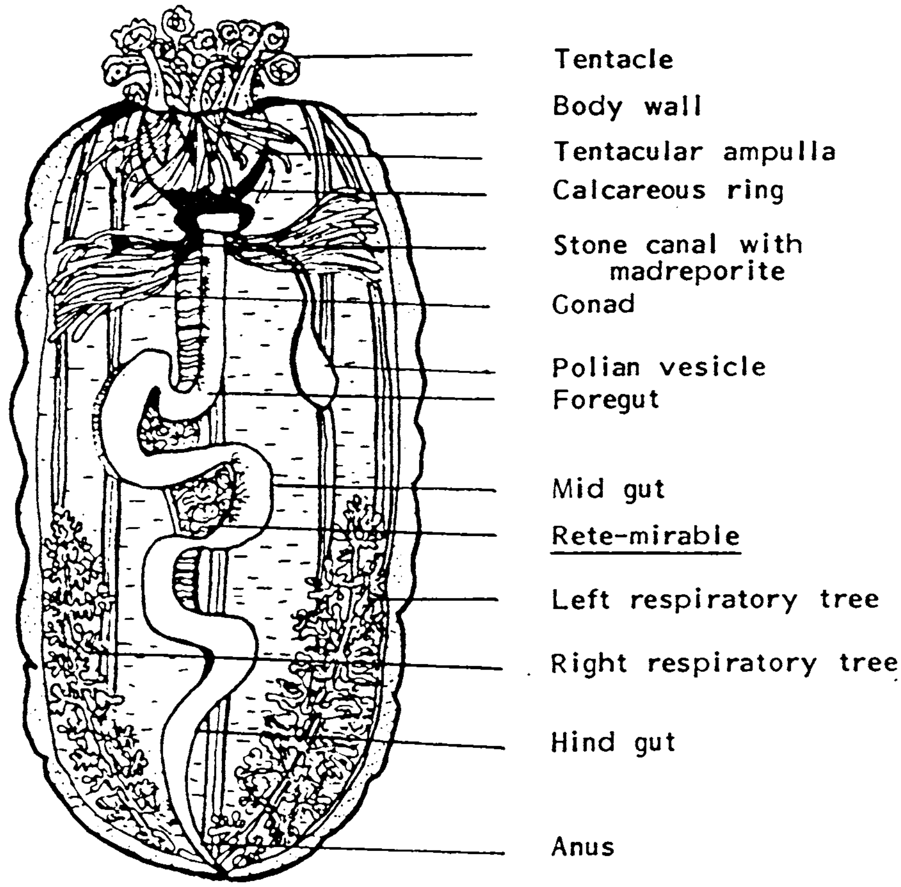


Fig.18. Anatomy of Stichopus variegatus.

Habitat : Found in sea-grass bed.

Morphology (Pl. XVI A) : Body rectangular and soft; olive green in live condition and dark brown in preservation and contraction; papillae on dorsal surface pink and scattered throughout body, pedicels black and in three rows on ventral side; peltate and brownish yellow tentacles twenty.

Spicules (Pl. XVI B) : Tables and rods; rods 'c' shaped. Tables round with small marginal holes and four big holes at the centre in four corners, some tables with eight radiating forked spines.

Anatomy (Fig. 18) : Body wall 0.3 cm thick; five calcareous rings; single polian vesicle with spindle shaped free end and single stone canal; intestine long with two loops and filled with fine sediments and algal matters; haemal vessels at the anterior gut visible, while it is extended all along the intestine; short and light yellow respiratory trees one each on both sides; sexes separate, two tufts of gonad packed with full of mature ova.

Distribution : Throughout the Indo-Pacific region and the Indian Ocean. Lakshadweep Islands.

Remarks : It is another rare species recorded.

Synapta maculata (Chamisso and Eysenhardt, 1821)
(PL. XVII A & B, Fig. 19)

Holothuria maculata Chamisso and Eysenhardt, 1821 : p. 352.

Synapta maculata Clark, 1924 : p. 471-473; Heding, 1928 : p. 113; Domantay, 1954 : p. 353; James, 1969 : p. 62; 1986 : p. 587; 1989 : p. 132; Clark and Davies, 1966 : p. 603; Clark and Rowe, 1971 : p. 186; Geronimo, 1976 : p. 100-101; Rowe and Doty, 1977: p. 234; Nagabhushanam and Rao, 1972 : p. 291; Mukhopadhyay and Samanta, 1983 : p. 310-312.

PLATE XVII A. Synapta maculata

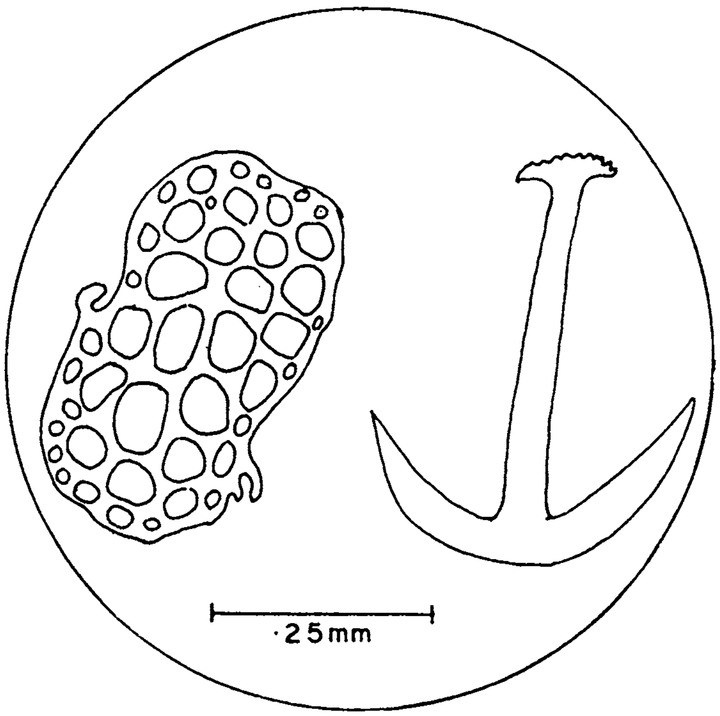


PLATE XVII B. Spicules of Synapta maculata

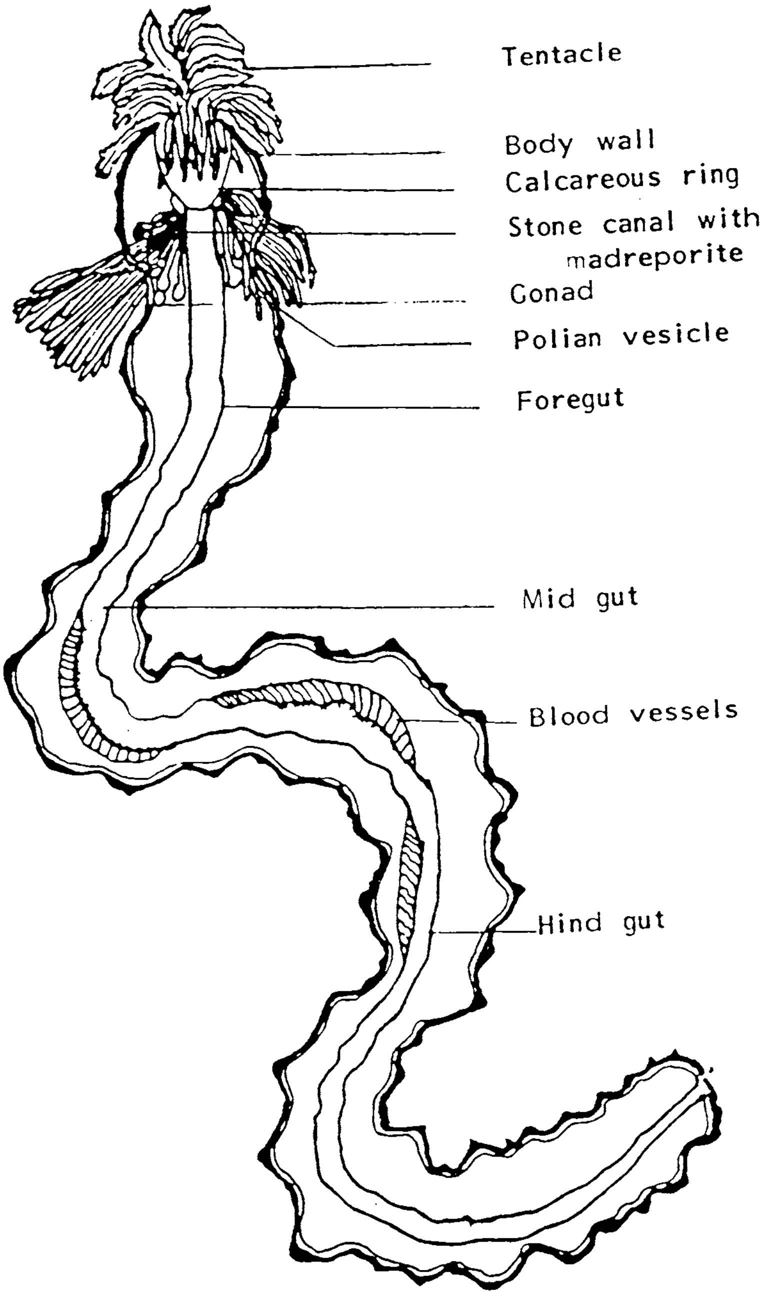


Fig.19. Anatomy of *Synapta maculata*.

Habitat : Found in sea-grass bed.

Morphology (Pl. XVI A) : Body rectangular and soft; olive green in live condition and dark brown in preservation and contraction; papillae on dorsal surface pink and scattered throughout body, pedicels black and in three rows on ventral side; peltate and brownish yellow tentacles twenty.

Spicules (Pl. XVI B) : Tables and rods; rods 'c' shaped. Tables round with small marginal holes and four big holes at the centre in four corners, some tables with eight radiating forked spines.

Anatomy (Fig. 18) : Body wall 0.3 cm thick; five calcareous rings; single polian vesicle with spindle shaped free end and single stone canal; intestine long with two loops and filled with fine sediments and algal matters; haemal vessels at the anterior gut visible, while it is extended all along the intestine; short and light yellow respiratory trees one each on both sides; sexes separate, two tufts of gonad packed with full of mature ova.

Distribution : Throughout the Indo-Pacific region and the Indian Ocean. Lakshadweep Islands.

Remarks : It is another rare species recorded.

Synapta maculata (Chamisso and Eysenhardt, 1821)
(PL. XVII A & B, Fig. 19)

Holothuria maculata Chamisso and Eysenhardt, 1821 : p. 352.

Synapta maculata Clark, 1924 : p. 471-473; Heding, 1928 : p. 113; Domantay, 1954 : p. 353; James, 1969 : p. 62; 1986 : p. 587; 1989 : p. 132; Clark and Davies, 1966 : p. 603; Clark and Rowe, 1971 : p. 186; Geronimo, 1976 : p. 100-101; Rowe and Doty, 1977: p. 234; Nagabhushanam and Rao, 1972 : p. 291; Mukhopadhyay and Samanta, 1983 : p. 310-312.

Type locality : South Pacific Islands.

Materials : Three specimens - 1 male and 2 females. Length 50.0 to 100.0 cm and weight 300 to 500 gram.

Habitat : Found in sea-grass bed and under coral reef boulders.

Morphology (Pl. XVII A) : Body extremely long and cylindrical, snakelike; body wall thin, fragile, sticks to finger; colour grey to black with equidistant alternating wide cream to brown bands and five distinct longitudinal dark bands; when external condition is not suitable, body forms fold and alter the whole length, which vary greatly with size of the animal; pinnate tentacles grey and fifteen in number. Papillae and pedicels absent.

Spicules (Pl. XVII B) : Spicules consisted of anchor and plates with numerous holes characteristics of the family.

Anatomy (Fig. 19) : Body wall very thin and fragile; ten calcareous rings, eight polian vesicles, with round free end, single stone canal; straight and long intestine with calcareous materials; shrinks during dissection, simple haemal system attached with midportion of intestine; no respiratory tree; sexes separate, two tufts of free and unbranched gonad on either side.

Distribution : Throughout the Indo-West Pacific, except Persian Gulf and Hawaiian Islands. It is abundant in Andaman & Nicobar Islands, Lakshadweep Islands.

Remarks : Extremely thin, long, slender and fragile body makes unsuitable for processing. Rare occurrence.

Euapta godeffroyi (Semper, 1868)

(PL. XVIII A & B, Fig. 20)

Synapta godeffroyi Semper, 1868 : p. 231.

Euapta godeffroyi Ostergren, 1898 : p. 113; Heding, 1928 : p. 137; Domantay, 1954 : p. 353; Clark and Davies, 1966 : p. 600; James, 1969 : p. 62; 1986 : p. 587; 1989 : p. 132; Clark and Rowe, 1971 : p. 184; Rowe and Doty, 1977 : p. 235-236.

Type locality : Navigator Island.

Material : Only one male specimen examined. Length 12.0 cm and weight 15 gram.

Habitat : Found among brown algae (Turbinaria sp.).

Morphology (Pl. XVIII A) : Body uniformly cylindrical, long fragile and snake-like with prominent terminal mouth and anus; colour light yellow with darker transverse line on dorsal side, ventrally creamy white; pinnate tentacles fourteen and united by thin web. Papillae and pedicels absent.

Spicules (Pl. XVIII B) : Spicules consisted of anchor and plates with large hole at one end and small hole at another end.

Anatomy (Fig. 20) : Body wall very thin and fragile; eight calcareous rings, four polian vesicles with round ends and single stone canal; straight and long intestine very short on dissection with fine sediments, visible through intestinal wall; absence of respiratory tree characteristic; haemal system very simple concentrates at middle of intestine on alternate sides; sexes separate, single tuft of gonad on left side of the mesentery.

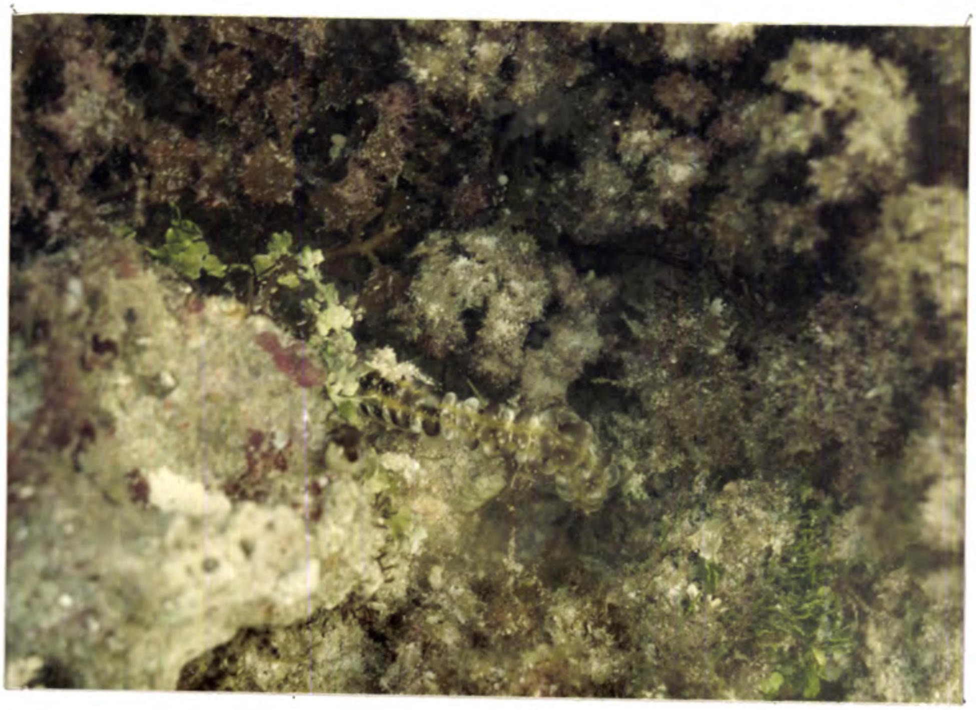


PLATE XVIII A. Euapta godeffroyi

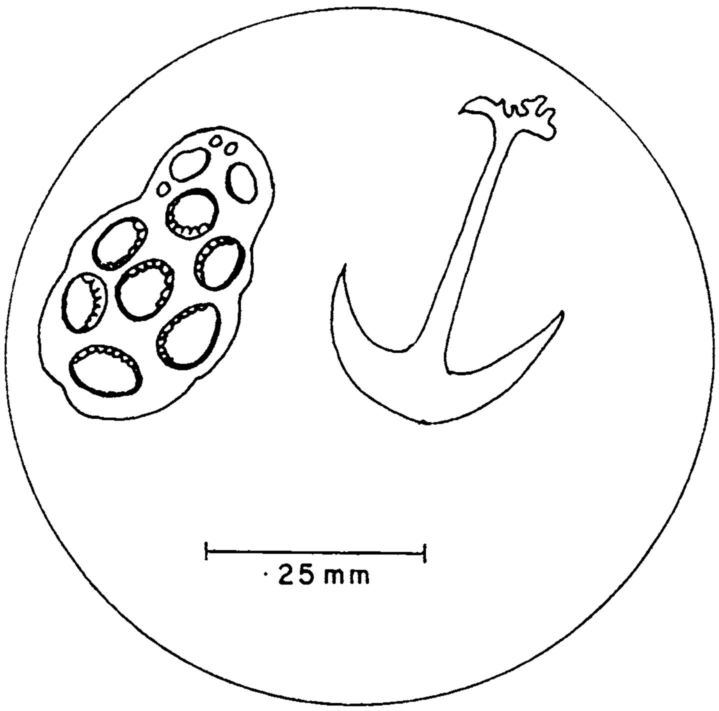


PLATE XVIII B. Spicules of Euapta godeffroyi

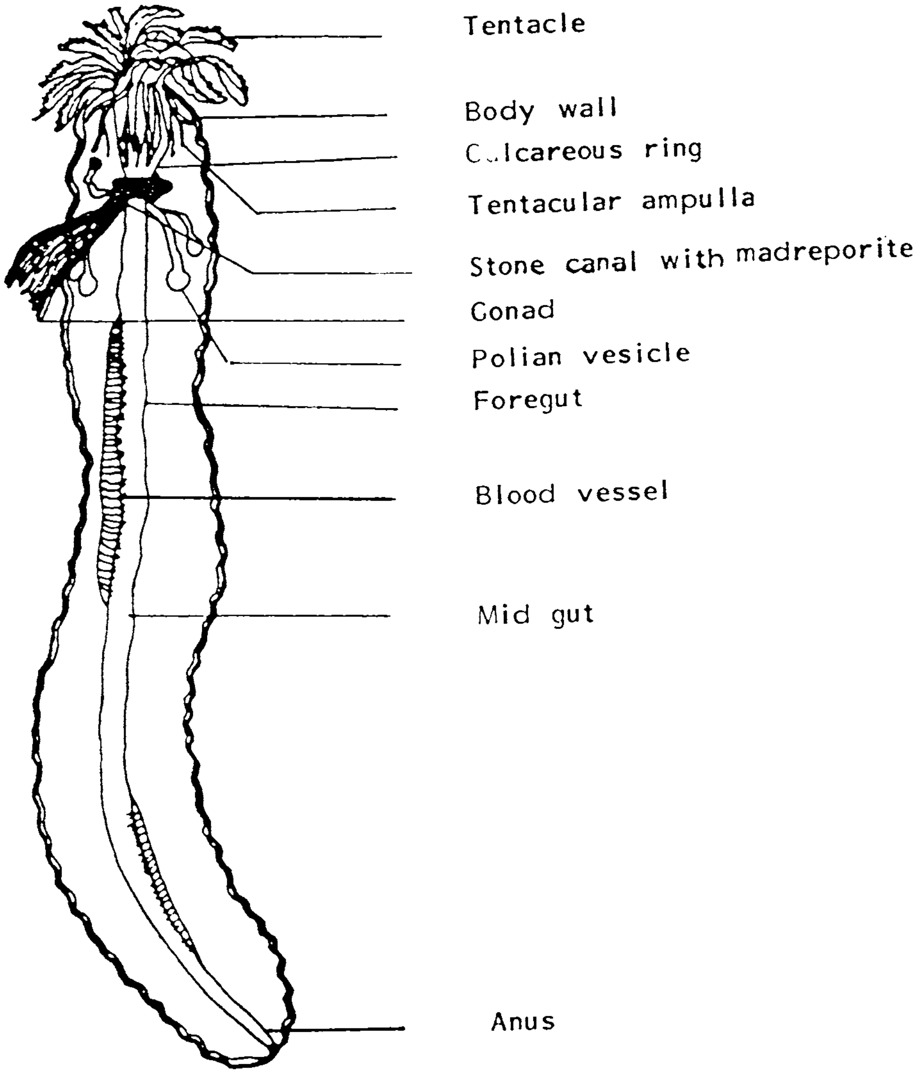


Fig.20. Anatomy of <u>Euapta godeffroyi</u>.

Distribution : Throughout Indo-West Pacific and Lakshadweep Islands in India.

Remarks : This species is not of commercial value due to its small nature and rare occurrence.

CHAPTER 2

CHAPTER II. MORPHOMETRY AND BIOMETRY OF *HOLOTHURIA NOBILIS* AND *ACTINOPYGA MAURITIANA*

INTRODUCTION

The echinoderms particularly holothurians are well known for changing their body shape and do not have a static body shape. Moreover they have external papillae and pedicels all over the body taking the measurements difficult. The study of morphometry in holothurian is still a contraversial subject. However, attempts had been made by certain authors and obtained results using the length and weight of some of these species (Bonham and Held, 1963 on *H. atra*; Conand, 1990 on *H. nobilis*, *H. scabra* and *T. ananas*; Shelley, 1985 on *H. scabra*). At the same time Bakus (1973) reported that morphometry on holothurians will not give a reliable results, because of their shrinking nature (Bakus, 1973; Harriot, 1979). But recently Sewell (1991) stated that the length of the animal is not reliable, but weight could be used for certain aspects of morphometry. It is emphasized here that body weight also greatly variable in holothurians due to their water intake through the well developed water-vascular system and evisceration phenomenon prevailed in holothurians. In the opinion of the candidate, morphometry namely length and weight (total, drained and gutted weight) of holothurian is possible to some extent and careful understanding of the animal both in the field and in the laboratory. With this view in mind, an attempt has been made and the results are reliable and interesting to the maximum extent, which are presented in this chapter.

MATERIALS AND METHODS

Fortnightly sampling of *Holothuria nobilis* from nine stations in the lagoon and *Actinopyga mauritiana* from three stations along reef flat were collected for morphometric study, from January 1990 to December 1991. These two species were selected for the study as they are commercially important and commonly available in the Minicoy Island.

Collection

Holothuria nobilis was collected by skin diving from the lagoon and *Actinopyga mauritiana* was collected by hand picking from the reef flat. These animals were put in a gunny bag and brought to the laboratory by boat.

Measurement of Length and Weight

As the sea-cucumbers are known for their body contraction, the animals were kept in 100 litres capacity aquarium tanks with pure seawater and allowed for 30 minutes for relaxation and to recover their normal body size. After ensuring that the animals fully recovered from contraction, quickly and without disturbance the total length (TL) to the nearest 0.5 cm was measured dorsally from mouth to anus using flexible Tailor's measuring Tape. This was followed uniformly throughout the study. The weight of these sea-cucumbers were measured as follows:

Total weight : Maximum care was taken to lift from the aquarium tank and place it on the pan with minimum disturbance to avoid evisceration and enormous expulsion of body water and weight was taken to the nearest 5 gm using monopan balance ISHIDA (5 - 3000 gm).

Drained weight : The same animal was taken out from the balance, a gentle slit was made near the anal region and allowed to expell or drain the body water totally. The body was cleaned with blotting paper and cotton wool to absorb the water completely. On satisfaction of the water draining, the drained weight of the animal was taken to the nearest 5 gm using monopan balance ISHIDA (5 - 2000 gm).

Gutted weight : After drained weight was taken, a longitudinal slit was made from the mouth to anus on ventral side and the whole internal organs were completely removed and only the body wall was measured using BRAUN (5 - 1000 gm) monopan balance to the nearest 5 gm and recorded.

Data analysis

In total 488 *H. nobilis* from the lagoon and 939 *A. mauritiana* from the reef flat of Minicoy Island were collected for this study. The data were used for three aspects such as morphometric analyses, size-frequency distribution and biometric relationship of these two species.

Morphometric characters : Total length, total weight, drained weight and gutted weight were taken for this aspect and results presented for *H. nobilis* in the form of minimum, maximum, mean and standard deviation for stationwise - male, female sex combined, male and female separately, whole population of male, female and pooled over 9 stations (1 to 9) data as a whole population for entire period of study for whole area. In *A. mauritiana* as there is no male and female sex, the results are presented in the form of stationwise population and pooled over 3 reef stations (10, 11 & 12) for entire period of study as a whole population.

Size frequency analysis : The morphometric characters were analysed for size frequency study by histogram for both species as follows:

Length : 4 cm class interval for *H. nobilis* and 5 cm class interval for *A. mauritiana* were used for length frequency analysis, as the length of former species varied from 20.0 cm to 39.0 cm and latter species ranged from 4.0 cm to 30.0 cm.

Weight : 300 gm class interval for H. nobilis and 200 gm class intervals for A. mauritiana were taken for total weight, drained weight and gutted weight frequency analysis. In H. nobilis total weight varied from 500 to 2200 gm, drained weight from 480 to 1900 gm and gutted weight from 300 to 1400 gm and in A. mauritiana the total weight varied from 18 to 1000 gm, drained weight from 10 to 1000 gm and gutted weight from 5 to 850 gm.

Biometric relationship : Biometric relationship between length and weight (total weight, drained weight and gutted weight) were investigated by regression analysis using the formula $Y = a x^b$ for H. nobilis and A. mauritiana. ANCOVA analysis was used for slope test.

SECTION A : MORPHOMETRY

Holothuria nobilis

The results of morphometric characters of total length (TL) total weight (TW), drained weight (DW) and gutted weight (GW) of H. nobilis have been studied here for nine lagoon stations individually for male and female sex combined, male and female population separately and pooled population of male and female of nine lagoon stations and pooled over nine stations data as a whole populations during the period January 1990 to December 1991.

Morphometry of stationwise population

Male and female combined : The total length ranged from 20.0 to 39.0 cm with total weight between 500 and 2200 gm, drained weight between 420 and 1900 gm and gutted weight between 300 and 1450 gm. Within 9 stations the mean total length varied between 31.0 ± 4.48 to 33.5 ± 3.60 cm, mean total weight between 1392.50 ± 481.77 to 1577.77 ± 429.62 gm, mean drained weight between 1125.83 ± 384.60 to 1250.50 ± 410.32 gm and mean gutted weight between 885.83 ± 279.51 to 1100.20 ± 273.90 gm (Table 1).

Male : The range of total length, total weight, drained weight and gutted weight were 20.0 - 39.0 cm, 500 - 2200 gm, 420 - 1900 gm and 300 - 1450 gm respectively. Within 9 stations the mean total length of male varied between 29.50 ± 4.10 and 31.68 ± 4.12 cm, mean total weight between 1280.33 ± 393.28 to 1480.15 ± 512.60 gm, mean drained weight between 1009.33 ± 321.84 and 1220.18 ± 312.15 gm and gutted weight between 863.00 ± 267.87 and 960.10 ± 230.00 gm (Table 2).

Female : Table 3 gives the minimum, maximum, mean and standard deviation of morphometric characters for female H. nobilis for all the nine stations studied in the lagoon. The total length ranged from 20 to 39 cm, total weight between 580 to 2200 gm, drained weight between 420 and 1900 gm and gutted weight between 365 and 1400 gm. Within 9 stations, the mean total length varied between 30.40 ± 4.09 and 32.12 ± 5.82 cm, mean total weight 1346.31 ± 527.47 and 1512.05 ± 412.00 gm, mean drained weight between 1071.33 ± 300.96 and 1282.58 ± 467.40 gm, and gutted weight between 862.80 ± 218.10 and 1110.55 ± 260.00 gm.

Moreover, Table 4 gives the picture of morphometric characters separately for male and female pooled over 9 stations and for whole populations (both sex combined) during the study period for whole area.

Size Frequency

The results of the size frequency studies carried out on

TABLE 1. **Stationwise morphometry of combined population (both male and female) of *H. nobils* pooled over 24 months (January 1990 - December 1991) at Minicoy Island**

Stations	Number of animals	Total length (cm)			Total weight (gm)			Drained weight (gm)			Gutted weight (gm)		
		Minimum	Maximum	Mean & SD	Minimum	Maximum	Mean & SD	Minimum	Maximum	Mean & S.D	Minimum	Maximum	Mean & SD
1	91	24.0	39.0	32.54 ± 3.65	500.0	2200.0	1577.77 ± 429.62	430.0	1890.0	1233.30 ± 344.22	365.0	1400.0	972.80 ± 259.20
2	63	20.0	38.5	31.56 ± 4.76	580.0	2100.0	1452.70 ± 487.43	420.0	1800.0	1173.81 ± 400.11	300.0	1350.0	921.11 ± 291.28
3	42	20.0	38.0	31.97 ± 4.37	540.0	2200.(	1486.52 ± 446.21	430.0	1750.0	1205.22 ± 356.36	370.0	1310.0	951.30 ± 265.54
4	61	24.0	38.5	32.36 ± 4.08	700.0	2200.0	1487.38 ± 408.07	610.0	1900.0	1233.78 ± 403.75	500.0	1400.0	952.05 ± 291.93
5	32	21.5	37.0	31.00 ± 4.48	600.0	2100.0	1392.50 ± 481.77	520.0	1700.0	1125.83 ± 384.60	450.0	1310.0	885.83 ± 279.51
6	43	22.0	38.0	31.75 ± 3.98	590.0	2200.0	1450.50 ± 450.12	450.0	1900.0	1200.40 ± 369.71	400.0	1450.0	915.80 ± 269.51
7	45	20.0	38.5	31.15 ± 4.50	500.0	2200.0	1520.70 ± 440.30	420.0	1900.0	1250.50 ± 410.32	350.0	1410.0	1100.20 ± 273.90
8	42	24.5	39.0	33.50 ± 3.60	720.0	2200.0	1452.20 ± 480.41	600.0	1750.0	1210.80 ± 390.60	480.0	1300.0	900.00 ± 301.23
9	63	24.5	38.0	31.00 ± 4.05	700.0	2200.0	1520.22 ± 460.21	585.0	1830.0	1200.50 ± 400.71	490.0	1410.0	1000.00 ± 260.51

TABLE 2. Stationwise morphometry of male *H. nobilis* pooled over 24 months (January 1990 - December 1991) at Minicoy Island

Stations	Number of animals	Total length (cm)			Total weight (gm)			Drained weight (gm)			Gutted weight (gm)		
		Minimum	Maximum	Mean & SD	Minimum	Maximum	Mean & SD	Minimum	Maximum	Mean & S.D	Minimum	Maximum	Mean & SD
1	32	24.0	38.5	31.68± 4.12	500.0	2200.0	1480.15± 512.60	680.0	1710.0	1220.18± 312.15	490.0	1400.0	960.10± 230.00
2	31	21.5	38.0	31.15± 4.21	600.0	2100.0	1410.16± 451.12	420.0	1890.0	1102.50± 364.74	300.0	1350.0	863.00± 267.87
3	30	20.0	37.0	29.50± 4.10	540.0	1800.0	1280.33± 393.28	430.0	1500.0	1009.33± 321.84	400.0	1220.0	867.00± 260.00
4	30	24.0	37.0	31.00± 3.60	800.0	1800.0	1363.70± 415.51	700.0	1900.0	1133.70± 331.60	520.0	1280.0	884.63± 250.34
5	21	21.5	36.5	30.42± 4.82	600.0	2000.0	1340.00± 476.26	520.0	1700.0	1110.76± 377.50	450.0	1210.0	860.48± 260.20
6	26	22.0	37.5	31.27± 4.39	590.0	2100.0	1396.62± 545.77	450.0	1700.0	1040.11± 360.40	500.0	1450.0	900.50± 270.00
7	17	20.0	37.0	29.60± 4.70	800.0	2000.0	1412.10± 530.20	610.0	1650.0	1180.16± 370.33	350.0	1160.0	890.15± 302.00
8	21	24.5	39.0	30.75± 4.05	890.0	2200.0	1460.15± 410.05	500.0	1580.0	1040.10± 305.25	480.0	1300.0	905.11± 292.00
9	39	24.0	37.5	29.68± 4.10	700.0	1900.0	1305.10± 400.50	700.0	1600.0	1180.15± 385.12	510.0	1120.0	910.11± 320.00

TABLE 3. **Stationwise morphometry of female *H. nobilis* pooled over 24 months (January 1990 - December 1991) at Minicoy Island**

Stations	Number of animals	Total length (Cm)			Total weight (gm)			Drained weight (gm)			Gutted weight (gm)		
		Minimum	Maximum	Mean & SD	Minimum	Maximum	Mean & SD	Minimum	Maximum	Mean & S.D	Minimum	Maximum	Mean & SD
1	48	20.0	39.0	32.12 ± 5.82	610.0	2200.0	1440.60 ± 380.15	430.0	1800.0	1200.15 ± 310.15	365.0	1260.0	900.15 ± 312.00
2	32	20.0	38.5	31.55 ± 5.24	580.0	2100.0	1346.31 ± 527.47	430.0	1800.0	1121.25 ± 381.78	400.0	1220.0	862.80 ± 218.10
3	16	20.5	38.0	31.53 ± 4.95	620.0	2200.0	1360.63 ± 483.87	500.0	1750.0	1101.25 ± 322.25	370.0	1340.0	903.33 ± 265.84
4	30	25.0	38.5	32.17 ± 4.66	700.0	2200.0	1424.52 ± 534.85	610.0	1850.0	1282.58 ± 467.90	500.0	1310.0	904.33 ± 207.90
5	15	22.0	37.0	30.40 ± 4.07	700.0	2100.0	1367.43 ± 487.38	540.0	1780.0	1071.33 ± 300.96	500.0	1310.0	904.33 ± 200.90
6	22	24.0	38.0	31.55 ± 4.15	680.0	2200.0	1415.20 ± 530.00	600.0	1900.0	1260.15 ± 412.15	400.0	1340.0	890.00 ± 312.15
7	25	22.5	38.5	30.50 ± 4.19	800.0	2200.0	1500.63 ± 480.15	420.0	1900.0	1160.40 ± 405.00	610.0	1400.0	1110.55 ± 260.00
8	19	24.5	38.0	31.12 ± 5.02	725.0	2100.0	1380.18 ± 430.28	630.0	1710.0	1190.15 ± 360.00	510.0	1125.0	890.33 ± 380.15
9	25	24.0	36.5	30.93 ± 4.60	800.0	2200.0	1512.05 ± 412.00	710.0	1790.0	1265.63 ± 382.70	490.0	1400.0	960.65 ± 315.90

TABLE 4. Morphometric of male, female and combind population pooled for all 9 stations of lagoon during all the 24 months in Minicoy Island

Serial Number	Morphometric Characters	Male population			Female population			Total Population		
		Minimum	Maximum	Mean & SD	Minimum	Maximum	Mean & SD	Minimum	Maximum	Mean & SD
1	Total length (cm)	20.0	39.0	32.18 ± 3.98	20.0	39.0	34.03 ± 4.83	20.0	39.0	33.78 ± 5.87
2	Total weight (gm)	500.0	2200.0	1580.70 ± 412.05	500.0	2200.0	1620.10 ± 433.50	500.0	2200.0	1680.20 ± 485.43
3	Drained weight (gm)	400.0	1800.0	1200.00 ± 340.72	400.0	1800.0	1262.00 ± 352.10	400.0	1800.0	1301.00 ± 412.60
4	Gutted weight (gm)	300.0	1450.0	980.92 ± 260.10	300.0	1400.0	995.00 ± 284.08	300.0	1450.0	982.00 ± 295.51

H. nobilis during the study period in Minicoy Lagoon are presented below for the whole population, male and female separately, station-wise (9 lagoon stations) and for the whole area.

Male and female combined

Total Length : In general, an overall observation in all of 9 stations studied in the Minicoy Lagoon, showed a single peak uniformly for H. nobilis population at class interval 32.0 - 36.0 cm size only (Fig. 21 A) which is an interesting finding. In this class interval the minimum composition of 36% at station 4 and 6 and the maximum 52% at stations 3 and 9 were seen. However, the fluctuation in length observed in station 1 was between 24.0 cm and 39.0 cm with 12% at class interval 24.0 - 28.0 cm and 26.5 % at class interval 36.0 - 40.0 cm size group. The highest mode was observed at class interval 32.0 cm to 36.0 cm with 38 %. Station 2 showed a minimum size of 20.0 cm, which is the smallest size of the animal observed for the whole population also with 8% at class interval 20.0 - 24.0 cm and maximum size of 38.5 cm with 19.5% at class interval 36.0 - 40.0 cm. The highest peak with 48.57 was observed in class interval 32.0 - 36.0 cm. Station 3 indicated minimum size at 20.0 cm and maximum 38.0 cm with 7.5% at the class interval 20.0 - 24.0 cm and 15% at the class interval 36.0 - 40.0 cm. The highest peak was at the class interval 32.0 - 36.0 cm with 52% in this station. From station 4, it was observed that the smallest at 24.0 cm with 18% and longest at 38.5 cm with 25.5%. The highest mode observed in this station at class interval 32.0 - 36.0 cm was with 36%. Minimum size of 21.5 cm with 11.5% at the class interval 20.0 - 24.0 cm and maximum 37.0 cm with 15% at the class interval 36.0 - 40.0 cm were seen in station 5. The highest peak observed in this station at class interval 32.0 - 36.0 was 44%. It was noticed in station 6 that the minimum size was 22.0 cm with 4% at class interval 20.0 - 24.0 cm and maximum size 38.0 cm with 19% at the class interval 36.0 - 40.0 cm. Further the highest mode was noticed at the class

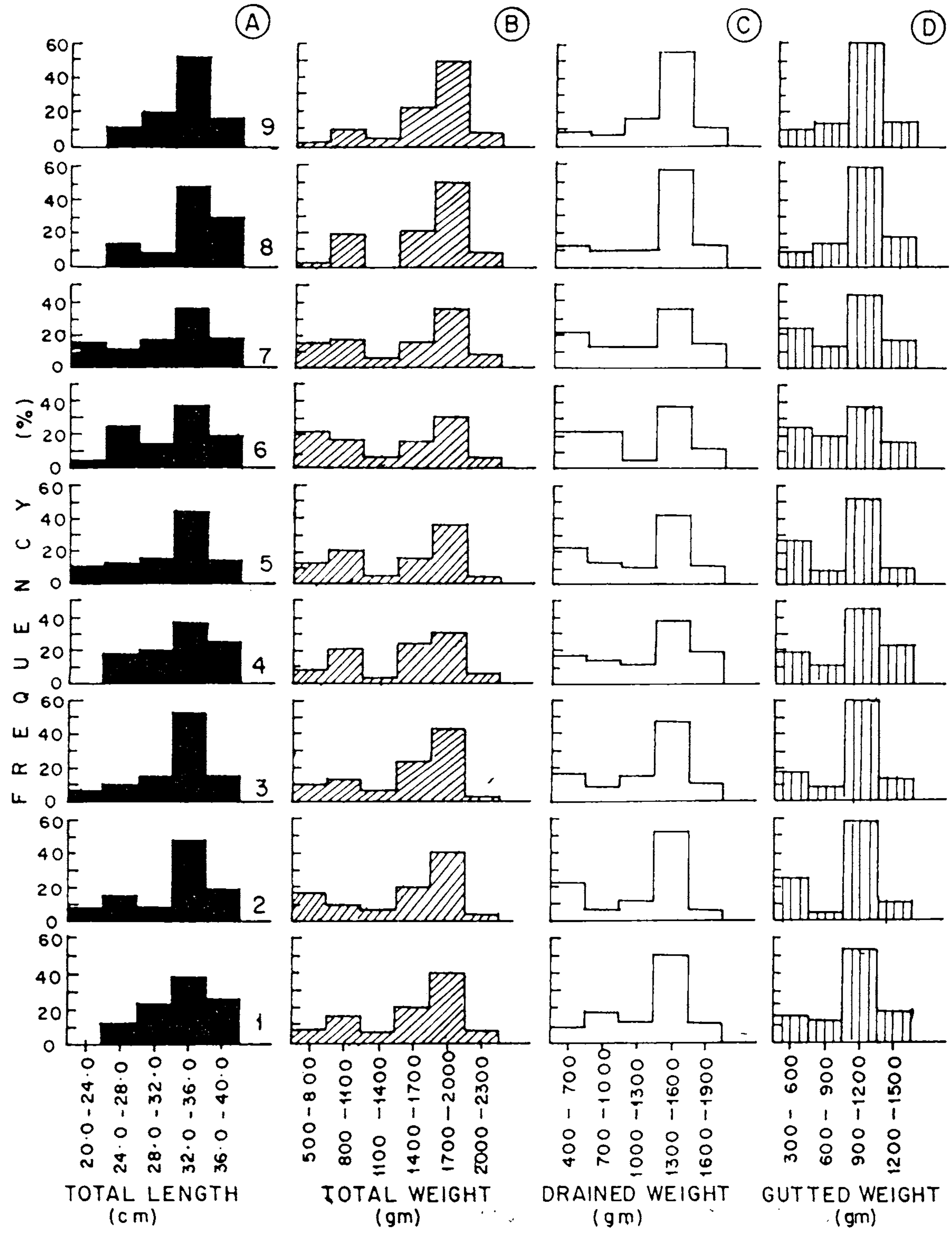


Fig.21. Size frequency distributions of combined (male and female) population of H.nobilis in 9 stations of lagoon at Minicoy Island during January 1990 - December 1991.

interval 32.0 - 36.0 cm with 37.5%. Station 7 indicated minimum size of 20.0 cm with 16% at the class interval 20.0 - 24.0 cm and maximum size of 38.5 cm with 19% at the class interval 36.0 - 40.0 cm. The highest mode observed in this station at class interval 32.0 - 36.0 cm was 36% and unusually the lowest composition with 11.5% at class 24.0 - 28.0 cm. In station 8, the animal length varied from 24.5 cm to 39.0 cm with 14% at the class interval 24.0 - 28.0 cm and 30% at the class interval 36.0 - 40.0 cm. The highest mode noticed at 32.0 - 36.0 cm size group was 48%. No animal was observed in class 20.0 - 24.0 cm as in the case of station 1, 4, 8 and 9. In station 9, the smallest animal was 24.5 cm with 11.5% at the class interval 24.0 - 28.0 cm and maximum size of 38.0 cm with 17% at the class interval 36.0 - 40.0 cm. The highest composition was noticed with 52% at the class interval 32.0 - 36.0 cm in this station, as in the case of station 3. However, in station 1, 4, 8 and 9 there was no animal belonging to class interval 20.0 - 24.0 cm during the study period.

Total weight : It is characteristic that in all 9 stations, single peak was observed in total weight (Fig. 21 B) at the class interval 1700 - 2000 gm. Among the peaks in all 9 stations the minimum was 31.3% at station 4 and 6, and 50% maximum was at station 8 and 9. However, the fluctuation in total weight observed in station 1 was between 500 gm and 2200 gm with a minimum percentage composition of 6.6% at the class interval 1100 - 1400 gm and maximum of 40.7% at class interval 1700 - 2000 gm, but the heaviest animal constituted only 7.7% at the class interval 2000 - 2300 gm. In station 2, the smallest animal with 580 gm and largest with 2100 gm constituting 17.5% at class interval 500 - 800 gm and 4.8% at the class interval 2000 - 2300 gm respectively were observed. The minimum composition of 4.8% was observed at class interval 2000 - 2300 gm and maximum of 41.3% at class interval 1700 - 2000 gm in this station. In station 3, the weight varied from 540 gm to 2200 gm with 10.9% at class interval 500 - 800 gm and 2.2% at class interval 2000 - 2300 gm. The lowest composition was 2.2 % at class interval 2000 - 2300 gm and highest was 43.5% at class interval 1700 - 2000 gm. Station 4 indicated the minimum weight 700 gm with 8% at class interval 500 - 800 gm and maximum weight 2200 gm with 11.5% at class interval 2000 - 2300 gm. However, in this station the lowest value of 3.3% at class interval 1100 - 1400 gm and highest value 31.3% at class interval 1700 - 2000 gm were seen. Minimum weight of 600 gm with 13.9% at class interval 500 - 800 gm and maximum weight of 2100 gm with 5.6% at class interval 2000 - 2300 gm were noticed in station 5. Further in this station the lowest composition 5.6% at class interval 1100 - 1400 gm and the higher composition 36.1% at class interval 1700 - 2000 gm were also noticed in this station. It was observed in station 6 that the minimum weight was 590 gm with 22.9% at class interval 500 - 800 gm, and maximum weight 2200 gm with 6.3% at class interval 2000 - 2300 gm. The lowest composition was at class interval 1100 - 1400 gm with 6.3% and highest was at class interval 1700 - 2000 gm with 31.3%. Station 7 showed the minimum of weight 500 gm with 15.6% at class interval 500 - 800 gm and maximum of 2200 gm with 8.9% at class interval 2000 - 2300 gm. The lowest composition was 6.7% at class interval 1100 - 1400 gm and highest composition was 35.6% at class interval 1700 - 2000 gm in this station. Station 8 showed weight variation between 720 gm and 2200 gm with 2.4% at class interval 500 - 800 gm. and 7.2% at class interval 2000 - 2300 gm but no animal was observed at class interval 1100 - 1400 gm and the percentage composition was 50% at class interval 1700 - 2000 gm. From station 9, it was observed that the minimum weight at 700 gm with 2.9% at class interval 500 - 800 gm and maximum weight at 2200 gm with 8.8% at class interval 2000 - 2300 gm. Further the lowest composition observed at class interval 1100 - 1400 gm was 5.9% and highest composition at class interval 1700 - 2000 gm was 50%.

Drained weight : As in the case of total weight (Fig. 21 B), in all 9 stations showed a single peak for drained weight also at class interval 1300 - 1600 gm (Fig. 21 C). Among the peaks of 9 stations the minimum was 37.5% at station 4, 6 and 7 and the maximum of 57.9% at station 8 and 9 were seen. However, the variation in drained weight observed in station 1 was between 430 gm and 1890 gm with 8.8% at class interval 400 - 700 gm and 11% at class interval 1600 - 1900 gm. The highest composition was 50.6% at class interval 1300 - 1600 gm. It could be seen from station 2 that, the minimum drained weight was 420 gm with percentage composition of 23.8% at class interval 400 - 700 gm and maximum drained weight was 1800 gm with 6.4% at class interval 1600 - 1900 gm. The minimum composition in this station was 6.4% at class interval 700 - 1000 gm and maximum was 52.4% at class interval 1300 - 1600 gm. In station 3, the smallest animal was 430 gm at class interval 400 - 700 gm and largest animal was 1750 gm. The lowest composition was 8.7% at class interval 700 - 1800 gm and highest composition was 47.8% at class interval 1300 - 1600 gm. In station 4, the animal with 610 gm and maximum 1900 gm were recorded with 16.4% at class interval 400 - 700 gm and 19.9% at class interval 1600 - 1900 gm. The minimum composition observed in this station was 11.5% at class interval 1000 - 1300 gm and highest composition was 37.5% at class interval 1300 - 1600 gm. Station 5 indicated the drained weight ranged from 520 gm to 1700 gm with 22.2% at class interval 400 - 700 gm and 11.2% at class interval 1600 - 1900 gm. The minimum composition noticed in this station was 11.2% at class interval 1000 - 1300 gm and maximum was 42.7% at class interval 1300 - 1600 gm. From station 6 it was observed that the lowest weight was at 450 gm with 22.9% at class interval 400 - 700 gm and highest weight was at 1900 gm with 12.5% at class interval 1600 - 1900 gm. Further the minimum composition of 4.2% at class interval 1000 - 1300 gm and maximum 37.5% at class interval 1300 - 1600 gm were also seen in this station. Minimum weight of 420 gm with 22.3% at class interval 400 - 700 gm and maximum weight of 1900 gm with 12.5% at class interval 1600 - 1900 gm were noticed in station 7, but the minimum composition was 13.3% at class interval 700 - 1000 gm and 1000 - 1300 gm and maximum composition was 35.5% at class interval 1300 - 1600 gm. Station 8 showed minimum weight of 600 gm and maximum of 1750 gm both with 12% at class interval 400 - 700 gm and 1600 - 1900 gm. Further in this station the minimum composition of 9.5% was noticed at class interval 700 - 1000 gm and 1000 - 1300 gm and maximum 57.9% was at class interval 1300 - 1600 gm. The drained weight varied between 585 gm and 1830 gm with 8.8% at class interval 400 - 700 gm and 11.8% at 1600 - 1900 gm respectively in station 9. Further the minimum composition of 7.4% was at class interval 700 1000 gm and maximum was 57.9% at class interval 1300 - 1600 gm in this station.

Gutted weight : Similar to total weight and drained weight in all 9 stations a single peak was observed for gutted weight also (Fig. 21 D) at the class interval 900 - 1200 gm with minimum composition of 37.5% among the peaks at station 6 and maximum composition of 60% at station 3 and 9. However, the fluctuation in gutted weight observed in station 1 was between 365 gm and 1400 gm with 15.4% at class interval 300 - 600 gm and 18.7% at class interval 1200 - 1500 gm. The lowest composition 12% was observed at class interval 600 - 900 gm and highest 53.9% was at class interval 900 - 1200 gm. Station 2 showed minimum weight of 300 gm and maximum weight 1350 gm with 25.4% at class interval 300 - 600 gm and 11% at class interval 1200 - 1500 gm respectively. Further the lowest composition was noticed in this station was 4.8% at class interval 600 - 900 gm and highest was 58.7% at class interval 900 - 1200 gm. In station 3, the gutted weight ranged from 370 gm to 1310 gm with 17.4% at class interval 300 - 600 gm and 13.9% at class interval 1200 - 1500 gm. The minimum composition observed in this station at class interval 600 - 900 gm was 8.7% and maximum at class interval

900 - 1200 gm was 60%. Minimum weight of 500 gm with 19.7% at class interval 300 - 600 gm and maximum weight of 1400 gm with 23% at class interval 1200 - 1500 gm were seen in the station 4. However, the lowest composition was 11.5% at class interval 600 - 900 gm and highest was 45.9% at class interval 900 - 1200 gm were seen. It could be seen in the station 5 that the weight range varied from 450 gm to 1310 gm with 27.8% at class interval 300 - 600 gm and 11% at class interval 1200 - 1500 gm, but the lowest composition could be seen in the class interval 600 - 900 gm with 8.3% and highest composition in the class interval 900 - 1200 gm with 52.9%. Station 6 showed the gutted weight variation of 400 gm with 25% at class interval 300 - 600 gm and 1450 gm with 16.7% at class interval 1200 - 1500 gm which was also the lowest composition among all class intervals. The maximum composition observed in this station was 37.5% at class interval 900 - 1200 gm. In station 7, the recorded minimum weight was 350 gm with 24.4% at class interval 300 - 600 gm and maximum weight was 1410 gm with 17.9% at class interval 1200 - 1500 gm. The lowest composition of 13.3% in the class interval 600 - 900 gm and highest composition 44.4% in the class interval 900 - 1200 gm were also recorded in this station. It was noticed in station 8 that, the minimum weight was 480 gm with 9.5% at class interval 300 - 600 gm which was also the lowest among all class interval and maximum weight was 1300 gm with 19% at class interval 1200 - 1500 gm. The highest composition was noticed at class interval 900 - 1200 gm was 57.9%. Minimum 490 gm with 10% at class interval 300 - 600 gm and maximum 1410 gm with 14% at class interval 1200 - 1500 gm were observed at station 9. Further the highest animal composition belonging to class interval 900 - 1200 gm constituted 60%.

Male

Total length : The overall observation in all of 9 stations studied in the lagoon showed a single peak uniformly for male *H. nobilis* population at class interval 32.0 - 36.0 cm size only (Fig. 22 A).

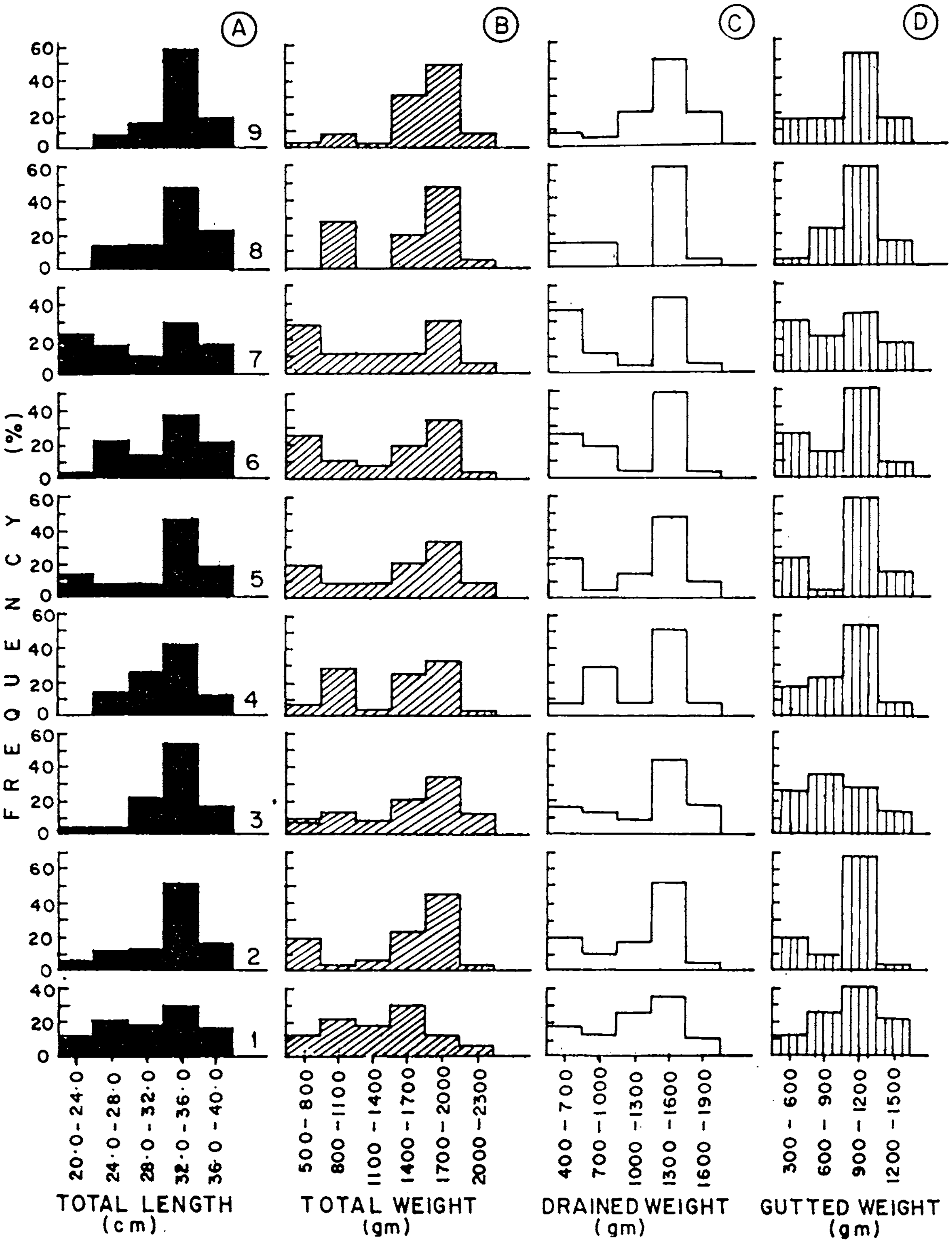


Fig.22. Size frequency distributions Male H.nobilis in 9 stations of lagoon at Minicoy Island during Janaury 1990 - December 1991.

In this class interval the minimum composition was 29.5% at station 1 and 7 and the maximum was 59% at station 9. Moreover, the fluctuation observed in toal length at station 1 was between 24.0 cm and 38.5 cm with 12.5% at class interval 20.0 - 24.0 cm and 17.5% at class interval 36.0 - 40.0 cm. The highest composition noticed at class interval 32.0 - 36.0 cm was 29.5%. Station 2 showed a minimum size of 21.5 cm with 6.5% at class interval 20.0 - 24.0 cm, which was also the lowest composition among all class intervals and maximum size of 38 cm with 16.1% at class interval 36.0 - 40.0 cm. The peak composition was 51.6% at class interval 32.0 - 36.0 cm in this station. Station 3 indicated minimum size of 20.0 cm with 4.4% at class interval 20.0 - 24.0 cm and maximum of 37.0 cm with 17.3% at class interval 36.0 - 40.0 cm. Further this station indicated the peak composition of 52.2% at class interval 32.0 - 36.0 cm. From station 4, it was observed that the length range varied from 24.0 cm to 37.0 cm with 14% at class interval 24.0 - 28.0 cm and 14.3% at class interval 36.0 - 40.0 cm, but the highest composition 42.9% was at class interval 32.0 - 36.0 cm. Minimum size of 21.5 cm with 14.3% at class interval 20.0 - 24.0 cm and maximum size of 36.5 cm with 19.1% at class interval 36.0 - 40.0 cm were seen in station 5. Further in this station the lowest composition 9.5% was seen in the class interval 24.0 - 28.0 cm and 28.0 - 32.0 cm and highest composition 47.6% was at class interval 32.0 - 36.0 cm. It was noticed in station 6 that the minimum size was 22.0 cm with 37.5% at class interval 20.0 - 24.0 cm, which was also lowest composition among all class intervals and in all 9 stations, and maximum size was 37.5 cm with 22.2% at class interval 36.0 - 40.0 cm. Further the highest composition was 37.1% at class interval 32.0 - 36.0 cm in this station. In station 7, the length varied between 20.0 cm and 37.0 cm with 23.3% at class interval 20.0 - 24.0 cm and 17.7% at class interval 36.0 - 40.0 cm. Further, in this station lowest composition was 11.8% at class interval 28.0 - 32.0 cm and highest composition was 29.5% at class interval 32.0 - 36.0 cm. Station 8 showed the minimum length 24.5 cm with 14.3%

at class interval 24.0 - 28.0 cm and maximum length 39.0 cm with 23.8% at class interval 36.0 - 40.0 cm. The highest composition was 47.6% at class interval 32.0 - 36.0 cm. The minimum length of 24.0 cm and maximum of 37.5 cm recorded in station 9 with 7.6% at class interval 24.0 - 28.0 cm which was also smallest composition among the all class intervals and 18% at class interval 36.0 - 40.0 cm. The highest composition was 59% at the class interval 32.0 - 36.0 cm in this station. However, in station 4, 8 and 9 there was no animal belonging to the class interval 20.0 - 24.0 cm during the study period.

Total weight : The frequency analyses of total weight showed a single peak at class interval 1700 - 2000 gm from station 2 to 9 whereas in station 1 it was at class interval 1400 - 1700 gm with 29.8% (Fig. 22 B). Among the peaks in station 2 to 8 the minimum composition was 32.2% at station 4 and maximum was 48.7% at station 9. However, the fluctuation observed in total weight at station 1 was between 500 gm and 2200 gm with 12.8% at class interval 500 - 800 gm and 6.4% at class interval 2000 - 2300 gm, which was also lowest composition. The highest composition was 29.8% at class interval 1400 - 1700 gm in this station. Station 2 showed weight variation from 600 gm to 2100 gm with 19.3% at class interval 500 - 800 gm and 3.2% at class intervals 800-1100 & 2000-2300 gm was also observed. The highest composition was 45.2% at class interval 1700 - 2000 gm in this station. In station 3, the weight varied from 540 gm to 1800 gm with minimum of 8.7% at class interval 500 - 800 gm. However, same composition of 8.7% was also observe at class interval 1100 - 1400 gm. Highest composition of 34.8% at class interval 1700 - 2000 gm was seen in this station. Station 4 indicated the minimum weight of 800 gm with 7% at class interval 500 - 800 gm and maximum of 1800 gm with 3.6% at class interval 2000 - 2300 gm, which was also smallest composition among the other class intervals. Further smallest composition of 3.6% was also observed at class interval 1100 - 1400 gm. Highest was 32.2% at class interval 1700 - 2000 gm.

Minimum weight of 600 gm and maximum of 2000 gm with 19% at class interval 500 - 800 gm and 9.5% at class interval 2000 - 2300 gm were noticed in station 5. In this station the lowest composition of 9.5% was noticed at class intervals 800 - 1100 gm and 1100 - 1400 gm and highest composition of 33.3% at class interval 1700 - 2000 gm. In station 6 the weight was recorded between 590 gm and 2100 gm. 25.9% at class, interval 500 - 800 gm and 3.7% at class interval 2000 - 2300 gm were observed. The peak composition in this station was 33.3% at class interval 1700 - 2000 gm. Station 7 represented with lowest weight of 800 gm. With 29.4% at class interval 500 - 800 gm and maximum weight of 2000 gm with 5.4% at class interval 2000 - 2300 gm. However, the lowest composition of 5.4% was at the highest class interval in this station and 11.8% at class intervals 800 - 1100, 1100 - 1400 and 1400 - 1700 gm are noticeable. The lowest value of 890 gm with 28.6% at class interval 800 - 1100 gm and highest value of 2200 gm with 4.8% at class interval 2000 - 2300 gm, which was also smallest composition among the all other class interval were seen in station 8. Further the peak composition of 47.6% was also noticed at class interval 1700 - 2000 gm in this station. No animal was recorded at class intervals 500 - 800 and 1100 - 1400 gm. In station 9, the weight was recorded between 700 gm and 1900 gm with 2.3% at class interval 500 - 800 gm and 8% at class interval 2000 - 2300 gm. Further, one more smallest composition of 2.3% was recorded at class interval 1100 - 1400 gm. The highest composition 48.7% at class interval 1700 - 2000 gm.

Drained weight : A single peak in all the 9 stations was significant for drained weight at class interval 1300 - 1600 gm (Fig. 22 C). Among the peaks of 9 stations the minimum composition was noticed at station 1 with 34% and maximum was at station 8 with 59%. The variation in drained weight observed in station 1 was from 680 gm with 17% at class interval 400 - 700 gm to 1710 gm with 10.6% at class interval 1600 - 1900 gm, which has also smallest composition among all class intervals in this station. Further the highest composition of 34% was observed at class interval 1300 - 1600 gm. It is seen from station 2 that the minimum drained weight was 420 gm with 19.4% at class interval 400 - 700 gm and maximum was 1800 gm with 3.2% at class interval 1600 - 1900 gm, which was also smallest composition among the all class intervals in this station. The highest composition was 51.6% at class interval 1300 - 1600 gm was also seen. The drained weight variation in station 3 was between 430 gm and 1500 gm both with 17.4% at class interval 400 - 700 gm and 1600 - 1900 gm. Further the lowest composition 8.7% was noticed at class interval 1000 - 1300 gm and highest composition 43.5% at class interval 1300 - 1600 gm. In station 4, the minimum 700 gm and maximum 1900 gm drained weight was recorded with 7.2% for both the weights at class interval 400 - 700 gm and 1600 - 1900 gm and which were also smallest composition of this station. The highest composition of 50% at class interval 1300 - 1600 gm was also recorded in this station. The drained weight varied between 520 gm and 1700 gm with 23.8% at class interval 400 - 700 gm and 9.5% at class interval 1600 - 1900 gm respectively in staion 5, but the lowest composition of this station was 4.8% at class interval 700 - 1000 gm and highest was 47.6% at class interval 1300 - 1600 gm. From station 6, it was observed that the lowest weight at 450 gm with 25.9% at class interval 400 - 700 gm and highest weight at 1700 gm with 3.7 % at class interval 1600 - 1900 gm which was also smallest composition among the all class intervals. Further in this station the composition of 3.7% was noticed at class interval 1000-1300 gm also and highest composition 48.2% at class interval 1300 - 1600 gm. Minimum of 610 gm with 35.3% at class interval 400 - 700 gm and maximum of 1650 gm with 5.9% at class interval 1600 - 1900 gm were recorded in station7, but the smallest composition was 4.9% at class interval 1000 - 1300 gm and highest composition was 42.2% at class interval 1300 - 1600 gm. Station 8 showed the drained weight variation between 500 gm to 1580 gm with 14.3% at class interval 400 - 700 gm and 4.3% at class interval 1600 - 1900 gm. Further the highest composition was 59% at class interval 1300 -

1600 gm and there was no animal recorded at class interval 1000 - 1300 gm in this station. The drained weight varied between 700 gm and 1600 gm with 7.7% at class interval 400 - 700 gm and 20% at class interval 1600 - 1900 gm in station 9. However, the lowest composition was noticed at class interval 700 - 1000 gm with 5.4% and peak composition at class interval 1300 - 1600 gm was 50%.

Gutted weight : Except station 3 where the peak was at the class interval 600 - 900 gm with 34.8%, in all other 8 stations a single peak was noticed in the class interval 900 - 1200 gm (Fig. 22 D) with minimum composition of 32.4% at station 7 and maximum composition of 67.7% at station 2. However, the fluctuation in gutted weight observed in station 1 was between 490 gm and 1400 gm with 12.8% at class interval 300 - 600 gm which was also minimum composition among all the class intervals and 21.3% at the class interval 1200 - 1500 gm. Further the highest composition with 40.0% was noticed at class interval 900 - 1200 gm. Station 2 showed minimum weight of 300 gm with 19.4% at class interval 300 - 600 gm and maximum of 1350 gm with 3.2% at class interval 1200 - 1500 gm which was also smallest composition among all the class intervals in this station. The peak composition noticed at class interval 900 - 1200 gm was 67.7%. The situation is slightly changed in station 3 with gutted weight ranging from 400 gm to 1220 gm with 26.4% at class interval 300 - 600 gm and 14% at class interval 1200 - 1500 gm, which was also lowest composition among all other class intervals, but the highest composition was 34.8% at class interval 600 - 900 gm. Minimum weight of 520 gm and maximum of 1280 gm with 17.9% at class interval 300 - 600 gm and 7.1% at class interval 1200 - 1500 gm were recorded in station 4. But the peak percentage composition was 53.6% at class interval 900 - 1200 gm. It is seen in the statiion 5 that the weight range varied between 450 gm to 1210 gm with 23.8% at class interval 300 - 600 gm and 13.5% at class interval 1200 - 1500 gm which was also smallest composition among the all class intervals in this station. The class interval 900 -

1200 gm constituted 58%. Station 6 showed the gutted weight variation between 500 gm and 1450 gm with 25.9% at class interval 300 - 600 gm and 7.4% at class interval 1200 - 1500 gm which was also a small composition among the all class intervals. The peak composition noticed was 50.0% at class interval 900 - 1200 gm. In station 7 the recorded minimum weight was 350 gm with 29.4% at class interval 300 - 600 gm and maximum was 1160 gm with percentage composition 17.7% at class interval 1200 - 1500 gm, which was also lowest composition among all the class intervals in this station. Further the highest composition of 32.4% was recorded at class interval 900 - 1500 gm. Station 8 showed the gutted weight range between 480 gm and 1300 gm with 4.5% at class interval 300 - 500 gm, and 14.5% at class interval 1200 - 1500 gm respectively. The smallest percentage composition 4.5% was seen in the class interval 300 - 600 gm. The highest composition in the class interval 900 - 1200 gm was 57.2%. Minimum 510 gm and maximum 1120 gm of gutted weight were noticed at station 9 with 15.4% for both respectively at class interval 300 - 600 gm and 1200 - 1500 gm. The highest composition of 53.8% was noticed in this station at class interval 900 - 1200 gm.

Female

Total length : As in the case of total population and male population in general all of the 9 stations studied in the Minicoy Lagoon, showed significantly a single peak uniformly for total length for female *H. nobilis* population at class interval 32.0 - 36.0 cm size only (Fig. 23 A). In this class interval the minimum composition of 30% at station 1 and the maximum 45% at station 8 were seen. However the fluctuation in length observed at station 1 was between 20.0 cm and 39.0 cm with 10% at class interval 20.0 - 24.0 cm, which was also smallest composition among the all class intervals and 15% at class interval 36.0 - 40.0 cm. The peak composition observed at class interval 32.0 - 36.0 cm was 30%. Station 2 showed a minimum of 20.0 cm with 9.5% at class interval 20.0 - 24.0 cm and maximum

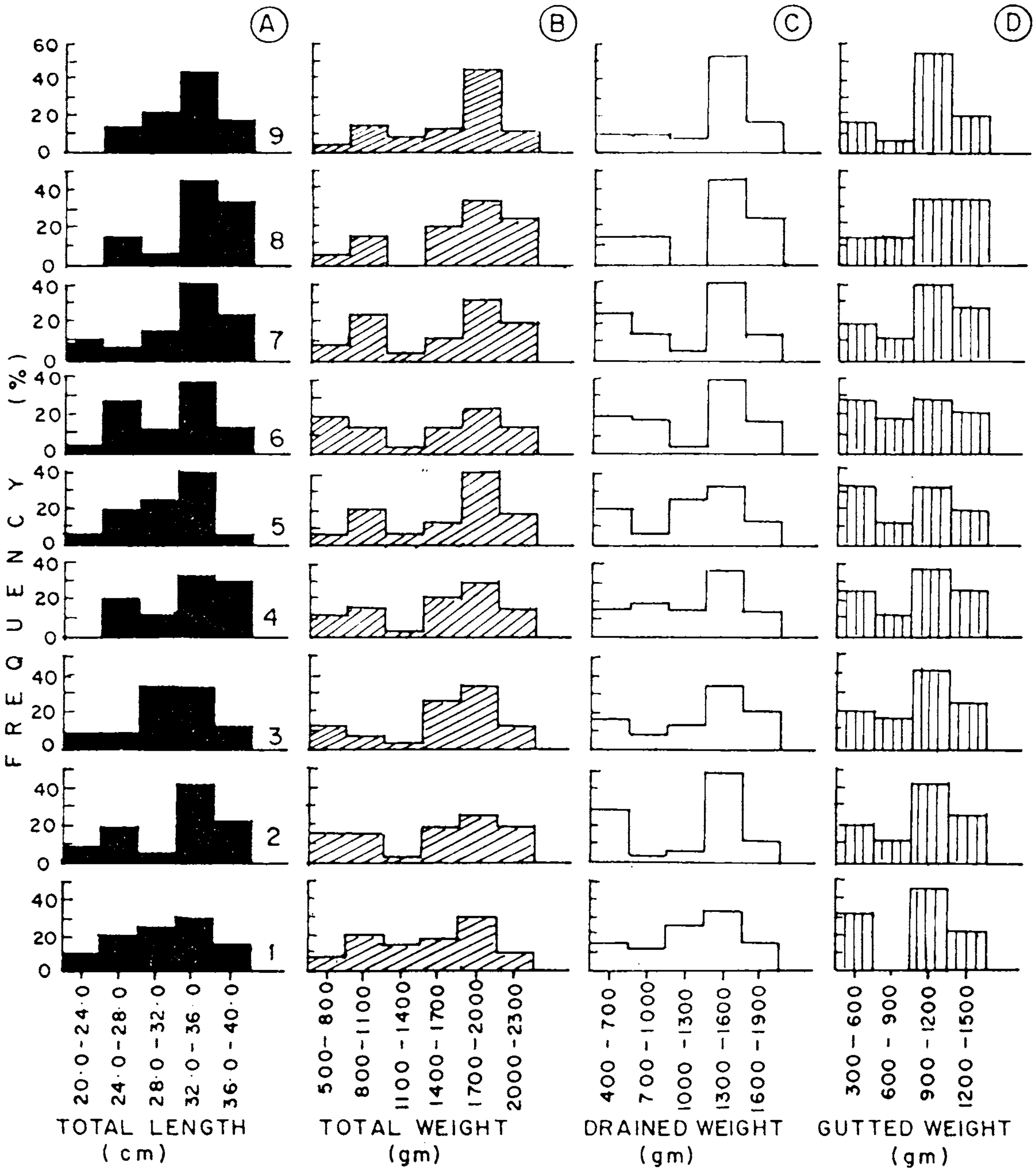


Fig.23. Size frequency distributions of female *H.nobilis* in 9 stations of lagoon at Minicoy Island during January 1990 - December 1991.

of 38.5 cm with 22.6% at class interval 36.0 - 40.0 cm. Further the lowest composition with 6.5% was noticed at class interval 28.0 - 32.0 cm, while the highest composition with 42% was at class interval 32.0 - 36.0 cm. Station 3 indicated minimum size of 20.5 cm with 9% at class interval 20.0 - 24.0 cm, which was also smallest composition among all the class intervals and maximum size of 38.0 cm with 13.1% at class interval 36.0 - 40.0 cm. The highest size frequency was noticed at class interval 28.0 - 32.0 cm and 32.0 - 36.0 cm with 34.8%. Minimum size of 25.0 cm and maximum of 38.5 cm with 21.9% at class interval 24.0 - 28.0 cm and 31.24% at class interval 36.0 - 40.0 cm respectively recorded in station 4. However no animal was found at class interval 20.0 - 24.0 and the lowest frequency was at 28.0 - 30.0 class interval with 12.5%. The highest composition of 34.4% was at class interval 32.0 - 36.0 cm. In station 5, the length varied between 22.0 cm and 37.0 cm with 6.7% for both size at class interval 20.0 - 24.0 cm and 36.0 - 40.0 cm. The highest composition was 40% at class interval 32.0 - 36.0 cm. It was noticed in station 6 that the length 24.0 cm with minimum frequency of 4.8% at class interval 20.0 - 24.0 cm and maximum length of 38.0 cm with 14.3% at class interval 36.0 - 40.0 cm. However, the highest percentage composition was 38.1% at class interval 32.0 - 36.0 cm. Station 7 was represented with animals of minimum length at 22.5 cm with 12% at class interval 20.0 - 24.0 cm and maximum at 38.5 cm with 24% at class interval 36.0 - 40.0 cm. Further, in this station the lowest composition was observed at class interval 24.0 - 28.0 cm with 8% and highest composition was at class interval 32.0 - 36.0 cm with 40%. Minimum length of 24.5 cm with 15% at class interval 24.0 - 28.0 cm and maximum length of 38.0 cm with 35% at class interval 36.0 - 40.0 cm were noticed in station 8, but the lowest composition of 5% was at class interval 28.0 - 32.0 cm and highest composition of 45% was at class interval 32.0 - 36.0 cm. Station 9 showed length variation from 24.0 cm to 36.5 cm with 14.8% at class interval 24.0 - 28.0 cm and 18.5% at class interval 36.0 - 40.0 cm. The highest composition of 44.5% was observed at class interval 32.0 - 36.0 cm in this station. However in station 4, 8 and 9, there was no animal recorded belonging to class interval 20.0 - 24.0 cm during this study period.

Total weight : A single peak was noticeable in total weight also at the class interval 1700 - 2000 gm for all of 9 stations at Minicoy Lagoon (Fig. 23 B) as in the case of total and male population. Among the all peaks, the minimum percentage composition was 23.8% at station 6 and maximum composition of 46.9% at station 9 were noticed. However, the fluctuation in the weight observed in station 1 was between 610 gm and 2200 gm with 7.5% at class interval 500 - 800 gm and 10% at class interval 2000 - 2300 gm respectively. The peak composition was noticed at class interval 1700 - 2000 gm was 30% in this station. Minimum size observed was 580 gm with 16.1% at class interval 500 - 800 gm and maximum size of 2100 gm within class interval 2000 - 2300 gm constituting 19.4% was recorded in station 2. Further the smallest composition of 3.1% was noticed at class interval 1100 - 1400 gm and highest composition of 25.9% at class interval 1700 - 2000 gm. The total weight variation observed in station 3 was between 620 gm and 2200 gm with 13% for both the smallest class interval 500 - 800 gm and highest 2000 - 2300 gm class interval respectively. The lowest composition in this station was 4.3% at class interval 1100 - 1400 gm and highest composition was 34.8% at class interval 1700 - 2000 gm. Station 4 showed, minimum weight of 700 gm with 12.9% at class interval 500 - 800 gm and maximum weight of 2200 gm with 16.1% at class interval 2000 - 2300 gm. However, the lowest composition was noticed at class interval 1100 - 1400 gm with 3.2% and highest composition at class interval 1700 - 2000 gm with 29.1%. Station 5 represented the minimum weight of 700 gm with 6.7% at class interval 500 - 800 gm and maximum weight of 2100 gm with 18.1% at class interval 2000 - 2300 gm. Further, the peak composition of 40% was noticed at class interval 1700 - 2000 gm. The smallest animal with minimum weight of 680 gm at class interval 500 - 800 gm with 19.1% and maximum weight of 2200 gm at class interval 2000 - 2300 gm with 14.3% were recorded in station 6, but the lowest composition of 4.8% was noticed at class interval 1100 - 1400 gm and peak composition of 23.8% was at class interval 1700 - 2000 gm. In station 7, the weight varied from 800 gm to 2200 gm with 8% at class interval 500 - 800 gm and 20% at class interval 2000 - 2300 gm respectively. The lowest peak was observed at class interval 1100 - 1400 gm was 4% while highest peak at class interval 1700 - 2000 gm was 32% in this station. Station 8 showed minimum weight at 725 gm with 5% at class interval 500 - 800 gm and maximum weight of 2100 gm with 25% at class interval 2000 - 2300 gm. The peak was observed in this station was 35% at class interval 1700 - 2000 gm and no animal was recorded at class interval 1100 - 1400 gm. In station 9, the minimum weight was 800 gm within class interval 500 - 800 gm constituting 3.1% and maximum weight was 2200 gm at class interval 2000 - 2300 gm with 12.5%. The peak composition was noticed at class interval 1700 - 2000 gm with 46.9% in this station.

Drained weight : Single peak was observed as in the case of total and male population for drained weight also at class interval 1300 - 1600 gm in all 9 stations. Among the peaks, the smallest composition was 32.5% at station 1 and highest composition was 53.1% at station 9 were seen (Fig. 23 C). However, the fluctuation noticed in drained weight at station 1 was between 430 gm and 1800 gm with 15% for both weight at class interval 400 - 700 gm and 1600 - 1900 gm respectively. The smallest composition in this station noticed at class interval 700 - 1000 gm was 12.5% and highest composition at class interval 1300 - 1600 gm was 32.5%. Station 2 represented the minimum drained weight of 430 gm with 29.1% at class interval 400 - 700 gm and maximum drained weight of 1800 gm with 12.9% at class interval 1600 - 1900 gm. The lowest composition at this station was 3.1% at class interval 700 - 1000 gm and highest composition was 48.1% at class interval 1300 - 1600 gm. Station 3 showed the minimum weight of 500 gm with 17.4% at class interval 400 - 700 gm and maximum weight of 1750 gm with 26.1% at class interval 1600 - 1900 gm, but the lowest frequency was 8.7% at class interval 700 - 1000 gm and highest composition was 34.9% at class interval 1300 - 1600 gm. Minimum of 610 gm and maximum of 1850 gm with 15.2% for both lowest and highest at class interval 400 - 700 gm and 1600 - 1900 gm were recorded in station 4 respectively. The highest composition of 36.4% was recorded at class interval 1300 - 1600 gm. It is seen from station 5 that the drained weight varied between 540 gm and 1780 gm wih 20% at class interval 400 - 700 gm and 13.1% at class interval 1600 - 1900 gm respectively. The lowest composition was seen at class interval 700 - 1000 gm with 6.7% and highest was at class interval 1300 - 1600 gm with 33.1%. Station 6 showed minimum weight of 600 gm with 19.3% at class interval 400 - 700 gm and maximum weight of 1900 gm with 18.2% at class interval 1600 - 1900 gm. Further the lowest composition 4.8% was noticed at class interval 1000 - 1300 gm and highest 39.1% at class interval 1300 - 1600 gm in this station. Station 7 represented the minimum weight at 420 gm with 25.4% at class interval 400 - 700 gm and maximum weight at 1700 gm with 13.1% at class interval 1600 - 1900 gm, but the minimum composition was 5.4% at class interval 1000 - 1300 gm and maximum composition was 40.0% at class interval 1300 - 1600 gm. It was noticed in station 8 that the lowest weight was 630 gm with 15% at class interval 400 - 700 gm and highest weight was 1710 gm with 25% at class interval 1600 - 1900 gm, but the highest composition was 45% at class interval 1300 - 1600 gm and there was no animal noticed in the class interval 1000 - 1300 gm. The observed, minimum weight was 710 gm and maximum weight was 1790 gm in station 9 with 10.8% at class interval 400 - 700 gm and 17.9% at class interval 1600 - 1900 gm respectively. However, the lowest frequency was observed at class interval 1000 - 1300 gm with 7.1% and highest was at class interval 1300 - 1600 gm with 53.1% in this station.

<u>Gutted weight</u> : Similar to the trend of total weight and drained weight the peak composition observed in all 9 stations was at class interval 900 - 1200 gm and within the peaks the minimum composition of 28.8% at station 6 and maximum composition 55.2% at station 9 were seen (Fig. 23 D). In station 1, minimum gutted weight was 365 gm and maximum was 1260 gm with 32.20% at class interval 300 - 600 gm and 21.9% at class interval 1100 - 1500 gm respectively. The maximum composition was 45.9% at class interval 900 - 1200 gm and no animal recorded at class interval 600 - 900 gm in this station. In station 2, the smallest gutted weight was 400 gm and heaviest was 1220 gm with 20% at class interval 300 - 600 gm and 25% at class interval 1200 - 1500 gm respectively, but the minimum composition of 12.5% was noticed at class interval 600 - 900 gm and maximum of 42.5% was at class interval 900 - 1200 gm in this station. Minimum weight of 370 gm with 21.7% at class interval 300 - 600 gm and maximum weight of 1340 gm with 21.4% at class interval 1200 - 1500 gm were recorded in station 3. Further the lowest composition 17.4% was recorded at class interval 600 - 900 gm and highest composition 43.5% was at class interval 900 - 1200 gm. It was noticed in station 4 that the weight varied between 500 gm and 1310 gm both with 25% at class interval 300 - 600 gm and 1200 - 1500 gm, but the lowest composition was noticed in the class interval 600 - 900 gm was 12.5% and highest percentage of 37.5% was in the class interval 900 - 1200 gm. Station 5 indicated minimum weight of 500 gm and heaviest of 1310 gm with 33.3% at class interval 300 - 600 gm and 20.0% at class interval 1200 - 1500 gm. The peculiarity seen in this station is that the highest percentage composition was 33.3% at class interval 300 - 600 gm and 900 - 1200 gm. The lowest composition at this station was 13.4% at class interval 600 - 900 gm. It was noticed in station 6 that the minimum weight at 400 gm with 28.6% at class interval 300 - 600 gm and maximum weight at 1340 gm with 23.8% at class interval 1200 - 1500 gm, but the lowest composition noticed in this station was 19.1% at class interval 600 -

900 gm and highest peak was 28.8% at class interval 900 - 1200 gm. In station 7, the gutted weight ranged from 610 gm to 1400 gm with 20.0% at class interval 300 - 600 gm and 28% at class interval 1200 - 1500 gm respectively, but the lowest composition of 12% was noticed at the class interval 600 - 900 gm and highest composition of 40% at class interval 900 - 1200 gm in this station. Station 8 showed the weight variation between 510 gm and 1225 gm with 15% at class interval 300 - 600 gm and 35% at class interval 1200 - 1500 gm respectively. Further the highest composition at this station showed 35% at class interval 900 - 1200 gm. Minimum weight of 490 gm with 17.3% at class interval 300 - 600 gm and maximum weight of 1400 gm with 20.1% at class interval 1200 - 1500 gm were recorded in station 9 and the lowest composition of 6.9% was recorded at class interval 6000 - 900 gm and highest composition of 55.2% was at class interval 900 - 1200 gm.

So far it has been studied the composition in percentage of H. nobilis stationwise, collectively for whole population and male and female separately with interesting results with regard to total length, total weight, drained weight and gutted weight. It was felt to know whether any remarkable change is seen while pooling the data of all these stations as a whole and the results are presented in (Fig. 24) for male and female population and in Fig. 25 for both sex combined, which showed almost similar trends as in the case of stationwise observation.

SECTION B : BIOMETRY

Holothuria nobilis

The biometric relationship between total length and weight (TW, DW and CW) could be described by regression equation $Y = a\,x^{b}$.

The relationship was done for H. nobilis for each station pooled over data of 24 months for male and female sex combined

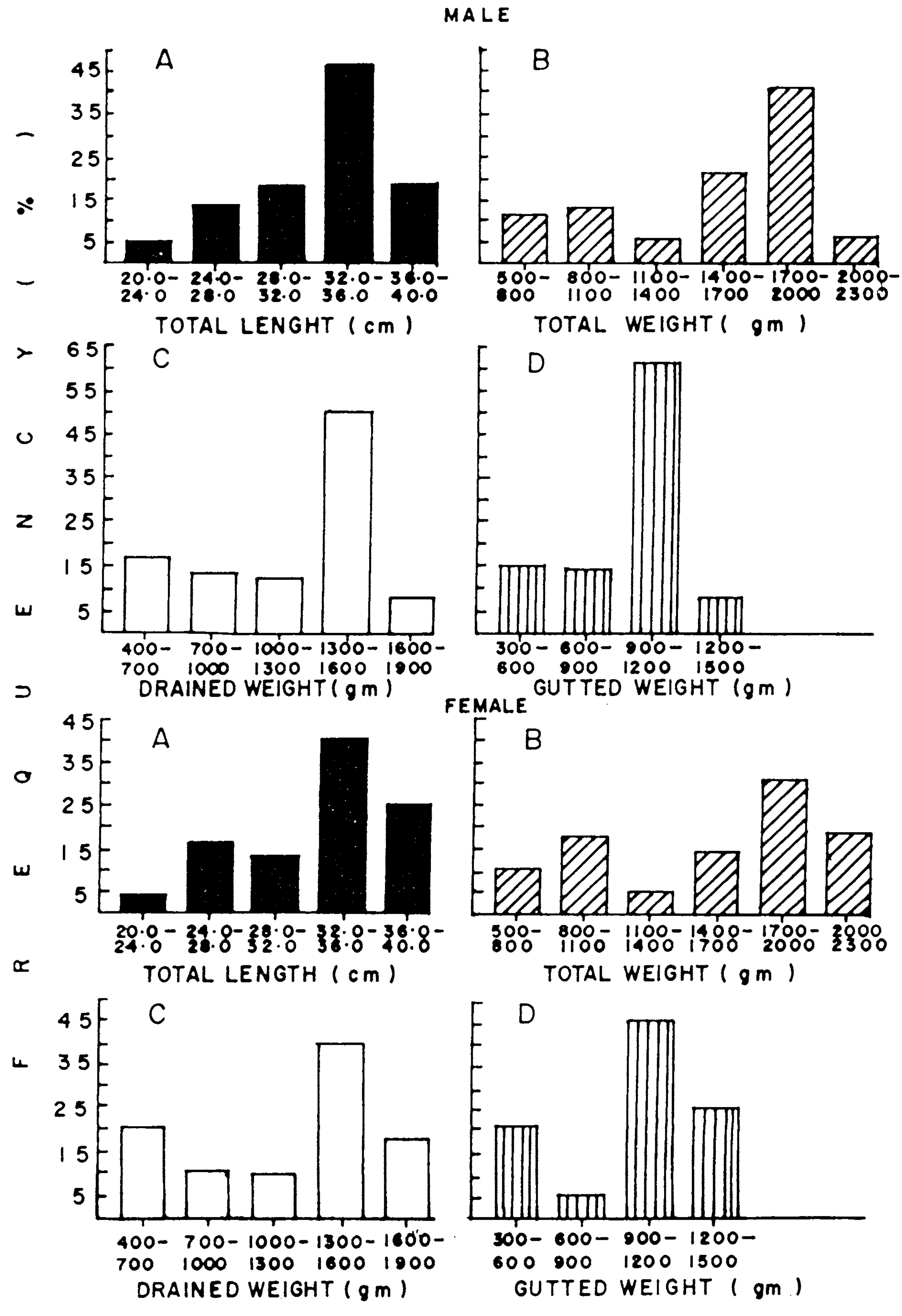


Fig.24. Size frequency distributions of male and female populations pooled over 9 Lagoon Stations at Minicoy Island during January 1990 - December 1991.

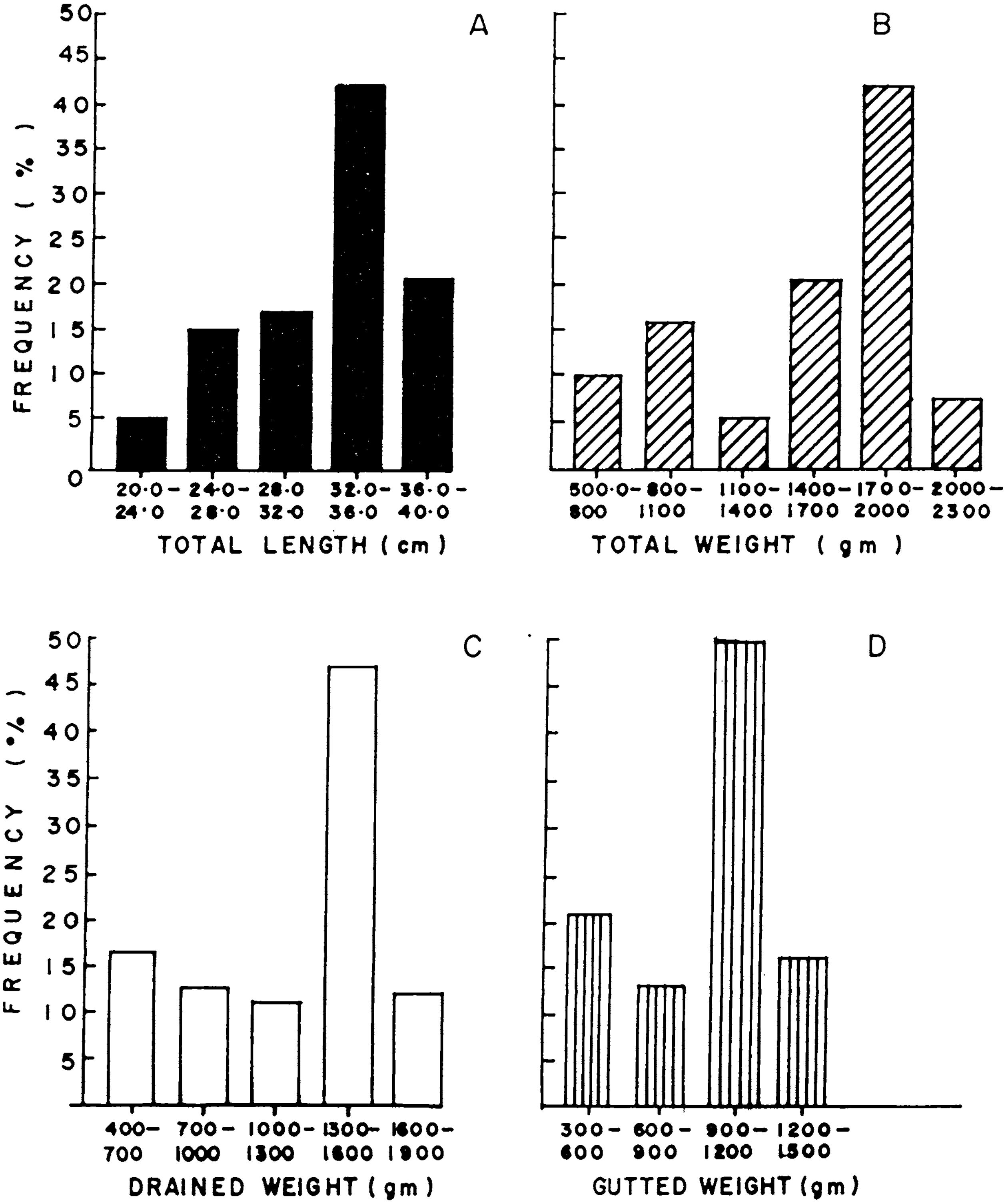


Fig.25. Size frequency distributions of total population of H.nobilis at Minicoy Island during January 1990 - December 1991.

(Table 5), male (Table 6) and female (Table 7) separately. The pooled data of 9 stations' population of male and female and both sex combined as a whole (Table 8) were also studied for this relationship. All these results show that the b value is less than usual cubic relationship (b = 3) and r value is between 0.80 and 0.95%. The analysis of covariance (ANCOVA) revealed no significant differences in slopes among the stations for male and female population (Table 9, Fig. 26) and for total population (Table 10, Fig. 27).

DISCUSSION

Morphometry : A scrutiny of literature indicates that there is no report on the morphometry of *H. nobilis* except the one by Conand (1990) and it is the only one available for comparison. The results obtained from morphometric studies on *H. nobilis'* population of Minicoy Lagoon are comparable with some variations with that of Conand (1990) who observed that total length from 180 mm to 560 mm, total weight from 300.0 to 4300.0 gm, drained weight from 280.0 to 2450.0 gm and gutted weight from 200.0 to 1900.0 gm for *H. nobilis* in New Caledonia. These variations between the observations of the candidate and Conand (1990) are attributed to the reason that Conand has collected more number of specimen for her study in New Caledonia, because of the well developed *Beche-de-mer* fishery and people are engaged with SCUBA diving to collect more specimens from upto 10 m depth. In Minicoy Island absolutely no sea-cucumber fishery or sophisticated facilities like SCUBA diving available to go upto 10 m depth to collect more animals for the present study.

Further Conand (1990) has studied only on total population of *H. nobilis* and not studied the morphometry separately for male and female populations. The present results indicate that the weight is more in females than in males which is due to the presence of heavier ovary in females as observed by the candidate and evidence

TABLE 5. Biometric relationship between morphometric characters [total length and weight (TW, DW and GW)] of both male and female combind _H. nobilis_ in stationwise during the period January 1990 - December 1991 in Minicoy Lagoon

Station	X	Y	df	r	$Y = a x^b$
1.	TL	TW	90	0.91	$Y=0.16822 \times^{2.6047}$
	TL	DW	90	0.93	$Y=0.15655 \times^{2.5673}$
	TL	GW	90	0.90	$Y=0.19886 \times^{2.4313}$
2.	TL	TW	62	0.90	$Y=0.46150 \times^{2.3211}$
	TL	DW	62	0.94	$Y=0.26769 \times^{2.4163}$
	TL	GW	62	0.91	$Y=0.32182 \times^{2.2946}$
3.	TL	TW	45	0.92	$Y=0.56741 \times^{2.2619}$
	TL	DW	45	0.91	$Y=0.45301 \times^{2.2666}$
	TL	GW	45	0.92	$Y=0.50972 \times^{2.1655}$
4.	TL	TW	60	0.89	$Y=0.19785 \times^{2.5556}$
	TL	DW	60	0.90	$Y=0.15966 \times^{2.5631}$
	TL	GW	60	0.86	$Y=0.26933 \times^{2.3400}$
5.	TL	TW	35	0.92	$Y=0.39455 \times^{2.3663}$
	TL	DW	35	0.93	$Y=0.34542 \times^{2.3434}$
	TL	GW	35	0.91	$Y=0.64086 \times^{2.0960}$
6.	TL	TW	47	0.92	$Y=0.19062 \times^{2.5668}$
	TL	DW	47	0.91	$Y=0.21282 \times^{2.4778}$
	TL	GW	47	0.92	$Y=0.22195 \times^{2.4022}$
7.	TL	TW	44	0.92	$Y=0.46318 \times^{2.3155}$
	TL	DW	44	0.91	$Y=0.40242 \times^{2.2968}$
	TL	GW	44	0.93	$Y=0.52395 \times^{2.1517}$
8.	TL	TW	41	0.89	$Y=0.44102 \times^{2.3363}$
	TL	DW	41	0.89	$Y=0.45185 \times^{2.2677}$
	TL	GW	41	0.90	$Y=0.55951 \times^{2.1373}$
9.	TL	TW	67	0.86	$Y=0.28429 \times^{2.4708}$
	TL	DW	67	0.84	$Y=0.26180 \times^{2.4361}$
	TL	GW	67	0.83	$Y=0.45100 \times^{2.2014}$

TL = Total length, TW = Total weight, DW = Drained weight, GW = Gutted weight, DF = Degree of freedom

TABLE 6. **Biometric relationship between morphometric characters [total length and weight (TW, DW and GW)] of male _H. nobilis_ in stationwise during the period January 1990 - December 1991 in Minicoy Lagoon**

Station	X	Y	df	r	$Y = a\,x^{b}$
1.	TL	TW	47	0.91	$Y=0.26512\ x^{2.4815}$
	TL	DW	47	0.91	$Y=0.29032\ x^{2.4028}$
	TL	GW	47	0.93	$Y=0.23225\ x^{2.3910}$
2.	TL	TW	31	0.93	$Y=0.36172\ x^{2.3964}$
	TL	DW	31	0.89	$Y=0.28287\ x^{2.4065}$
	TL	GW	31	0.90	$Y=0.32150\ x^{2.2980}$
3.	TL	TW	15	0.91	$Y=0.33072\ x^{2.4112}$
	TL	DW	15	0.93	$Y=0.48150\ x^{2.2531}$
	TL	GW	15	0.91	$Y=0.33285\ x^{2.2807}$
4.	TL	TW	29	0.92	$Y=0.23581\ x^{2.5189}$
	TL	DW	29	0.91	$Y=0.19062\ x^{2.5115}$
	TL	GW	29	0.90	$Y=0.31207\ x^{2.3073}$
5.	TL	TW	14	0.93	$Y=0.34210\ x^{2.9053}$
	TL	DW	14	0.91	$Y=0.32590\ x^{2.3620}$
	TL	GW	14	0.90	$Y=0.36905\ x^{2.2580}$
6.	TL	TW	21	0.91	$Y=0.43418\ x^{2.3460}$
	TL	DW	21	0.93	$Y=0.51502\ x^{2.2256}$
	TL	GW	21	0.91	$Y=0.52731\ x^{2.1617}$
7.	TL	TW	24	0.91	$Y=0.20811\ x^{2.5471}$
	TL	DW	24	0.89	$Y=0.23625\ x^{2.4610}$
	TL	GW	24	0.93	$Y=0.25632\ x^{2.3610}$
8.	TL	TW	18	0.91	$Y=0.32500\ x^{2.4216}$
	TL	DW	18	0.91	$Y=0.29154\ x^{2.3800}$
	TL	GW	18	0.89	$Y=0.32201\ x^{2.2856}$
9.	TL	TW	24	0.89	$Y=0.39008\ x^{2.3618}$
	TL	DW	24	0.87	$Y=0.26584\ x^{2.4201}$
	TL	GW	24	0.92	$Y=0.35976\ x^{2.2693}$

TABLE 7. Biometric relationship between morphometric characters [(total length and weight (TW, DW and GW)] of Female H. nobilis in stationwise during the period January 1990 - December 1991 in Minicoy Lagoon

Station	X	Y	df	r	$Y = a x^b$
1.	TL	TW	31	0.90	$Y=0.34522 x^{2.4016}$
	TL	DW	31	0.90	$Y=0.28504 x^{2.3856}$
	TL	GW	31	0.92	$Y=0.32215 x^{2.3010}$
2.	TL	TW	30	0.89	$Y=0.31058 x^{2.4315}$
	TL	DW	30	0.91	$Y=0.32149 x^{2.3678}$
	TL	GW	30	0.90	$Y=0.46532 x^{2.1972}$
3.	TL	TW	29	0.90	$Y=0.46721 x^{2.3217}$
	TL	DW	29	0.92	$Y=0.53058 x^{2.2178}$
	TL	GW	29	0.90	$Y=0.64731 x^{2.0951}$
4.	TL	TW	29	0.90	$Y=0.26021 x^{2.4812}$
	TL	DW	29	0.90	$Y=0.22635 x^{2.4510}$
	TL	GW	29	0.92	$Y=0.33101 x^{2.2815}$
5.	TL	TW	20	0.89	$Y=0.33322 x^{2.4156}$
	TL	DW	20	0.90	$Y=0.36158 x^{2.3258}$
	TL	GW	20	0.93	$Y=0.42105 x^{2.2215}$
6.	TL	TW	25	0.90	$Y=0.16261 x^{2.6075}$
	TL	DW	20	0.89	$Y=0.23107 x^{2.4512}$
	TL	GW	20	0.91	$Y=0.26102 x^{2.3413}$
7.	TL	TW	16	0.93	$Y=0.25181 x^{2.4932}$
	TL	DW	16	0.91	$Y=0.26025 x^{2.4209}$
	TL	GW	16	0.91	$Y=0.32156 x^{2.2836}$
8.	TL	TW	20	0.91	$Y=0.28156 x^{2.4618}$
	TL	DW	20	0.91	$Y=0.28085 x^{2.4015}$
	TL	GW	20	0.93	$Y=0.38176 x^{2.2800}$
9.	TL	TW	38	0.89	$Y=0.26531 x^{2.4863}$
	TL	DW	38	0.92	$Y=0.22051 x^{2.4705}$
	TL	GW	38	0.91	$Y=0.31635 x^{2.3018}$

TABLE 8. **Biometric relationship between morphometric characters [(total length and weight (TW, DW and GW)] of Pooled 9 lagoon stations male, female and total population of _H. nobilis_ during the period January 1990 - December 1991 in Minicoy Lagoon**

	X	Y	df	r	$Y = a\,x^{b}$
Male	TL	TW	263	0.94	$Y=0.27640\,x^{2.4650}$
	TL	DW	263	0.93	$Y=0.26195\,x^{2.4205}$
	TL	GW	263	0.93	$Y=0.34531\,x^{2.2736}$
Female	TL	TW	223	0.90	$Y=0.36081\,x^{2.3913}$
	TL	DW	223	0.91	$Y=0.26408\,x^{2.4243}$
	TL	GW	223	0.94	$Y=0.36240\,x^{2.2617}$
Total Popula-tion (Pooled over 9 stations	TL	TW	499	0.93	$Y=0.31895\,x^{2.4257}$
	TL	DW	499	0.90	$Y=0.26590\,x^{2.4191}$
	TL	GW	499	0.92	$Y=0.35973\,x^{2.2629}$

TABLE 9. Analysis of covariance (ancova) for morphometric characteristic relationship of male and female *H. nobilis*

A. **Total length and total weight**

Source	Degree of freedom	Sum of squares	Mean square	F value	Probability
Difference in level	1	0.016	0.016	0.75	-
Error	487	10.672	0.022	-	-
Difference in slope	1	0.013	0.013	0.60	-
Error	486	10.659	0.022	-	-

B. **Total length and gutted weight**

Source	Degree of freedom	Sum of squares	Mean square	F value	Probability
Difference in level	1	0.006	0.006	0.30	-
Error	487	9.874	0.020	-	-
Difference in slope	1	0.000	0.000	0.02	-
Error	486	9.874	0.020	-	-

C. **Total length and drained weight**

Source	Degree of freedom	Sum of squares	Mean square	F value	Probability
Difference in level	1	0.054	0.054	2.43	0.12
Error	487	10.781	0.022	-	-
Difference in slope	1	0.000	0.000	0.00	-
Error	486	10.781	0.622	-	-

Difference in level = a value
Difference in slope = b value

TABLE 10. Analysis of covariance (ancova) for morphometric characteristic relationship of total population of *H. nobilis*

A. **Total length and total weight**

Source	Degree of freedom	Sum of squares	Mean square	F value	Probability
Difference in level	8	0.262	0.033	1.51	0.15
Error	490	10.617	0.022	-	-
Difference in slope	8	0.148	0.019	0.85	-
Error	482	10.468	0.022	-	-

B. **Total length and drained weight**

Source	Degree of freedom	Sum of squares	Mean square	F value	Probability
Difference in level	8	0.184	1.023	1.03	0.41
Error	490	0.022	0.022	-	-
Difference in slope	8	0.115	0.014	0.64	-
Error	482	10.823	0.022	-	-

C. **Total length and gutted weight**

Source	Degree of freedom	Sum of squares	Mean square	F value	Probability
Difference in level	8	0.090	0.011	0.55	-
Error	490	10.057	0.021	-	-
Difference in slope	8	0.125	0.016	0.76	-
Error	490	9.932	0.021	-	-

Difference in level = a value
Difference in slope = b value

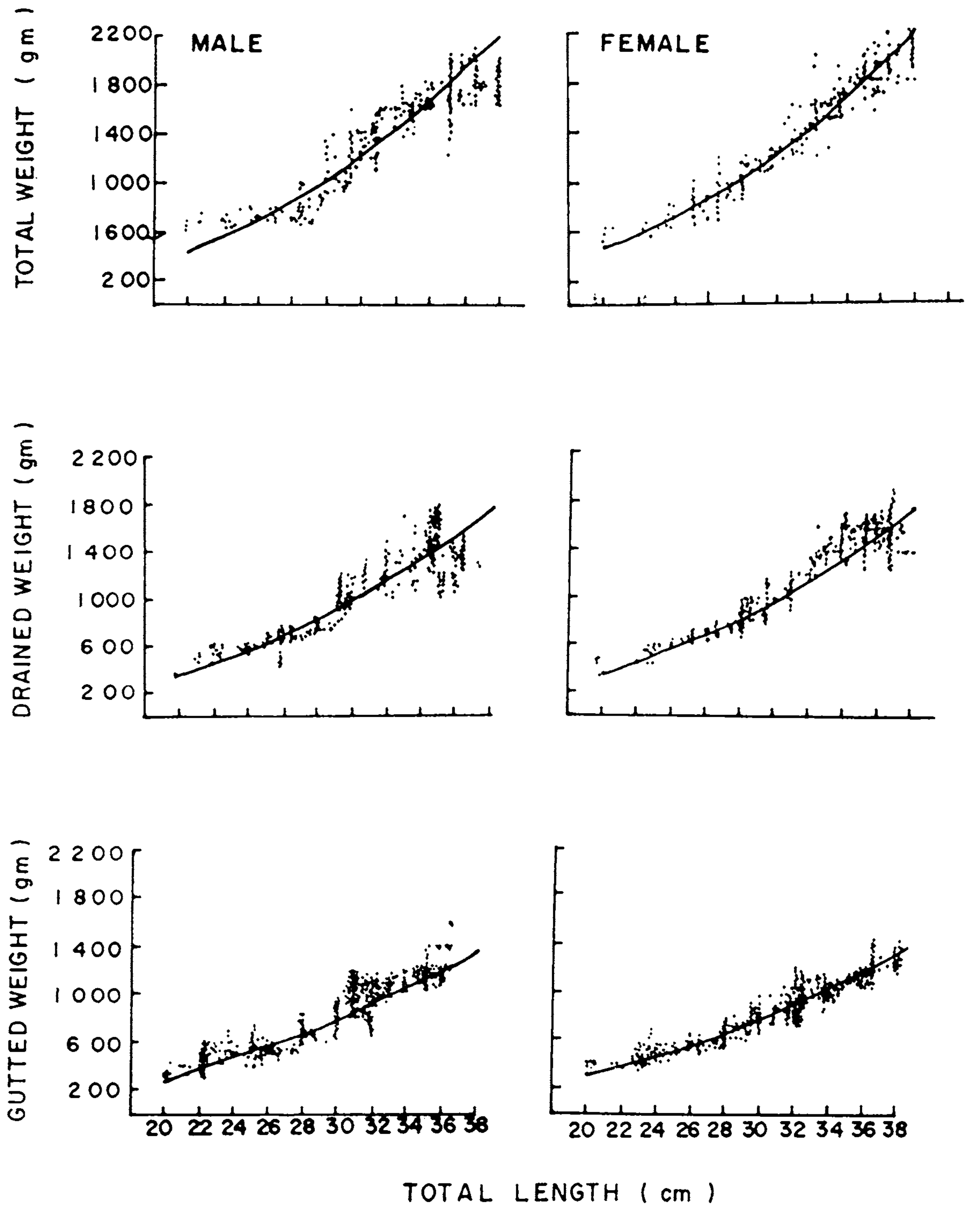


Fig.26. Biometric relationship between total length and weight (TW,DW & GW) of male and female H.nobilis.

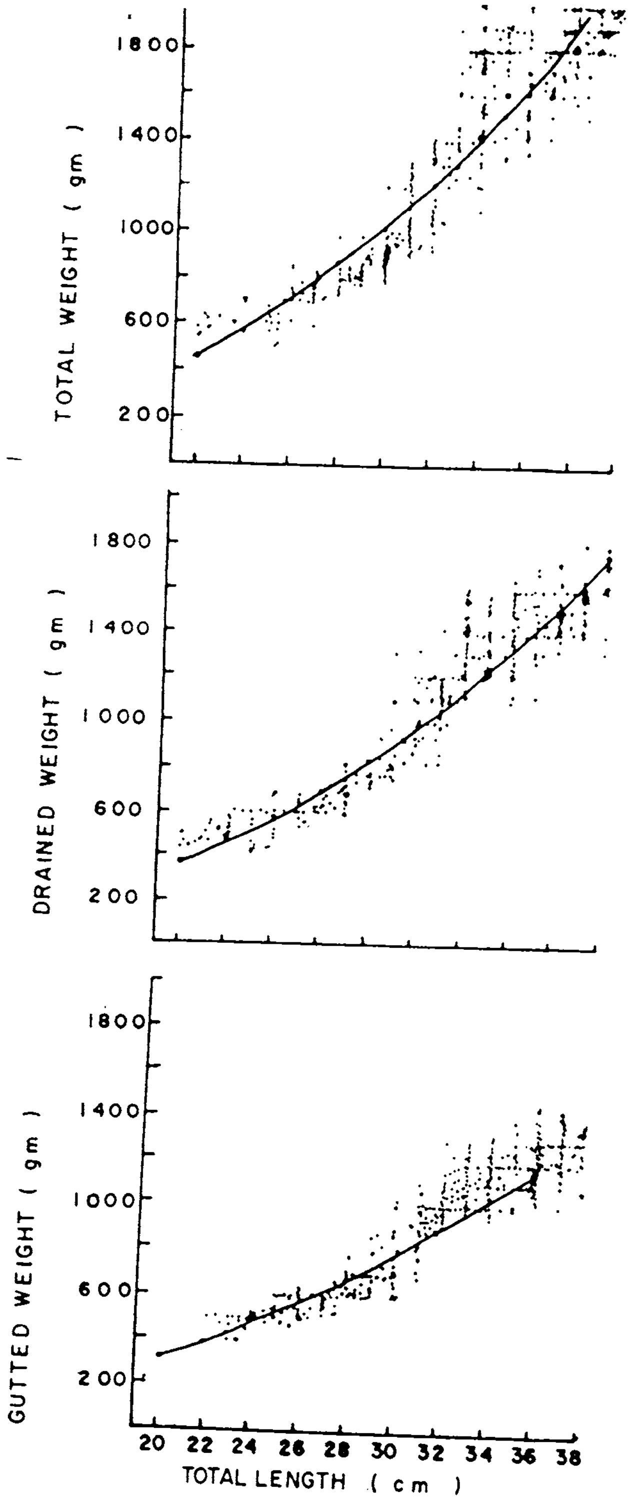


Fig.27. Biometric relationship between Total length and weight (TW,DW & GW) of total population <u>H.nobilis</u> at Minicoy Island.

by the results of reproductive biology on a later chapter in this Thesis.

Size frequency : The studies on size frequency distribution and percentage composition of *H. nobilis* for total population and for both the sexes at Minicoy Lagoon have given many interesting results. Only a single peak for all the morphometric character was observed. The peaks observed were at class interval 32.0 - 36.0 cm for total length, 1700 - 2000 gm for total weight, 1300 - 1600 gm for drained weight and 900 - 1200 gm for gutted weight, which are all of adult and mature animals as observation by the candidate.

The restricted size distribution of *H. nobilis* in Minicoy Lagoon, can be attributed to the environmental preference of this species, particularly when they are attaining sexual maturation. This is further supported by that the younger ones were not observed in the lagoon. But Conand (1990) reported through size frequency analysis of *H. nobilis* at different stations in New Caledonia that the highest composition always constituted by larger animals while younger ones were poorly noticed. The same observation was also made in the present study. Gentle (1972) also reported similar trend for white teat-fish *H. fuscogilva* at Fiji Island. These authors attributed the reason that various size groups of this species distributed at different depths according to their environmental selections and sampling stations were close enough for migration of this species from coral slope to lagoon during the growth phase. Moreover, the availability of larger matured adult animals in the lagoon may well be related to the withstandability of the animal to varying ecological conditions with the heavy gonad weight. They are able to tolerate the high temperature, wave action, water current and tidal effect, etc. in the lagoon, because of more weight. The studies on reproductive biology of this species showed that the matured animals measuring 32.0 - 36.0 cm having the gonad weight nearly 200 - 250 gm. In other stages it was between 10 and 100 gm.

This view is further strengthened from the present result that, the animals belonging to class interval 36.0 - 40.0 cm were very less in percentage composition. The animals in this class interval were either spent or spawning.

Further it is seen from the result, that there is considerable fluctuation in percentage composition of the animals belonging to other class intervals at Minicoy Island. Similar trend was experienced by Conand (1990) for H. nobilis at New Caledonia especially for gutted weight, which showed remarkable variation in its percentage composition and remarked that "it is very hard to explain this fluctuation or variation". But this author assumes and relates the length and weight of the animal to their environmental selectivity with good availability of food and shelter and described this type of distribution as "biotope based distribution".

Fish (1967) reported that a single peak for Cucumaria elongata from Durham Coast with different small mode is possibly due to the slow growing and long living. Choe (1963) found that the size distribution of the red and green varieties of Stichopus japonicus from the coast of Japan depends on the water depth of the habitat. Ebert (1978) reported in Enewetak Atoll, Marshall Islands, H. atra was found in very large sizes around the atoll with maximum length of 42.0 cm which is similar to Bonham and Held (1963) observation for H. atra at Kabelle Island, Rongelap Atoll. Further in Enewetak Atoll in certain area this larger ones are not found. The reason Ebert (1978) indicated is that it may be due to "environmental features, which could promote asexual production and in such location only small to medium size animals would be found". Conand (1983) reported in New Caledonia T. ananas measured 180 - 670 mm total length, 220 - 6250 gm total weight, 205 - 5830 gm drained weight and 175 - 4800 gm gutted weight and M. fuscogilva measured 230 -570 mm total length, 1005 - 3600 gm total weight, 655 - 2500 gm drained weight, 320 - 2000 gm gutted weight and the size frequency distribution of these were unimodal though it contain large population and they reveal the phenomenan of 'one size class in a locality' (Bakus, 1973). The majority of specimen encountered were adults with rare young ones. Conand (1993) reported the size frequency distribution of S. variegatus in New Caledonia which showed unimodal at the station on the typical lagoon floor, with a majority of individuals being relatively large (Mean TL 390 mm; mean TW 1427 gm).

On the reef flat station the individuals were smaller (Mean TL 263 mm; mean TW 542 gm). This difference in mean size between habitats and the occasional presence of small juveniles on reef flat lead to the hypothesis that this species recruits to shallow water (on reef flats and shallow sea-weed or sea-grass beds) and migrates later into deeper water. Tuwo and Conand (1992) observed a unimodal frequency distribution of the total length and body wall wet weight of Holothuria forskali at Penfrct Island in the Glenan Archipelago, Brittany. The average length of male was 272 mm and of female 269 mm and average weights were 154 gm for male and 151 gm for female. Small individuals (150 mm and 71 gm) were not found much at this site. Further they explained that the size and weight distribution were similarly shaped to those for other holothurians with few or no juveniles (Ebert, 1978; Muscat, 1983; Conand, 1981, 1989; Sewell, 1990).

Moreover the 'one size class in a locality' (Bakus, 1973) reported in the abyssal holothurian population also. Tyler and Billett (1987) observed P. longicauda on the Porcupine Abyssal Plain dominated by large specimens (130 mm) generally and some reaching a length of 280 mm. The size distribution of this species showed unclear modes in small sample size, but in the larger population a bimodal distribution is evident. Tyler et al. (1987) observed that length measurement of C. utriculus suggests a unimodal distribution in length frequencies with occasional samples displaying a bimodal distribution. They found 1.5 mm long as smallest and 7.0 mm as largest. Further their results showed although appearing essentially unimodal in its size distribution there is considerable variation about the mean size and a number of the samples appear to be skewed to either a higher or lower size distribution. This difference may be related to either temporal variability or as the result of sampling a population composed of a spatial mosaic in demographic composition.

The absence of larval settling and juvenile forms of H. nobilis in the lagoon is a very significant finding during the study period. The absence may be attributed mainly to the effect of water current, wave action and similar ecological factors which are mainly responsible for the larval shifting from the lagoon to the nearby reef and deeper areas. The findings of Gentle (1979) strengthens this view as he has observed the young forms in superficial bed of Syringodium isoetifolium at the depth between 5 and 10 m. Whereas the depth at Minicoy Lagoon hardly upto 5 or 6 m. Moreover Hyman (1955) stated that the holothurian larvae are plankton feeders with their non-functional tentacles and this larvae would have gone away from the lagoon to the neighbouring reef area which supposed to be very productive with abundant phytoplankton. According to Tyler et al. (1985) temperature plays a vital role in the holothurian development particularly the reduced rate of metabolism to enhance the larval longevity to find out a suitable substratum for settlement and movement between their settling area to the spawning site. Bakus (1973) also found difficulties to locate and assess the young holothurians and their larvae during his studies in Tropical seas. Conand (1983, 1990) also reported from New Caledonia that young forms of H. nobilis and H. fuscogilva are appearing very rarely and she also pointed out that at the Utoe Pass in New Caledonia the larval individuals disposed in the flag stone at depths between 5 and 30 m.

A thorough analysis of the literature available on the larval development of certain holothurians as discussed earlier, clearly shows that the ecological parameters of the environment, water depth and water current play important role. Here in Minicoy Lagoon also further detailed studies will give more lights on the above subjects definitely in future.

Biometry : The b value of all the relationship is at the range of 2.0 to 2.4. This indicates that H. nobilis shows allometric relationship between the morphometric characters when it deviates from the usual cubic relationship (b = 3). This value is in accordance with the biometric relationship obtained by Conand (1990) for the combined population of H. nobilis in New Caledonia. This difference is most probably related to food availability, suitable substratum for growth and physical and chemical parameters of ecosystem, which may have direct effect on their growth.

SECTION C : MORPHOMETRY

Actinopyga mauritiana

The results of morphometric character such as total length (TL), total weight (TW), drained weight (DW), and gutted weight (GW) of Actinopyga mauritiana have been studied here for three reef flat stations individually and as pooled population for the 3 stations together. No sexual dimorphism in this species and it reproduces by asexual means.

Morphometry of stationwise population

Station 10 : In this station 430 animals were collected during the study period. The individual length measured from 6.0 to 30.0 cm with mean value 15.83 ± 5.04. The total weight was between 18 and 1000 gm with mean weight 254.27 ± 183.30. The drained weight varied from 10 to 800 gm, the mean drained weight being 185.20 ± 132.64 gm, while gutted weight at the range of 8 to 625 gm gave a mean weight 157.67 ± 75.10 gm.

Station 11 : Among 260 animals studied in this station, the smallest was 6.0 cm and largest was 30.0 cm with mean length of 16.71 ± 6.78 cm. The total weight was between 15 and 1000 gm with mean weight 273.11 ± 188.60 gm. The drained weight varied from 10 to 800 gm with mean drained weight 202.81 ± 146.50 gm, while the gutted weight ranged from 5 gm to 640 gm with mean weight 154.47 ± 82.15 gm.

Station 12 : This station recorded 249 animals in total. The individual length measured from 6.0 cm to 30.0 cm with mean length 16.47 ± 5.80 cm. The total weight was between 10 gm and 940 gm with mean total weight of 265.20 ± 163.50 gm. The drained weight varied from 89 to 810 gm, the mean drained weight being 189.49 ± 136.10 gm, while the gutted weight in ranged from 5 to 660 gm, gave a mean gutted weight 145.50 ± 1012 gm.

Morphometry of pooled population

In total in all three stations there were 939 animals. The smallest and longest animals measured 6.0 and 30.0 cm respectively with mean length 18.42 ± 5.8012 cm. The total weight was between 10 and 1000 gm with mean total weight of 312.14 ± 168.50 gm. The drained weight varied from 8 to 820 gm, the mean drained weight being 240.10 ± 130.12 gm, while the gutted weight ranged between 5 and 640 gm, gave a mean gutted weight of 182.72 ± 62.10 gm.

Size Frequency

The results of the size frequency studies carried out on *A. mauritiana* from Minicoy Island are presented below for stationwise population and for total pooled population for the three stations.

Size frequency of stationwise population

Total length : In general, an overall observation in station 10, 11 and 12 studied in the reef flat of Minicoy Island showed a single peak uniformly for A. mauritiana population at class interval 15.0 - 20.0 cm with 36.37%, 35.55% and 39.20% respectively (Fig. 28 A). However, the fluctuation in total length observed in station 10 was between 6.0 cm and 30.0 cm with 9.33% at class interval 5.0 - 10.0 cm and 4.80% at class interval 25.0 - 30.0 cm, which constitutes smallest composition among the class intervals. The highest composition observed at class interval 15.0 - 20.0 cm was 36.37% in this station. Station 11 indicated the minimum length of 6.0 cm with 7.42% at class interval 5.0 - 10.0 cm and maximum length of 30.0 cm with 7.87% at class interval 25.0 - 30.0 cm. The highest composition recorded in this station was 35.5% at class interval 15.0 - 20.0 cm. Station 12 represented with minimum length of 6.0 cm with 8.40% at class interval 5.0 - 10.0 cm and maximum length of 30.0 cm with 8% at class interval 25.0 - 30.0 cm. The maximum composition recorded in this station was 39.20% at class interval 15.0 - 20.0 cm. However, the animals belonging to size class 10.0 - 15.0 cm also showing considerable percentage in its composition 31.20%, 30.15% and 25.80% respectively for three stations.

Total weight : The frequency analysis of total weight showed a single peak at class interval 0 - 200 gm in all three stations with 44.76%, 44.99% and 40.0% respectively (Fig. 28 B). However the fluctuation observed in total weight at station 10 was between 18 and 1000 gm with 44.76% at class interval 0 - 200 gm and 1.61% at class interval 800 - 1000 gm which was also highest and lowest composition respectively among the all other class intervals. It was noticed in station 11 that, the total weight varied from 15 to

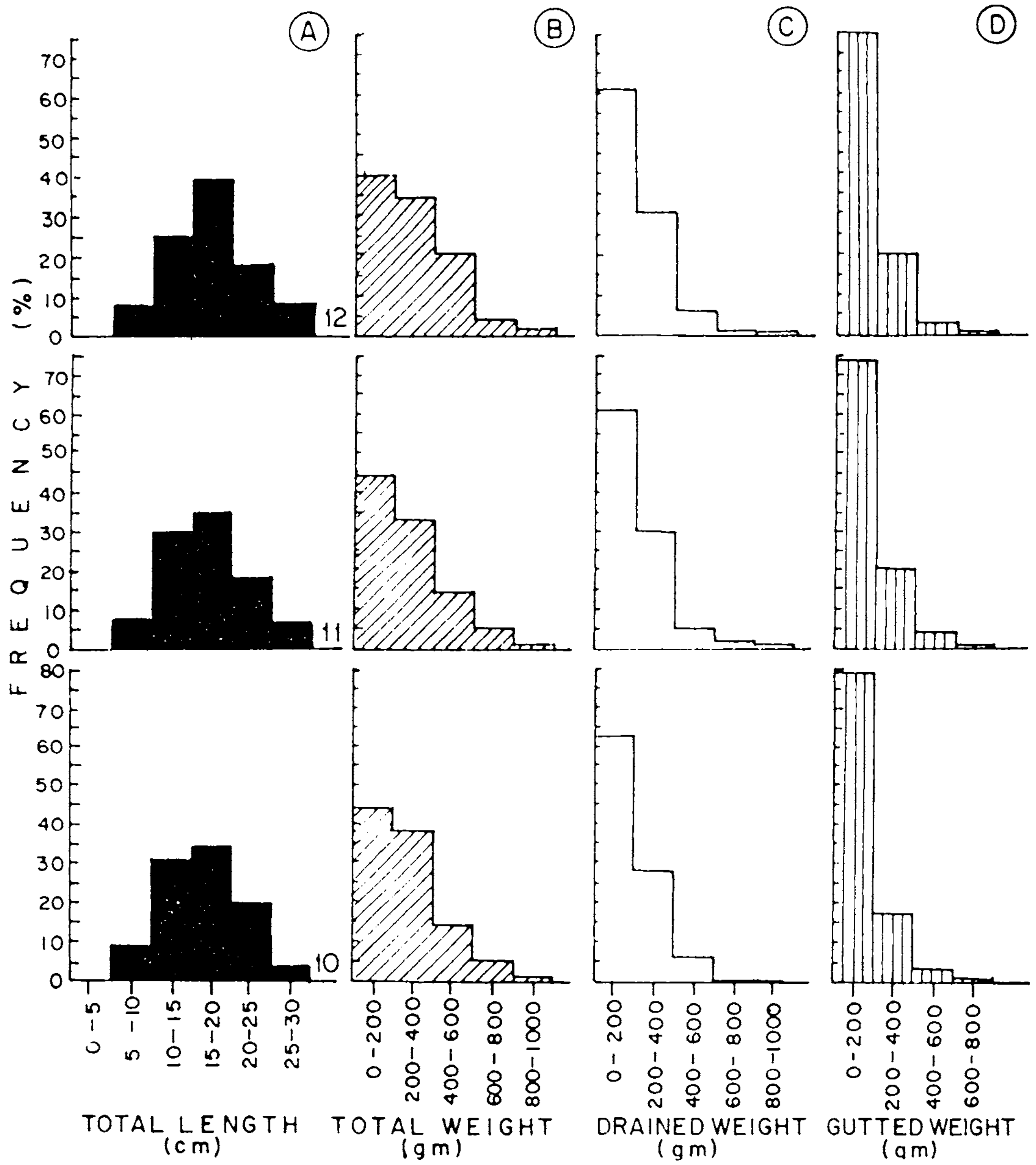


Fig.28. Size frequency distributions of A.mauritiana in 3 reef flat stations at Minicoy Island during January 1990 - December 1991.

1000 gm with 44.99% at class interval 0 - 200 gm and 1.86% at class interval 800 - 1000 gm. These two values were indicating the highest and lowest composition at this station. In station 12, the minimum total weight was 20 gm with 40% at class interval 0 - 200 gm and maximum total weight was 1000 gm with 2% at class interval 800 - 1000 gm.

Drained weight : Drained weight also similar pattern of frequency like total weight that a single peak at class interval 0 - 200 gm with 63.40%, 61.15% and 61.69%, in station 10, 11 and 12 respectively (Fig. 28 C). The fluctuation in drained weight at station 10 was noticed between 10 and 800 gm with 63.40% at class interval 0 - 200 gm and 0.48% at class interval 800 - 1000 gm respectively. In station 11, the minimum drained weight was 10 gm with 61.15% at class interval 0 - 200 gm and maximum weight was 820 gm with 0.71% at class interval 800 - 1000 gm, which were also representing highest and lowest composition among all class intervals. It was noticed in station 12 that, the drained weight varied between 20 gm and 810 gm with 61.69% at class interval 0 - 200 gm and 0.40% at class interval 800 - 1000 gm.

Gutted weight : Gutted weight also showed peak in all three stations like total weight and drained weight at class interval 0 - 200 gm with 79.25%, 74.23% and 75% respectively (Fig. 28 D). However the fluctuation noticed in gutted weight at station 10 was between 8 and 625 gm with 79.25% at class interval 0 - 200 gm and 0.7% at class interval 600 - 800 gm. In station 11, the minimum gutted weight recorded was 5 gm with 74.23% at class interval 0 - 200 gm and maximum was 640 gm with 1.15% at class interval 600 - 800 gm. Station 12 indicated minimum weight of 5 gm with 75% at class interval 0 - 200 gm and maximum weight of 660 gm with 0.8% at class interval 600 - 800 gm and these two values represent highest and lowest composition among the all other class intervals.

Size frequency of pooled population

Total weight : The size frequency for pooled population of 3 stations at reef flat of Minicoy Island ranged between 6.0 cm and 30.0 cm with 10.92% at class interval 5.0 - 10.0 cm and 7.28% at class interval 25.0 - 30.0 cm, which was also lowest composition among all other class intervals. The highest composition noticed was 36.28% at class interval 15.0 - 20.0 cm for pooled population (Fig. 29 A).

Total weight : Total weight varied between 10 and 1000 gm with 43.25% at class interval 0 - 200 gm and 1.82% at class interval 800 - 1000 gm which also represent highest and lowest composition among all other class intervals (Fig. 29 B).

Drained weight : This weight showed the variation at the range of 8 - 820 gm with 62.08% at class interval 0 - 200 gm and 0.53% at class interval 800 - 1000 gm (Fig. 29 C).

Gutted weight : The gutted weight of pooled population showed the minimum value of 5 gm with 76.16% at class interval 0 - 200 gm the highest composition among all other class interval and maximum value of 640 gm with 0.81% at class interval 600 - 800 gm which forms lowest composition among all other class intervals (Fig. 29 D).

SECTION D : BIOMETRY

A. mauritiana

The emprical relationship obtained between the characters total length and weights (TW, DW and GW) by using regression equation $Y = a\ x^b$ for *A. mauritiana* is given in Table 11 for stations 10, 11 and 12, and for total population (pooled over 3 stations). It shows the b value is lesser than usual cubic relationship (b = 3), and r values are nearly between 0.90 and

TABLE 11. Biometric relationship between morphometric characters [(total length and weight (TW, DW and GW)] of *A. mauritiana* in Stations 10, 11 and 12 and for total population during the period January 1990 - December 1991 in Minicoy Reef Flat

Stations	X	Y	df	r	$Y = a x^b$
10	TL	TW	429	0.95	$Y=0.596400474\ x^{2.111165}$
	TL	DW	429	0.94	$Y=0.350433612\ x^{2.180848}$
	TL	GW	429	0.92	$Y=0.156753777\ x^{2.361459}$
11	TL	TW	259	0.95	$Y=0.0.600897565\ x^{2.124799}$
	TL	DW	259	0.94	$Y=0.363487998\ x^{2.191516}$
	TL	GW	259	0.94	$Y=0.176146895\ x^{2.342873}$
12	TL	TW	248	0.95	$Y=0.551587938\ x^{2.152237}$
	TL	DW	248	0.94	$Y=0.295331448\ x^{2.252925}$
	TL	GW	248	0.93	$Y=0.125651761\ x^{2.342873}$
Total Population (Pooled over 3 stations)	TL	TW	938	0.94	$Y=0.585610726\ x^{2.1257}$
	TL	DW	938	0.92	$Y=0.3381384\ x^{2.2031}$
	TL	GW	938	0.95	$Y=0.152498579\ x^{2.3803}$

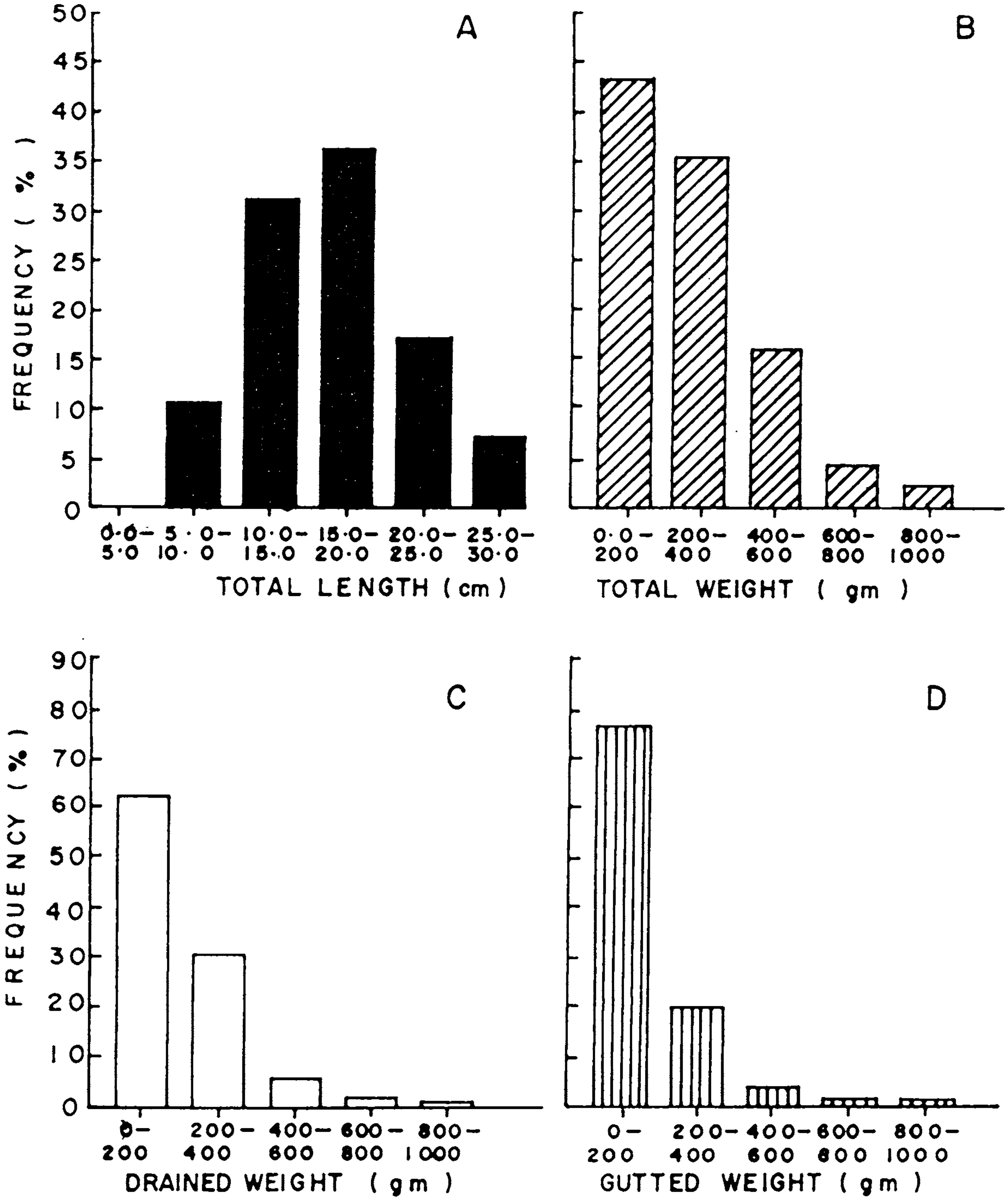


Fig.29. **Size frequency distributions of total population of <u>A.mauritiana</u> at Minicoy Island.**

0.95%, for stationwise and for total population also. The analysis of covariance (ANCOVA) revealed no significant differences in slopes among the stations (Table 12, Fig. 30).

DISCUSSION

Morphometry : Hyman (1955) written that the Holothuroidea are mostly of moderate size, but vary within wide limits like most animal groups. Further the Aspidochirota are mostly of moderate to large size and the largest holothurians that retain the cucumber shape occur in the Aspidochirote genera *Holothuria*, *Actinopyga* and *Stichopus*, often 30 to 50 cm in length. In the present study *A. mauritiana* measured minimum of 6.0 cm with total weight of 8.0 gm and maximum of 30.0 cm weighing 1000.0 gm.

Actinopyga mauritiana is widespread in the tropical Indo-Pacific as observed by Clark and Rowe (1971). It is seen mainly at the outer reef flats influenced mainly by strong waves and currents (Conand, 1990). A New Caledonian Aspidochirote *A. echinites* 100 - 320 mm in total length, 0 - 780 gm in total weight, 0 - 540 gm in drained weight and 0 - 390 gm in gutted weight was reported by Shelley (1981). But she has not given any original value of size range of this species. There are no reports on the morphometry of *A. mauritiana* for comparison with the present study. Hence it is compared and discussed with the result obtained on *A. echinites* by Shelley, which belongs to same genus *Actinopyga*. Bakus (1968) in Enewetok Marshall Islands noticed *A. mauritiana* with 30.0 cm in length and 2800.0 gm wet weight, which is somewhat different in weight when compared to the present study (Table 13).

From the varying measurements of *A. echinites* studied by Shelley (1981) and *A. mauritiana* by Bakus (1968) and the candidate, it may be very well concluded that the size differences may perhaps be due to the environmental conditions which influence the growth and size of the population.

TABLE 12. Analysis of covariance (ancova) for morphometric characteristic relationship of total population of *A. mauritiana*

A. **Total length and total weight**

Source	Degree of freedom	Sum of squares	Mean square	F value	Probability
Difference in level	2	0.390	0.195	4.10	0.017
Error	935	44.517	0.048	-	-
Difference in slope	2	0.030	0.015	0.32	-
Error	933	44.486	0.048	-	-

B. **Total length and drained weight**

Source	Degree of freedom	Sum of squares	Mean square	F value	Probability
Difference in level	2	0.706	0.353	4.84	0.008
Error	935	68.246	0.073	-	-
Difference in slope	2	0.098	0.049	0.67	-
Error	933	68.149	0.073	-	-

C. **Total length and gutted weight**

Source	Degree of freedom	Sum of squares	Mean square	F value	Probability
Difference in level	2	0.692	0.346	3.42	0.033
Error	935	94.567	0.101	-	-
Difference in slope	2	0.202	0.101	1.00	0.368
Error	933	94.364	0.101	-	-

Difference in level = a value
Difference in slope = b value

TABLE 13. Comparative Statement on different morphometric parameters of _Actinopyga_ sp. by Shelly, Bakus and by the candidate

Species	Author	Total length (mm)		Total weight (gm)		Drained Weight (gm)		Gutted weight (gm)	
		Total	Mean SD	Total	Mean SD	Total	Mean SD	Total	Mean SD
A. mauritiana	Bakus(1968)	300	--	2300		--	--	--	
A. echinites	Shelly (1981)	100-300	217 ± 33	0.780	339 ± 126	0.540	256 ± 79	0.390	176 ± 66
A. mauritiana	Present Study	60-300	180 ± 50.82	10-1000	312.14 ± 168.50	8-820	240.10 ± 130.12	5-640	182.72 ± 82.101

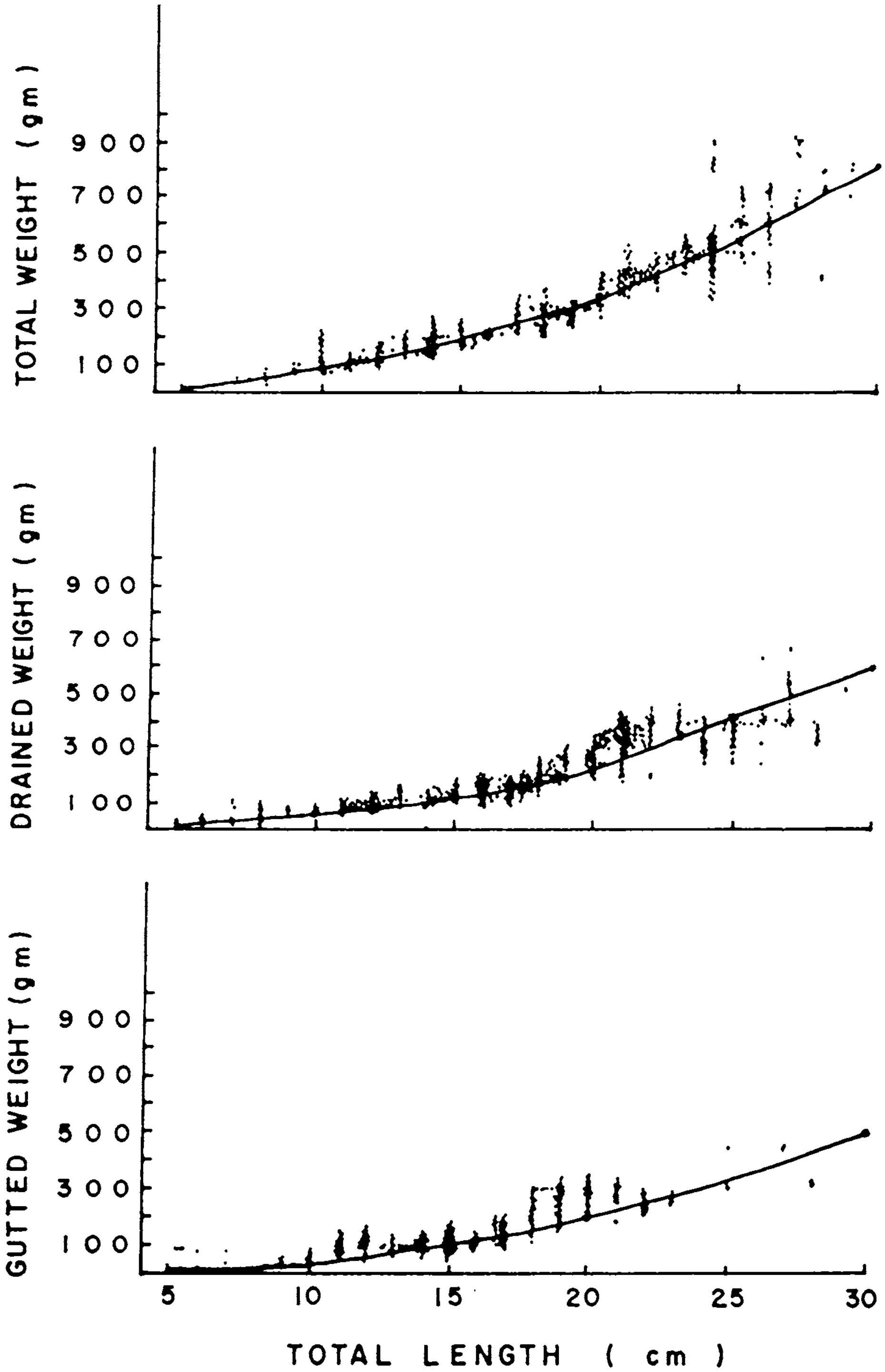


Fig.30. Biometric relationship between Total length and weight (TW, DW & GN) of total pupulation of *A.mauritiana* at Minicoy Island.

Further the present study showed that the size range of A. mauritiana was wide from 6.0 - 30.0 cm, but the mean length was 18.42 cm with mean total weight of 312.14 gm. The other weight such as drained and gutted weights also showed a similar pattern. The occurrence of comparatively smaller animals from the study area may perhaps be due to asexual reproduction of the animal by fission, as the sexual animals were not seen by the candidate from the Minicoy Island. This view is strengthened by the observations of Ebert (1978) on H. atra from Enewetak Island. Further Ebert reported that certain environmental features could promote asexual reproduction and in such location only small to medium size animals would be found. Crozier (1918) reported that Stichopus moebii of Bermuda Island has a tendency to be about the same general size in one locality. This phenomenon is common in a number of coral reef holothurians and it may be related to reproduction by transverse fission (Bakus, 1973).

Size frequency: Bakus(1973) reported from size frequency analysis of the tropical holothurians only an unimodal size frequency distribution, as observed in the present study. Crozier (1918) also noticed in S. moebii population in Bermuda, a unimodal size frequency distribution. Ebert (1978) also reported this unimodal frequency. This is characteristic for H. atra population in Enewatak Atoll Marshall Islands. These two authors have attributed the asexual reproduction for this unimodal size frequency in these species. Conand (1982) analysed the size frequency of A. echinites in New Caledonia and reported only one size class. Further Conand (1990) reported that this unimodal structure is common in H. nobilis, H. fuscogilva, A. echinites and T. ananas population in New Caledonia and the reason attributed was some ecological influence on this particular size groups. Conand (1993) studied the size frequency of S. variegatus an Indo-Pacific Coral reef cucumber from New Caledonia and observed only the unimodal pattern.

It could be seen from the results that though 15.0 - 20.0 cm animals dominating in their percentage, the previous size group i.e. 10.0 - 15.0 cm also contributing considerable percentage to the population in all three stations. Further these two size groups are consisting nearly 60 - 65%. This clearly indicates that the majority of the animals in this smaller size group only contribute much to the population at Minicoy Island. This further helps to conclude that the process of asexual reproduction may be very common in this age group only. Emson and Wilkie (1980) also reported the same observation in many holothurians and opined that the presence of collagen in the body wall of the smaller animals helps the process of asexual reproduction than the larger animals.

Biometry : The relationship established between the morphometric characters (TL and TW, TL and DW, TL and GW) for the population of the three stations individually and for pooled population of *A. mauritiana* at Minicoy reef flat shows a empirical curve and the b value of all these relationship, is at the range of 2 to 2.4. This data indicates that this species shows allometric relationship between the characters as compared to the usual cubic relationship (b = 3).

CHAPTER 3

CHAPTER III : BIOLOGY OF HOLOTHURIA NOBILIS AND ACTINOPYGA MAURITIANA

Part 1 : Food and Feeding of *H. nobilis* and *A. mauritiana*

INTRODUCTION

The knowledge on food availability and feeding mechanism of holothurians are essential to understand their habitat, ecological adaptation, energy requirements and the utilization of energy for their successful development from larvae to adult and reproduction. These studies on the economically important ones is a prerequisite for the culture of sea-cucumbers. Surprisingly till the 19th century little was known about the food and feeding of holothurians. Bakus (1973) has stated that "despite their economical and ecological importance, holothurians have received very little attention from ecologists; hence our understanding of their feeding biology and of the ecological effects of deposit feeding by tropical holothurians is incomplete".

The earlier report by Jaeger (1833) on various holothurian indicates that they are carnivores. This view was certainly accepted by the subsequent workers (Crozier, 1917, 1918; Yamanouti, 1939; Choe, 1963; Bonham and Held, 1963; Glynn, 1965). This is true, because they feed on sand deposit of coral reefs along with micro and macro organisms. But recently Kohn (1971) stated that deposit-feeders are more likely to be specialised to microhabitat than to food types. Rowe and Doty (1977) and Lawrence (1980) stated that the tropical epibenthic holothurians are showing resource partitioning on the basis of macro and micro habitat preference. Roberts and Bryce (1982) accepted the above said view and reported that if habitats do overlap, food partitioning and selective feeding could become factors reducing competitive pressure among the same group of animals. All these views and contradictary conclusion on type and selective of food, sediment particle consumption, assimilation and digestion are encouraging to study clearly more about food and feeding of different sea-cucumbers individually to understand the basic adaptive strategy for their existence.

The information down to us by Hyman (1955) on "holothurians feeding and digestive process", Trefz (1958) on the "physiology of digestion of H. atra", Bakus (1968, 1973) on "food and feeding of tropical holothurians" and others Sloan and Von Bodungen (1980) Hammond (1982) Briggs (1985) and Massin and Doumen (1986) on feeding habits related to their environmental habitat are very useful to acquire basic knowledge on this aspect. But all these reports are from various regions of the world except from Indian region.

So, in the present study the candidate has taken keen interest to study about food and feeding biology of H. nobilis and A. mauritiana. The significant findings are reported in detail and discussed here elaborately.

MATERIALS AND METHODS

Tentacle structure and feeding behaviour

Holothurians mainly feed on sediments. Tentacles are very important organ and they play a vital role in feeding by holothurians. The feeding depends upon the size and structure of tentacles. For this study, method by Fankboner (1978) was adopted. Based on this, tentacle structure and their function during feeding by Holothuria nobilis and Actinopyga mauritiana were determined from numerous field and visual observations in situ by skin diving. Tentacle function was also noted on feeding the animals maintained in the aquaria.

Further, tentacles were snipped from adult animals and lightly pressed between micro slides, and shape and texure of frond of tentacles were observed through magnifying lens. The drawings were made and presented in the results.

Gut and its characters

In H. nobilis and A. mauritiana the gut length, wet weight of the gut, dried weight of the gut contents were measured from each animal, to find out the relationship between the length and gut weight and animal size by regression analysis.

Condition of gut fullness

To justify, whether H. nobilis and A. mauritiana undergo eastivation or starvation, the gut content available was recorded as 1/4, 1/2, 3/4 and full in each animal from fortnightly collections. The results are arranged monthwise for gut content of these two species and statistically analysed.

Types of food consumed

To find out the food preference and selectivity of food items (biotic and abiotic organisms) from the habitat, the guts were removed, preserved in 5% formalin and analysed from 45 animals of Holothuria nobilis with sizes from 20.0 cm to 40.0 cm and 60 animals of Actinopyga mauritiana of 6.0 cm to 30.0 cm sizes. Since the food items were mixed with sediment particles, the contents were seived through a set of the seives with mesh sizes 1.0 mm, 0.7 mm, 0.5 mm, 0.25 mm and $<$ 0.25 mm respectively. The material which accumulated on the seives was washed and items of food were identified using a dissection microscope. Sediment and fecal pellets were collected and food items were identified and quantified for comparison.

The foregut, midgut and hindgut were analysed for food particles along with the faecal pellets and the sediment particles from where the specimens were collected. The samples were rinsed in clean tap water and dried in a oven at 60°C for 24 hours as adopted by Townsley and Townsley (1973). The grain size f the sediment, gut contents and faecal pellets were immediately studied. Later for grain size analysis geological seives (4.0, 2.0, 1.0, 0.7, 0.5 and $<$ 0.5 mm mesh) were used to study the grain size. Percentage composition of each sample was calculated on the basis of total dry weight of each aliquot. Further, relative gut percentage of food particle size were calculated using the following formula.

$$\text{Relative gut percentage} = \frac{\text{Foregut}}{\text{Substratum}} \times 100$$

Assimilation efficiency of organic carbon

As the holothurians are known for taking organic carbon from the sediment, this study is felt very essential to find out the assimilation efficiency.

Sample collection : Six to ten animals of each species were collected every month along with samples of the surface sediments and freshly voided faecal pellet size of the animals were noted. On return to shore, the animals were immediately dissected and the sediment in their foregut, midgut and hindgut removed separately in petridishes with proper labelling. All samples were rinsed with fresh water and covered with aluminium foil to prevent contamination and dried in an oven at 60°C. After 48 hours, these sediment samples were tansferred into glass vials with proper labelling and kept it in a desicator for further organic carbon analysis.

Estimation of organic carbon : The method of Walkey and Black (1934) was used to determine the organic carbon content of the sediment samples. In this method hot chromic acid was used to oxidise organic carbon present and the excess acid not reduced by the organic matter was determined volumetrically with ferrous salt. The results were calculated from the equation.

$$\text{Percentage organic carbon} = \frac{3.951}{G} \left(1 - \frac{T}{S}\right)$$

where

G = sample weight in gram

S = ml ferrous solution, standardisation blank titration

T = ml ferrous solution, sample titration

To calculate assimilation efficiency, the method of Webb *et al*. (1977) was used.

$$\text{Assimilation efficiency} = \%\ \text{organic carbon of foregut} - \frac{\text{organic carbon of midgut}}{\%\ \text{organic carbon of foregut}} \times 100$$

Applying this calculation and obtained values, monthly average (in percentage) of organic carbon, monthly assimilation efficiency and monthly average ratio of assimilation in foregut, midgut and hindgut were calculated. Further, assimilation efficiency in relation to various size groups were also investigated. The two way analysis of variance (ANOVA) was applied to find out the level of variation between the parameters studied.

Digestion

The process of digestion (the time required from ingestion to the egestion) in *H. nobilis* and *A. mauritiana* was studied by adopting the method of Yamanouti (1939). Accordingly various sizes of sea-cucumbers with full gut content were brought to the laboratory and separately kept in 50 to 100 litre capacity tubs with clean sea water and aeration (Pl. 19). If the animal egests gut content, it was carefully removed by a pipette to prevent dissolving the gut content in the water or retaking by the animal. The egested sand was washed, dried at 100°C, and weighed to the nearest mg and the percentage of gut content removal/hour was calculated. The data obtained from the above experiment was applied to estimate consumption of sand per day and per year in H. nobilis and A. mauritiana using the following steps suggested by Yamanouti (1939).

A. Time in which the gut is actually full in a day.

B. One cycle of digestion.

C. Number of digestive cycle in a day - calculated by dividing A by B.

D. Average amount of gut content.

E. Average amount of sand eaten by one individual per day (C x D).

F. The same amount per year (E x 365).

SECTION A : HOLOTHURIA NOBILIS

FEEDING ORGANS

Morphology of tentacles

The mouth of Holothuria nobilis is encircled by twenty tentacles of equal size. These tentacles are in a circle arranged equidistantly and uniformly around the mouth. The mouth is recessed at the base of muscle hood which is like a funnel by buccal membrance within which the tentacles can be retracted and can be unfolded from the hood as a crown at the time of feeding. Length of a tentacle is from 0.8 to 1.5 cm in living condition from the base of mouth

PLATE XIX A. Experiment for digestion in H. nobilis.

PLATE XIX B. Experiment for digestion in A. mauritiana.

depending on the size of the animal. The stalk of the tentacles is cylindrical and the distal end is with disk shaped fronds. Microscopic observation shows that the distal end i.e. frond is packed with numerous nodules and these help to trap the sand particles and food materials from the substratum. Surprisingly, no mucus Secretion was found on the nodules of this species. Each tentacle has an associated tentacular ampulla of the water vascular system located at the base of the tentacles (Fig. 31 A, B).

Feeding mechanism

The observation of feeding behaviour in the laboratory and natural bed shows that while the animal is feeding, the mouth is directed ventrally to enable all the tentacles to trap the food from the substratum. As the mucus secretion was not observed in the fronds to stick the food particles in this species, the musculature in the fronds act an important role to catch the food particles without falling and enable to take to mouth. The mouth is made up of spincter muscles and the oral cavity is opened and closed rhythmically which enables the animal to engulf the food particles. At rest the tentacles are retracted into the hood bearing a small opening of the mouth. This activity was discernible during the diving as also during the laboratory experiments (Fig. 31 C, D).

DIGESTIVE ORGANS

The details of the entire alimentary canal and other associated organs have been described in the chapter I : Taxonomy of *H. nobilis*. The entire gut of *H. nobilis* is semi-transparent and very thick. The particles may not be easily discerned through the gut wall. When the gut is empty it tends to become flattened medially rather than round and secretes digestive juice, which is yellowish in colour.

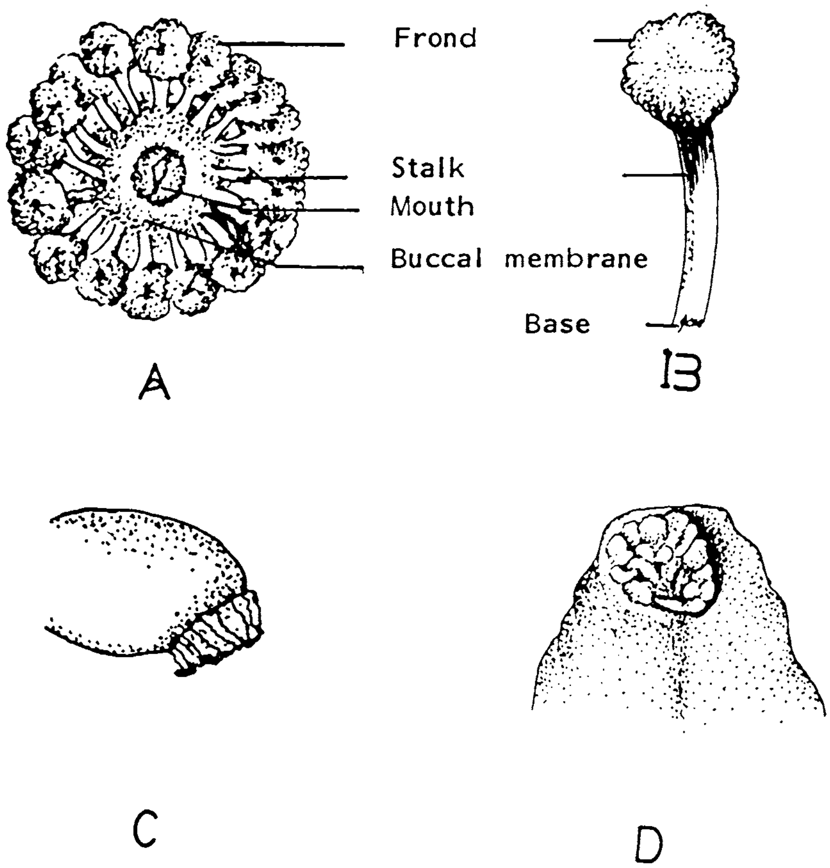


Fig.31. Oral region with associated tentacles in H.nobilis. A.Oral View to Show the arrangement of tentacle; B a. single tentacle; C. feeding position - lateral view and D. resting position with contracted tentacles inside the hood.

Gut structure and related proportions

The results of gut length, wet weight of the gut and dried weight of the gut content of H. nobilis are given in Table 14. In animals of size group 20.0 - 22.9 cm, the gut length is measured minimum 43.0 cm and maximum 55.0 cm with mean value of 51.64 ± 3.11 cm. The wet weight of the gut is minimum 40 gm and maximum 65 gm with mean weight of 53.05 ± 8.37 gm. Dried weight of the gut content showed the minimum 17 gm and maximum 28 gm with mean value of 21.86 ± 3.38 gm. In the size group 38.0 - 40.9 cm the gut length measured minimum 70.0 cm and maximum 112.0 cm with mean value of 108.15 ± 10.25 cm, the wet weight of the gut was minimum 85 gm and maximum 140 gm with mean value of 110.47 ± 13.90 gm. Dried weight of the gut sediment was minimum 38.6 gm and maximum 72.0 gm with mean value of 55.47 ± 9.36 gm.

The relationship established between these characters by correlation and regression are given in the Table 15 and 16. This indicates that there is greater correlation between gut length and body length since the b value is 3.2672 and r^2 = 94.2, which is agreed with hypothetical value of 3. But for other characters there is slight deviation on the lower side from the hypothetical value of 3. From these facts it is conveniently and statistically presumed that the gut length is remarkably related to the animal length and the gut length is generally three times longer than the body length.

Condition of the gut

Based on monthly observations on the gut condition, a significant variation in the feeding indensity of H. nobilis was noticed (Table 17). In the month of September 1990, 38.46% of the animals were found with full stomach and in June 1990, 71.42% of the animals were with full food contents, which were the minimum and maximum percentage of the animal with full gut content respectively. Similarly 59.04% of the animals in August 1991 were found with full gut contents.

TABLE 14. The minimum, maximum, mean and standard deviation of gut length in cm (GL), wet weight of gut in gram (WWG) and dried weight of gut sediment in gram (DWGS) in different size groups of *H. nobilis*

Animal Size group (cm)	No. of animals		Minimum	Maximum	Mean	and	SD value
20.0 - 22.9	22	GL	43.0	55.0	51.64	±	3.11
		WWG	40.0	65.0	53.05	±	8.37
		DWGS	17.0	28.0	21.86	±	3.38
23.0 - 25.9	46	GL	48.0	72.0	54.11	±	5.63
		WWG	40.0	90.0	63.98	±	12.44
		DWGS	20.0	45.0	30.92	±	6.92
26.0 - 28.9	40	GL	60.0	75.0	65.71	±	5.66
		WWG	55.0	100.0	74.95	±	12.23
		DWGS	30.0	41.9	36.10	±	3.49
29.0 - 31.9	52	GL	63.0	85.0	68.10	±	8.55
		WWG	40.0	100.0	77.13	±	14.66
		DWGS	25.5	50.0	37.38	±	6.85
32.0 - 34.9	50	GL	62.0	88.0	73.53	±	7.89
		WWG	60.0	112.0	87.69	±	14.89
		DWGS	34.1	60.0	42.78	±	6.29
35.0 - 37.9	66	GL	65.0	102.0	87.45	±	9.53
		WWG	60.0	130.0	97.37	±	14.48
		DWGS	25.5	70.1	47.96	±	9.88
38.0 - 40.9	70	GL	70.0	112.0	108.15	±	10.25
		WWG	85.0	140.0	110.47	±	13.90
		DWGS	38.6	72.0	55.47	±	9.36

TABLE 15. Relationship between body length (BL) and gut length (GL), total gut weight (TGW) and dried weight of the gut sediment (DWGS) of *H. nobilis*

Characters	df	$y = ax^b$	R^2
Gut length versus Body length	499	$GL = 17.2559\ Bl^{3.2672}$	94.2%
Total gut weight versus Body length	499	$TGW = 0.4875\ Bl^{1.5516}$	93.8%
Dry weight of gut sediment versus Body length	499	$DWGS = 0.13\ Bl^{1.7310}$	92.1%

TABLE 16. Relationship between gut length (GL) and total gut weight (TGW) and dried weight of the gut sediment (DWGS) of *H. nobilis*

Characters	df	$y = ax^b$	R^2
Total gut weight versus Gut length	499	$TGW = 0.3515\ Gl^{1.2774}$	92.9%
Dry weight of gut sediments versus Gut length	499	$DWGS = 0.0918\ Gl^{1.4216}$	95.4%

TABLE 17. Condition of the gut in H. nobilis in different months during 1990-1991

Month	No. of animals	Degree of fullness				
		Empty	1/4	1/2	3/4	Full
January 1990	17	-	5.89	29.40	5.89	58.82
February	24	-	8.34	16.66	12.50	62.50
March	28	3.57	17.86	278.57	7.14	42.86
April	16	6.25	12.56	37.56	-	43.75
May	19	-	5.26	42.11	10.54	42.11
June	14	-	7.15	14.28	7.15	71.42
July	12	-	16.67	33.33	8.33	41.67
August	17	-	-	41.18	11.76	47.06
September	28	-	26.92	34.62	-	38.46
October	23	-	26.09	30.43	-	43.48
November	22	-	22.73	18.18	13.64	45.45
December	19	-	15.79	26.32	-	57.89
MEAN SD	19.75± 4.90	0.82± 1.99	13.77± 8.70	29.38± 9.22	6.41± 5.26	49.62± 10.36
January 1991	20	-	10.00	20.00	25.00	45.00
February	23	8.70	30.43	17.34	8.70	34.78
March	21	-	38.10	23.80	-	38.10
April	20	5.00	10.00	45.00	-	40.00
May	18	5.56	16.66	22.22	5.56	50.00
June	14	7.14	28.57	21.43	-	42.86
July	17	-	29.41	29.41	5.89	35.29
August	22	4.55	27.27	-	9.09	59.04
September	20	5.26	10.53	15.79	15.79	52.63
October	15	-	26.67	13.33	6.67	53.33
November	24	-	29.17	20.83	8.33	41.67
December	20	5.00	30.00	15.00	5.00	45.00
MEAN SD	19.5± 3.03	3.43± 3.20	23.90± 9.53	20.35± 10.57	7.50± 7.15	44.81± 7.61

The percentage composition of the animal with empty, 1/4, 1/2, 3/4 and full of the gut are presented monthwise in Table 17.

TYPES OF FOOD CONSUMED

Food in the sediment

Table 18 shows the percentage of organisms present in the sediment. The biotic group contains polychaetes, bivalves, tubiculous-polychaetes, foraminiferans, crustacean larvae, nematodes and seaweeds. Abiotic group contains broken shells and spines of sea-urchins and crab appendages. The results of 9 samples from different localities showed that polychaetes, amphipods, tubiculous - polychaetes and seaweeds were dominant groups with 10 to 15%, while others occupy less than 10% in the lagoon sediment.

Food in the gut

Table 19 shows the percentage of food items in the sediment consumed by H. nobilis. It indicates that the constituents available in the gut are similar to the ones available in the sediment. Tubiculous polychaetes is dominant group in the gut content which occupied 13% among all the biotic and abiotic groups. Polychaetes, amphipods and seaweeds were secondary items. It evident from the above that the organisms of the sediment and in the gut content are similar in their percentage too.

Constituents in the faeces

Table 20 shows the percentage composition of matters in the faecal castings of H. nobilis which is generally undigested. This matter (biotic and abiotic organisms) is reflecting the organisms available in the sediment from the environment. However, the biotic

TABLE 18. Food constituents in percentage (biotic and abiotic organisms) in the lagoon sediment (*H. nobilis* habitat) of Minicoy Island (25gm wet sediment from the lagoon analysed)

		BIOTIC FAUNA									ABIOTIC FAUNA		
No. of Samples	No. of animals	Polychaetes	Amphipods	Gastropods	Bivalves	Tubiculous polychaetes	Foraminiferans	Crustacean larvae	Nematodes	Seaweeds	Echinoid broken shells	Sea urchin spines	Crab appendages
1	5	8.12	12.10	4.90	6.20	10.25	8.00	7.14	8.80	12.70	6.40	7.50	7.89
2	5	12.40	8.20	7.35	7.00	8.60	11.20	8.10	6.30	10.60	7.32	8.60	4.33
3	5	9.40	10.38	7.60	9.36	10.10	7.96	8.10	7.00	9.00	8.20	7.40	5.50
4	5	8.40	11.48	5.30	4.20	14.20	8.38	12.10	6.18	12.00	5.20	8.40	4.16
5	5	9.65	7.20	6.40	7.46	10.20	8.20	8.40	8.75	12.18	8.60	7.40	5.56
6	5	13.60	11.60	7.30	5.00	8.20	6.45	10.20	8.43	10.15	4.20	9.68	5.19
7	5	10.12	5.30	7.35	8.72	16.22	4.20	6.16	8.20	15.01	8.20	5.50	5.02
8	5	9.15	12.20	4.30	7.68	10.00	6.20	8.35	8.64	12.10	8.20	6.20	6.98
9	5	10.14	6.20	6.40	8.10	10.30	7.91	8.20	10.15	8.30	6.00	9.30	9.00
MEAN ± SD		10.11 ± 1.80	9.41 ± 2.71	6.32 ± 1.22	7.08 ± 1.69	10.90 ± 2.61	7.61 ± 1.91	8.53 ± 1.72	8.05 ± 1.31	11.34 ± 2.05	6.92 ± 1.56	7.78 ± 1.37	5.95 ± 1.65

TABLE 19. Food constituents in percentage (biotic and abiotic organisms) in the gut of _H. nobilis_ (25gm wet sediment from the gut analysed)

Station	No. of samples	BIOTIC FAUNA								ABIOTIC FAUNA			
		Polychaetes	Amphipods	Gastropods	Bivalves	Tubiculous polychaetes	Foraminiferans	Crustacean larvae	Nematodes	Seaweeds	Echinoid broken shells	Sea urchin spines	Crab appendages
1	5	10.20	10.19	6.20	3.00	13.15	4.12	9.00	5.00	14.00	6.02	14.02	5.10
2	5	13.12	10.00	8.24	6.12	12.20	8.10	8.00	6.00	8.15	8.12	8.10	3.85
3	5	10.80	6.20	8.00	7.54	8.60	7.10	6.32	8.34	7.15	12.00	9.30	8.65
4	5	12.99	9.60	5.04	4.20	12.20	7.20	8.25	9.10	6.22	10.10	7.10	8.00
5	5	10.20	10.19	6.20	3.00	13.15	4.12	9.00	5.00	14.00	6.02	14.02	5.10
6	5	14.10	10.40	8.20	6.60	10.10	6.20	6.10	6.00	9.40	7.20	8.10	7.60
7	5	12.10	8.00	5.90	5.50	20.00	6.05	8.00	7.00	8.00	5.13	10.15	4.17
8	5	10.50	6.62	8.31	7.52	10.90	8.81	8.20	7.10	10.10	8.20	5.20	8.54
9	5	8.20	7.90	5.80	8.20	6.30	9.92	8.86	5.00	7.10	10.92	12.20	9.60
MEAN ± SD		11.36 ± 1.86	8.79 ± 1.64	6.88 ± 1.29	5.74 ± 1.96	11.84 ± 3.80	6.85 ± 1.96	7.97 ± 1.08	6.50 ± 1.50	9.35 ± 2.89	8.19 ± 2.38	9.80 ± 3.08	6.73 ± 2.17

TABLE 20. Food constituents in percentage (biotic and abiotic organisms) and their percentage composition in the faecal castings of H. nobilis (10gm faecal casting analysed)

Station	No. of samples	BIOTIC FAUNA									ABIOTIC FAUNA		
		Polychaetes	Amphipods	Gastropods	Bivalves	Tubiculous polychetes	Foraminiferans	Crustacean larvae	Nematodes	Seaweeds	Echinoid broken shells	Sea urchin spines	Crab appendages
1	5	17.83	12.74	12.74	5.10	8.92	3.82	5.73	8.28	9.35	6.37	3.82	5.30
2	5	21.90	11.68	8.76	5.84	8.76	6.57	3.65	5.83	7.30	4.38	5.84	9.49
3	5	13.16	14.74	13.16	6.32	14.74	2.63	6.32	5.26	4.21	5.26	6.38	7.89
4	5	21.51	17.20	6.99	4.30	10.75	4.30	9.63	4.30	7.57	2.69	5.38	5.38
5	5	13.92	9.95	7.46	9.95	11.94	6.47	9.95	4.98	9.95	5.97	4.98	4.48
6	5	12.50	7.50	6.25	9.38	11.25	6.25	11.25	8.75	12.50	6.25	5.00	3.12
7	5	11.61	5.16	7.74	5.16	16.77	11.61	9.68	7.74	16.13	3.81	2.58	1.95
8	5	11.91	7.14	4.76	8.93	4.76	7.14	10.71	7.14	8.93	11.91	10.71	5.96
9	5	10.15	11.00	8.45	10.35	8.00	5.50	6.20	7.59	8.12	8.10	10.20	6.34
MEAN ± SD		14.94 ± 4.31	10.79 ± 3.84	8.48 ± 2.80	7.26 ± 2.37	10.65 ± 3.61	6.03 ± 2.56	8.13 ± 2.67	6.65 ± 1.59	9.35 ± 3.39	6.08 ± 2.70	6.09 ± 2.71	5.55 ± 2.29

groups such as polychaetes, amphipods and seaweeds are showing higher percentage when compared to those in the gut and lagoon sediment. But some polychaetes, nematodes, amphipods which had apparently been ingested by animal also remained viable after passing through the gut, while others are showing less motility. The faecal castings also contain many fragments of seaweeds (green and red algae) undigested along with sand particles without any modification.

Ratio of food items

Table 21 shows the ratio of food items in the (i) environmental sediment with (ii) gut and (iii) faecal matters of *H. nobilis*. The faecal matter showed highest composition of Polychaetes (1.0:1.12:1.48), amphipods (1.0:0.93:1.15), gastropods (1.0:1.03:1.29) and bivalves (1.0:0.81:1.29). In the environmental sediment crustacean larvae (1.0:0.93:0.95), nematodes (1.0:0.80:0.82) and seaweeds (1.0:0.84:0.82) were in highest ratio with gut and faecal matters respectively.

Percentage of food items in the gut in relation to various size groups.

Table 22 gives the percentage of the food items of the gut content in various size groups of *H. nobilis*. From this it is clear that there is no preference or selection of food items by this animal and there is no significant difference in the food consumed and ingested by *H. nobilis* with regard to the size of the animals. However, it is clear from Table 22 that polychaetes both free living and tubiculous forms and broken spines and shell of echinoids dominated in the food consumed.

Particle size and selectivity

Table 23 shows the percentage composition of food particle sizes in the substratum, foregut, midgut, hindgut and faeces from

TABLE 21. The ratio of constituents in the environment, gut and faecal matter of *H. nobilis*

Species	Sediment			Ratio
	Environment (i)	gut (ii)	Faecel (iii)	
Biotic fauna				
Polychaetes	10.10	11.36	14.94	1.0.1:12:1.48
Amphipodes	9.41	8.79	10.79	1.0.0:93:1.15
Gastropodes	6.32	6.54	8.48	1.0.1:03:1.29
Bivalves	7.08	5.74	7.26	1.0.0:81:1.02
Tubiculous polychaetes	10.90	11.84	10.65	1.0.1:08:0.97
Foraminiferans	7.61	6.85	6.03	1.0.0:90:0.79
Crustacean larvae	8.53	7.97	8.13	1.0.0:93:0.95
Nematodes	8.05	6.50	6.65	1.0.0:80:0.82
Sea weeds	11.34	9.55	9.35	1.0.0:84:0.82
Abiotic fauna				
Echinoid broken shells	6.92	8.19	6.08	1.0.1:28:0.87
Sea urchin spines	7.78	9.84	6.09	1.0.1:25:0.78
Crab appendages	5.96	6.74	5.55	1.0.1:12:0.93

TABLE 22. Percentage composition of food constituents (biotic and abiotic organisms) in the gut of different size group of *H. nobilis* (5gm wet gut casting analysed)

Animal size group (cm)	BIOTIC FAUNA									ABIOTIC FAUNA		
	Poly-chaetes	Amphi-pods	Gastro-pods	Bi-valves	Tubi-culous poly-chaetes	Fora-mini-ferans	Crusta-cean larvae	Nema-todes	Sea-weeds	Echi-noid broken shells	Sea urchin spines	Crab appen-dages
20.0 - 22.9	12.10	8.00	5.90	5.50	20.00	6.05	8.00	7.00	8.00	5.13	10.15	4.17
23.0 - 25.9	10.20	10.19	6.20	3.00	13.15	4.12	9.00	5.00	14.00	6.02	14.22	5.10
26.0 - 28.9	13.12	10.00	8.24	6.12	12.20	8.10	8.00	6.00	8.15	8.12	8.10	3.85
29.0 - 31.9	8.20	6.12	8.12	10.15	13.15	10.00	4.12	5.14	10.00	8.40	7.60	9.00
32.0 - 34.9	10.14	8.20	6.20	8.10	10.30	6.11	8.20	12.15	6.30	6.00	9.30	9.00
35.0 - 37.9	10.80	6.20	8.00	7.54	8.60	7.10	6.32	8.34	7.15	12.00	9.30	8.65
38.0 - 40.9	10.15	11.12	8.33	10.15	8.20	5.50	6.20	7.59	8.12	8.10	10.20	6.34
MEAN ± SD	10.67 ± 1.58	8.55 ± 1.97	7.28 ± 1.12	7.22 ± 2.58	12.23 ± 3.98	6.71 ± 1.91	7.12 ± 1.67	7.32 ± 2.46	8.82 ± 2.54	7.68 ± 2.30	9.84 ± 2.16	6.59 ± 2.29

TABLE 23. Percentage composition of food particle size in the environment substratum, foregut, midgut, hindgut and faces of *H. nobilis* by seive analysis (Number of sample 60)

Graine size (mm)	Environment Substratum	Foregut	Midgut	Hindgut	Faeces
4	19.25	20.24	19.37	21.93	20.54
2	12.34	11.88	11.42	10.89	11.17
1	13.72	13.44	14.11	13.48	12.12
0.7	15.64	14.64	15.51	14.21	13.10
0.5	16.12	18.03	15.48	14.55	14.33
< 0.5	20.48	21.77	22.03	23.42	17.38

TABLE 24. Food particle size relative index (as substratum 100) of *H. nobilis*

Graine size (mm)	Environment Substratum	Foregut	Midgut	Hindgut	Faeces
4	100	105.14	100.62	111.84	106.70
2	100	96.27	92.54	88.25	90.52
1	100	97.96	102.84	98.48	88.34
0.7	100	93.61	99.17	90.86	83.76
0.5	100	111.85	96.03	90.26	88.90
< 0.5	100	106.30	107.57	114.36	84.86

TABLE 25. Level of variation in Food particle percentage between different regions of the gut and between particle size. of *H. nobilis* by ANOVA II

Source	df	SS	MSS	F.value	Remarks
Treat	3	13.270	4.4233	2.38	Not Significant
Replication	5	357.157	17.4310	51.33	Significant

H. nobilis from sand analyses by seive method. The data clearly shows that there is no selection of particular food particle size by this animal and the percentage of particle size in the gut and in the substratum is almost similar. The sand particle size index study with substrate as 100 shows that highest (111.84) particle size of 4.0 mm and smallest (114.36) particle size of below 0.5 mm were found only in the hindgut. However, there was not much variation among other regions of the digestive system (Table 24). From this Table 24, it is significant to note that 4.0 mm particle size was highest in all regions of the gut and below 0.5 mm size was also uniformly seen in all region of the gut. Further more, the two-way ANOVA (Table 25) shows that there is no significant variation in the percentage of particle size between the various parts of the gut (F = 2.38), while significant variation is observed between the percentages of particle size (F = 51.33).

Food particles in different regions of the gut

Table 26 displays the differences in food particles size between various regions of the gut, which will help to find out any change in size and quantity in sand particles during digestion. The analysis of data and the results presented here clearly indicates that there is very little difference in percentage composition in food particles between and within different regions of the gut.

Food particle selection in relation to animal size

Table 27 explains the size of food particles consumed in relation to animal size of H. nobilis. The maximum content of 35.06% with particle size below 0.5 mm and lowest percentage of 6.63% in 2.0 mm particle size are found only in the animal size between 20.0 - 22.9 cm among the animal size groups of 20.0 - 40.9 cm studied in the present investigation. An overval observation indicates that

TABLE 26. Comparison of ingested food particles in different gut regions of *H. nobilis*

Various regions of the gut	Food particle size (mm)					
	4.0	2.0	1.0	0.7	0.5	<0.5
Foregut (FG)	20.24	11.88	13.44	14.64	18.03	21.77
Midgut (MG)	19.37	11.92	14.11	15.51	15.48	22.00
Difference (∿ FG and MG)	0.87	- 0.16	- 0.67	- 0.87	2.55	0.23
Hindgut (HG)	21.53	10.89	13.48	14.21	14.55	23.42
Difference (∿ FG and HG)	- 1.24	0.99	- 0.04	0.43	3.48	- 1.65
Faeces (H)	20.54	11.17	12.12	13.10	14.33	17.38
(∿ FG and F)	- 0.30	0.71	1.32	1.54	3.70	4.39

TABLE 27. Selection of food particles in relation to different size group of *H. nobilis* in an average of 100gm of gut content (n = number)

Grain size (mm)	Body length (cm)							
	20.0-22.9 (n-10)	23.0-25.9 (n-12)	26.0-28.9 (n-14)	29.0-31.9 (n-14)	32.0-34.9 (n-20)	35.0-37.9 (n-25)	38.0-40.9 (n-10)	Substratum
4.0	8.40	6.50	8.12	10.85	12.15	10.00	10.22	13.35
2.0	6.63	10.20	12.20	12.10	10.60	10.63	12.65	14.65
1.0	14.20	15.09	17.53	18.16	16.18	15.20	18.50	16.07
0.7	13.10	16.66	20.03	20.82	19.15	24.08	20.00	16.29
0.5	22.61	20.30	20.96	21.05	22.93	22.12	26.12	18.29
< 0.5	35.06	31.25	21.16	16.57	15.99	17.97	12.51	21.35

the higher percentage composition of food particles between 0.5 - <0.5 mm were generally higher among the different size groups of *H. nobilis* studied. The above result also reflects the sand particles analysed from the samples of the substratum, which shows 18.29% and 21.35% for 0.5 mm and < 0.5 mm sand particle size respectively. It is therefore concluded this animal is not a selective feeder, but it feeds on what is available in the substratum.

ASSIMILATION EFFICIENCY

Assimilation of organic carbon by *H. nobilis* in different months

Table 28 shows the monthly value in percentage of organic carbon in food particles of the substratum, foregut, midgut, hindgut and faeces for the two year period 1990 & 1991.

Organic carbon in bottom sediment

Organic carbon was the highest with 0.41% in August and the lowest with 0.34% in October 1990, and the same was 0.37% in May and October 1991, and 0.31% in July 1991. The annual mean of organic carbon was 0.36 ± 0.023% for 1990 and 0.34 ± 0.018% for 1991 with a difference of 0.2% between these two years.

Organic carbon in the gut

Foregut : Organic carbon in the foregut was the highest with 0.46% in March and August in 1990 and the lowest with 0.38% in April, July and December in 1990. The same were 0.43% in March and 0.36% in June and July in 1991. The annual average of organic carbon in the foregut were 0.41 ± 0.028% in 1990 and 0.39 ± 0.023% in 1991

TABLE 28. **Average monthly percentage of organic carbon in the food from substratum, foregut, midgut, hindgut and faeces of *H. nobilis* during 1990-1991**

Month	No. of obser-vations	Sediment	Foregut	Midgut	Hindgut	Faeces
January 1990	6	0.38	0.44	0.34	0.31	0.28
February	8	0.35	0.41	0.33	0.29	0.27
March	7	0.40	0.46	0.34	0.32	0.31
April	6	0.37	0.38	0.30	0.25	0.24
May	6	0.35	0.42	0.33	0.29	0.25
June	6	0.39	0.40	0.33	0.29	0.26
July	8	0.35	0.38	0.30	0.28	0.26
August	12	0.41	0.46	0.34	0.32	0.28
September	10	0.36	0.40	0.31	0.29	0.26
October	7	0.34	0.42	0.32	0.28	0.27
November	8	0.35	0.41	0.31	0.27	0.26
December	7	0.35	0.38	0.30	0.26	0.27
MEAN SD		0.36± 0.023	0.41± 0.028	0.32± 0.016	0.29± 0.02	0.27± 0.18

Month	No. of obser-vations	Sediment	Foregut	Midgut	Hindgut	Faeces
January 1991	9	0.33	0.41	0.32	0.27	0.26
February	12	0.34	0.41	0.33	0.30	0.26
March	8	0.35	0.43	0.33	0.29	0.27
April	6	0.34	0.38	0.31	0.28	0.26
May	6	0.37	0.40	0.31	0.29	0.26
June	6	0.32	0.36	0.29	0.27	0.24
July	6	0.31	0.36	0.29	0.27	0.24
August	6	0.34	0.38	0.31	0.29	0.26
September	8	0.33	0.37	0.30	0.28	0.25
October	6	0.37	0.42	0.33	0.31	0.27
November	10	0.34	0.40	0.31	0.28	0.24
December	14	0.33	0.39	0.31	0.27	0.25
MEAN SD		0.34± 0.018	0.39± 0.023	0.31± 0.010	0.28± 0.013	0.25± 0.010

with a difference 0.2% between these two years.

<u>Midgut</u> : Organic carbon in the midgut was the highest with 0.34% in January, March and August 1990 and lowest with 0.30% in April, July and December in 1990. The same were 0.33% in February, March and October 1991 and 0.29% in June and July 1991. The annual average of organic carbon in the midgut were 0.32 ± 0.016% in 1990 and 0.31 - 0.010% in 1991 with 0.1% difference between these two years.

<u>Hindgut</u> : Organic carbon in this region of the gut was the highest with 0.32% in March and August 1990 and the lowest of 0.25% in April 1990. The same were highest in October 1991 with 0.31% and in January, June, July and December 1991, the percentage was 0.27%. The annual average of organic carbon in the hind gut were 0.29 ± 0.02% in 1990 and 0.28 ± 0.013% in 1991 with 0.1% difference between these two years.

<u>Faeces</u> : Organic carbon in the faeces was the highest with 0.31% in March 1990 and the lowest with 0.24% in April 1990. The same were 0.27% in March and October in 1991 and 0.24% in June, July and November 1991. The average annual organic carbon in the faeces were 0.27 ± 0.018% in 1990 and 0.25 ± 0.010% in 1991. The difference in percentage of organic carbon between these two years was 0.2%.

The two-way ANOVA showed a highly significant variation in organic carbon between various regions of the gut (F = 281.33) and between months (F = 12.0) in 1990 and (F = 336.0) between parts of the gut and (F = 9.0) between months in 1991 (Table 29, 30).

<u>Assimilation efficiency of organic carbon in the gut</u>

The assimilation of organic carbon at various regions of the gut (Table 31) in *H. nobilis* is follows:

TABLE 29. Level of significance in variation of organic carbon between months and other sources such as substratum, foregut, midgut, hindgut and faeces of *H. nobilis* during 1990, analysed by ANOVA II

Source	df	SS	MSS	F-value	Remarks
Coloum	4	0.1689	0.0422	281.33	Highly Significant
Row	11	0.0197	0.0018	12.10	Significant
Error	44	0.0066	0.00015		
Total	59	0.1952			

TABLE 30. Level of significance in variation of organic carbon between months and other sources such as substratum foregut, midgut, hindgut and faeces of *H. nobilis* during 1991, analysed by ANOVA II.

Source	df	SS	MSS	F-value	Remarks
Coloum	4	0.1343	0.0336	336.0	Highly Significant
Row	11	0.0104	0.0009	9.0	Significant
Error	44	0.0043	0.00010		
Total	59	0.1490			

TABLE 31. Average monthly assimilation efficiency (%) of organic carbon in various regions of the gut of H. nobilis during 1990–1991

Month	No. of observation	Foregut to Midgut	Foregut to Hindgut	Foregut to Faeces
January 1990	6	23.50 ± 13.27	30.18 ± 6.30	36.06 ± 3.10
February	8	20.37 ± 8.27	31.62 ± 17.93	34.27 ± 21.85
March	7	25.12 ± 15.94	29.36 ± 19.86	32.57 ± 23.86
April	6	20.05 ± 10.78	35.03 ± 9.01	39.73 ± 9.32
May	6	24.50 ± 10.43	30.35 ± 9.58	41.73 ± 10.70
June	6	17.07 ± 5.32	28.39 ± 7.00	33.42 ± 7.21
July	8	21.83 ± 6.21	26.70 ± 20.79	30.79 ± 20.42
August	12	26.39 ± 17.13	30.76 ± 16.23	41.03 ± 18.12
September	10	22.54 ± 10.48	27.29 ± 12.93	36.36 ± 15.72
October	7	24.93 ± 11.05	33.35 ± 13.15	34.74 ± 19.83
November	8	25.60 ± 9.32	33.74 ± 14.06	35.64 ± 16.08
December	7	22.87 ± 15.07	32.65 ± 18.72	37.18 ± 20.73
January 1991	9	20.53 ± 4.06	33.60 ± 11.37	37.33 ± 12.65
February	12	19.52 ± 7.22	25.04 ± 9.25	36.18 ± 13.30
March	8	22.35 ± 12.73	32.92 ± 14.93	39.04 ± 15.80
April	6	17.60 ± 8.16	25.32 ± 11.65	31.44 ± 13.50
May	6	22.98 ± 10.31	28.79 ± 12.50	35.93 ± 15.54
June	6	20.17 ± 9.98	25.70 ± 10.20	32.90 ± 12.50
July	6	18.55 ± 6.37	24.47 ± 5.71	33.22 ± 6.01
August	6	17.09 ± 6.38	22.06 ± 6.28	31.38 ± 7.35
September	8	18.91 ± 5.45	24.53 ± 5.25	35.66 ± 6.37
October	6	20.29 ± 5.70	25.07 ± 6.16	34.94 ± 8.97
November	10	23.81 ± 6.15	30.25 ± 9.71	40.77 ± 12.25
December	14	18.73 ± 8.13	29.11 ± 12.50	36.16 ± 16.50

<u>In foregut</u> : In 1990, in this region maximum assimilation was observed in August (26.39 ± 17.13%) followed by March (25.12 ± 15.94%) and November (25.60 ± 9.32%) and the minimum assimilation was in June (17.07 ± 5.32%). In 1991, the maximum was in November (23.81 ± 6.15%) followed by March (22.35 ± 12.73%) and May (22.98 ± 10.31%). The minimum was observed in April (17.60 ± 8.16%) followed by August (17.09 ± 6.38%).

<u>In midgut</u> : In 1990, in this region maximum assimilation was observed in April (35.03 ± 9.01%) and minimum was in July (26.70 ± 20.79%). In 1991, the maximum assimilation was in January (33.6 ± 11.37%) followed by March (32.92 ± 14.93%), while minimum was in August (22.06 ± 6.28%).

<u>In hindgut</u> : In 1990, in this region maximum assimilation was observed in May (41.73 ± 10.70%) followed by August (41.03 ± 18.12), the minimum was observed in July (30.79 ± 20.42%). In 1991, the maximum assimilation was in November (40.77 ± 12.25%) and minimum was in April (31.44 ± 13.50%) followed by August (31.38 ± 7.35%).

From the above observations the calculated value of total assimilation of organic carbon in the whole gut is 36.12% in 1990 and 35.41% in 1991. Further, the two way ANOVA for 1990 showed that between different region of the gut, the variation of assimilation efficiency was highly significant (F = 89.93) and between months it is insignificant (F = 2.30) at 5% level (Table 32). But in 1991, there is highly significant variation between the regions of the gut (F = 270.72) and significant variation between the months (F = 7.95) at 5% level (Table 33).

<u>Rate of assimilation in each region of the gut</u>

The critical analysis of data presented in Table 34 very clearly indicates that the greater amount of organic carbon assimilation

TABLE 32. **Level of significance in variation of assimilation efficiency of organic carbon between months and various regions of the gut of *H. nobilis* during 1990, analysed by ANOVA II**

Source	df	SS	MSS	F-value	Remarks
Coloum	2	1063.02	531.51	89.93	Highly Significant
Row	11	149.66	13.60	2.30	Significant
Error	22	129.95	5.91		
Total	35	1342.63			

TABLE 33. **Level of significance in variation of assimilation efficiency of organic carbon between months and various regions of the gut of *H. nobilis* during 1991, analysed by ANOVA II**

Source	df	SS	MSS	F-value	Remarks
Coloum	2	1418.56	709.28	270.72	Highly Significant
Row	11	229.24	20.84	7.95	Significant
Error	22	57.72	2.62		
Total	35	1705.52			

TABLE 34. Average monthly rate of assimilation (%) in various regions of the gut of *H. nobilis* during 1990–1991

Month	No. of obser-vation	Foregut	Midgut	Hindgut
January 1990	6	23.50	6.60	5.88
February	8	20.37	11.25	2.65
March	7	25.12	4.25	3.20
April	6	20.05	14.90	4.78
May	6	24.50	5.85	11.35
June	6	17.07	11.32	5.03
July	8	21.83	4.87	4.09
August	12	26.39	4.37	10.27
September	10	22.54	4.75	9.07
October	7	24.93	8.42	1.39
November	8	25.60	8.14	1.90
December	7	22.87	9.78	4.53
MEAN ± SD		22.89 ± 2.72	7.88 ± 3.39	5.35 ± 3.25
Total assimilation				36.12
January 1991	9	20.53	13.07	3.73
February	12	19.52	5.52	11.14
March	8	22.35	10.57	6.12
April	6	17.60	7.72	6.12
May	6	22.98	5.81	7.14
June	6	20.17	5.53	7.20
July	6	18.55	5.92	8.75
August	6	17.09	4.97	9.32
September	8	18.91	5.62	11.13
October	6	20.29	4.78	9.87
November	10	23.81	6.44	10.52
December	14	18.73	10.38	7.05
MEAN ± SD		22.04 ± 2.10	7.19 ± 2.68	8.18 ± 2.32
Total assimilation				35.41

take place in the foregut than in midgut and hindgut. The annual mean and standard deviation of assimilation of organic carbon in the foregut were 22.89 ± 2.72%, 7.88 ± 3.39% in the midgut and 5.35 ± 3.25% in the hindgut with total assimilation of 36.12% for the year 1990. The same for 1991 were 22.04 ± 2.10%, 7.19 ± 2.68%, 8.18 ± 2.32% and 35.41% for foregut, midgut, hindgut and total assimilation respectively.

Beside the above observations, the two-way ANOVA calculated for 1990 (Table 35) showed that there was highly significant variation in the rate of assimilation between various region of the gut (F = 83.94) and insignificant between months (F = 0.29) at 5% level. For 1991 (Table 36) similar trend with highly significant variation between various region of the gut (F = 174.13) and insignificant variation between the months (F = 0.52) at 5% level were observed.

Percentage of organic carbon and assimilation efficiency in relation to size

The Table 37 summarises the availability of organic carbon (in %) in foregut, midgut, hindgut and faeces and the assimilation efficiency in these regions in relation to various size groups of *H. nobilis*.

It is clear from Table 37 that the animal in the age group of 20.0 - 22.9 cm, 26.0 - 28.9 cm and 29.0 - 31.9 cm are showing the almost a uniform pattern of organic carbon content (0.36 - 0.38% in foregut, 0.32 - 0.34% in midgut, 0.30 ± 0.31% in hindgut and 0.26 - 0.28% in faeces). In 32.0 - 34.9 cm animal size, a slight higher percentage value (0.43% in foregut, 0.35% in midgut, 0.30% in hindgut and 0.26% in faeces) are observed and in following two size groups 35.0 - 37.9 cm and 38.0 - 40.9 cm, these values have decreased. The two-way ANOVA gives clearly that there is highly significant

TABLE 35. **Level of significance in variation of assimilation rate between months and various regions of the gut of *H. nobilis* during 1990, analysed by ANOVA II**

Source	df	SS	MSS	F-value	Remarks
Coloum	2	2160.67	1080.34	83.34	Highly Significant
Row	11	41.08	3.73	0.28	Not Significant
Error	22	283.20	12.87		
Total	35	2484.95			

TABLE 36. **Level of significance in variation of assimilation rate between months and various regions of the gut of *H. nobilis* during 1991, analysed by ANOVA II**

Source	df	SS	MSS	F-value	Remarks
Coloum	2	1227.61	613.805	174.13	Highly Significant
Row	11	20.12	1.829	0.52	Not Significant
Error	22	77.54	3.525		
Total	35	1325.27			

TABLE 37. Percentage of organic carbon available and assimilation efficiency in various regions of the gut at different size group of *H. nobilis*

Animal size group (cm)	% of organic carbon					Assimilation efficiency		
	No. of animal	Foregut	Midgut	Hindgut	Faeces	Foregut to Midgut	Foregut to Hindgut	Foregut to Faeces
20.0-22.9	13	0.38	0.39	0.30	0.26	10.52	11.76	21.05
23.0-25.9	25	0.38	0.33	0.31	0.28	13.15	18.42	26.32
26.0-28.9	23	0.36	0.32	0.30	0.28	11.11	16.67	22.22
29.0-31.9	30	0.38	0.33	0.30	0.26	13.16	21.05	31.58
32.0-34.9	31	0.43	0.35	0.30	0.26	17.50	30.23	39.53
35.0-37.9	36	0.40	0.35	0.30	0.29	12.50	25.00	32.50
38.0-40.9	30	0.39	0.34	0.30	0.26	12.82	23.08	33.33

variation in percentage of organic carbon between the various parts of the gut (F = 101.5) and less significant in between size groups (F = 3) at 5% level (Table 38).

The assimilation efficiency also shows a similar trend with regard to size groups. Higher assimilation value was noticed in 32.0 - 34.9 cm animals and lower value in 26.0 - 28.9 cm animals. The two-way ANOVA indicates that there is highly significant variation in assimilation efficiency between various parts of the gut (F = 137.89) and less significant variation between the size groups (F = 11.60) of H. nobilis at 5% level (Table 39).

DIGESTION

Time taken for digestion by various size groups

Table 40 gives the average time from ingestion to egestion of sediments in H. nobilis is relation to various size groups. It is seen that when the animal size is increasing, the time for digestion also increasing gradually. The animals in size group 20.0 - 22.9 cm took 8 hours to excrete their entire intestinal material, while 23.0 - 25.9 cm and 26.0 - 28.9 cm groups took 12 hours for digestion. But in the size group 29.0 - 31.9 cm the time of digestion has gone upto 14 hours and decreased again to 12 hours in the 32.0 - 34.9 cm size group. In the size group 35.0 - 37.9 cm, the time taken for digestion was 14 hours. It is calculated that the average time taken for one cycle of digestion is 12 hours, which is indicating two cycles of digestion per day.

Quantity of sediment ingested by various size groups

Table 41 explains the cycle of digestion, the total amount of sand eaten per day and per year by various size groups of H.

TABLE 38. The level of significance in variation of organic carbon between size groups and various gut regions of *H. nobilis*, by ANOVA II

	% of organic carbon				
Source	df	SS	MSS	F-value	Remarks
Coloum	3	0.0609	0.0203	101.5	Highly Significant
Row	6	0.0034	0.0006	3.0	Not Significant
Error	18	0.0030	0.0002		
Total	27	0.0673			

TABLE 39. The level of significance in variation of assimilation efficiency between size groups and various gut regions of *H. nobilis*, by ANOVA II

	assimilation efficiency				
Source	df	SS	MSS	F-value	Remarks
Coloum	2	1152.71	576.36	137.89	Highly Significant
Row	6	291.12	48.52	11.60	Highly Significant
Error	12				
Total	20	1494.04			

TABLE 40. The average time from ingestion to egestion of *H. nobilis* in relation to various size groups

Animal size group (cm)	No. of animals per experiment	Rate of egestion								The average time from ingestion to the gestion	
		Time (Hours)	Average value of rate of egestion(%)	Time (Hours)	Average value of rate of egestion(%)	Time (Hours)	Average value of rate of egestion(%)	Time (Hours)	Average value of rate of egestion(%)	Time (Hours)	Average value of rate of egestion(%)
20.0-22.9	6	8	100.00	10	100.00	12	100.00	14	100.00	8	100.00
23.0-25.9	6	8	70.93	10	90.10	12	100.00	14	100.00	12	100.00
26.0-28.9	6	8	92.80	10	97.12	12	100.00	14	100.00	12	100.00
29.0-31.9	6	8	85.10	10	93.60	12	90.10	14	100.00	14	100.00
32.0-34.9	6	8	72.05	10	96.00	12	100.00	14	100.00	12	100.00
35.0-37.9	6	8	80.00	10	98.73	12	98.00	14	100.00	14	100.00

TABLE 41. The amount of sand eaten by different size groups of *H. nobilis* per day and year

Animal Size group (cm)	A in hour	B in hour	C per day	D gram	E gram	F gram
20.0-22.9	24	8	3.0	21.86	65.58	23,936
23.0-25.9	24	12	2.0	30.92	61.84	22,272
26.0-28.9	24	12	2.0	36.10	72.20	26,535
29.0-31.9	24	14	1.7	37.88	64.77	23,641
32.0-34.9	24	12	2.0	42.78	85.56	31,229
35.0-37.9	24	14	1.7	47.96	82.01	29,934
Average			2.06		70.50	28,533

A - Time in which the gut is actually full in a day
B - One cycle of digestion
C - Number of digestic cycle in a day calculated by dividing A by B
D - Average amount of gut content, referred from Table 17.
E - Average amount of sand eaten by one individual per day (CxD)
F - The same amount per year (E x 365)

nobilis. When the animal length is increasing the consumption of the sediment (dry weight) per day and year also increases, but the cycle of digestion per day is decreases. In the size group 20.0 - 22.9 cm, the cycle of digestion is 3/day and consumption is 65.58 gm of dry sediment per day and 23.936 kg per year. This value is different in other size group which is showing 2 and 1.71 cycle of digestion and consumption more than 60.0 to 80.0 gm dry sediment per day more than 25.0 kg per year by one individual. But notable difference is found in the size group 32.0 - 34.9 cm animal which is consuming more than 85.56 gm of dry weight per day and 31.229 kg per year by one individual. It is calculated that the average of all these events are 2 cycles of digestion per day and consumption of 70.50 gm of dry sediment per day and 18.333 kg of dry sediments per year by one individual of H. nobilis.

EXCRETION

Production of excretory boluses by H. nobilis

H. nobilis produced rounded excretory boluses which appeared to adhere tightly together with mucus when it comes from the cloaca at the time of gut is fully packed. Otherwise it is found broken into individual pellets or balls. When these excretory boluses disturbed by waves or water current it looses the packed nature and dissolves in water or mixed with substrate sediments. This measures 0.5 to 1.0 cm length with average dry weight of 0.5 gm to 2.0 gm per individual piece. These measurements and production of faeces may vary depending upon the size and structure of the animal and size of the gut and it can be related to feeding activity also. The composition of boluses varying from fine grain material to very coarse white material with some algal filaments and micro-organisms like crustaceans, copepodes and nematodes which is depend upon the nature of substratum (Table 42).

TABLE 42. Percentage of organic carbon uptake by *H. nobilis* in relation to different size groups

Animal size groups (cm)	Average weight of faeces (gm)	Average percentage or oganic carbon in sediments (%)	Average percentage of organic carbon in faeces (%)	Organic carbon removal (sediment-faces)	% organic per by (animal per day
20.0-22.9	6.50	0.36	0.26	0.10	15.60
23.0-25.9	8.00	0.38	0.28	0.10	19.20
26.0-28.9	12.50	0.35	0.28	0.07	21.00
26.0-31.9	12.95	0.34	0.26	0.08	24.86
32.0-34.9	16.30	0.39	0.24	0.15	58.68
35.0-37.9	15.78	0.35	0.28	0.07	26.51
38.0-40.9	15.10	0.36	0.26	0.10	36.24

DISCUSSION

Tentacle structure and feeding mechanism

The symmetrically arranged peltate type oral tentacles characteristic of the Order Aspidochirotida to which H. nobilis belongs, serve as a spoon to trap the food particles. Food particles mainly consist of sand particles and coral pieces. The structure and function of these peltate type oral tentacles have been variously described as cauliflower-like structure (Bouland et al., 1982), as a nasturtium leaf (Hyman, 1955), as a shovel and Broon - like structure (Macginite and Macginite, 1949; Mottet, 1976) whereby deposits are scooped into the sea-cucumber's mouth (Trefz, 1958; Cameron and Fankboner, 1984; Bouland et al., 1982; Masin, 1982).

However, in Situ observations on feeding behaviour of H. nobilis indicates that it is related to the nodules in the distal end or fronds of the tentacles, which is serving as a functional surface without any mucus secretion to trap the food particles. The absence of mucus secretion indicates that the food intaking is more a mechanical rather than chemical adherance. This observation coincides with the conclusion of Roberts (1979) that the particle selection achieved by different species of Indonesian holothurians depends upon the nodule structure and particle entrapment in nodule space which is dependent on the extend to which the water vascular system penetrates on the surface of nodules. Trefz (1958) and Bakus (1973) also explained that the concept of mechanical processing which does not involve adhesition of particulate fine substrate by Aspidochirote holothurians.

Gut structure and its related characters

The length of the intestine in sea-cucumber plays a vital role in digestion. Anderson (1966) mentioned that the sea-cucumber are the only echinoderm that has become significantly elongated in the oral-aboral axis. The gut is long, coiled tube which usually transverse the length of the body three times in passing from mouth to anus. The gut in the deep burrowing form is shorter than that of the surface feeding types, the variation involving differences in the length of the intestinal portion. In Thyone, for example, the intestine is very long while in Paracaudina it is relatively shorter. As H. nobilis is a surface sediment feeder, the gut is elongated and coiled as observed by the candidate. Further it is significant to note that when the gut is empty, it tends to become flattened medially and it secretes a yellowish digestive juice. Trefz (1958) noticed in H. atra that after starvation for two to three days an yellow digestive fluid was filled, which had a pH of 5.3 - 5.5 in the foregut and midgut and possibility of dissolving calcareous material by acid action. Crozier (1918) reported that the intestine in Stichopus moebii contain yellowish orange digestive fluid and by peristalic movement this fluid mixes with the ingested mud.

Further the present result shows that, the gut length of H. nobilis increases with the length of the body in a ratio 3:1, while dry weight of the sediment increases in a ratio of 1.0 to 1.5. This has also been proved by the correlation analysis that gut length and body length show very good relationship, while other characters show slight variation in their relationship with body length. The similar result was obtained by Crozier (1918) in Stichopus moebii. The total length of the gut increases rapidly with the size of the body and the maximal capacity is less than proportional to the cube of this length. Further, Crozier (1918) pointed out the slight deviation from the cubic relationship noticed between these characters, may be attributed to the fact that in most of the time the stomach is never entirely filled with sand, but always contain a fair volume of digestive juices. Hence with the full gut content, individuals show fair and accurate relationship in S. moebii.

The investigation of food content analyses and feeding rhythm of H. nobilis by degree of gut fullness indicated that most of the animals had always full gut contents or above 50% and the animals with empty stomach were poorly observed. This indicates that H. nobilis take food continuously day and night without any fixed rhythm. This view is further strengthened by the candidate's visual observation that when sampling was done fortnightly for this species for biology work at various hour of the day and different stages of tide, the gut always filled with contents either full or half. Empty gut was poorly noticed during the study period. These observations very well coincide with the finding of Yamanouti (1939) who found that H. atra, H. edulis and H. flavaculata in Palao Island were always with full stomach. Bakus (1973) reported that this type of feeding rhythm is characteristic to many tropical holothurians and it may vary slightly in certain holothurians, which may be related to type of the locality and of certain environmental effects on feeding.

Further the degree of gut fullness is related to time, which helps to find out the eastivation or dormacy phenomenon in sea-cucumbers at certain period. The feeding ceases in S. japonicus after spawning (Tokuhisa, 1915). This species undergoes summer eastivation with atrophied alimentary canal (Choe, 1963). But no such rhythm was noticed in H. nobilis in the present investigation, since the degree of gut fullness during spawning period June to August (Chapter III : reproductive biology of H. nobilis) and during transition period November to February in Minicoy Island were almost similar to that in other periods. Remarkably gut atrophy was not noticed during the present investigation in H. nobilis.

Food consumed

The results of the gut content analysis in the present study shows that while intaking surface sediment, H. nobilis feeds not only on biotic and abiotic organisms but also on sand particles. Bakus (1973) reported that more critical examination on feeding suggests that the tropical holothurians often feed on living micro-organisms and organic content of sand, mud, ooze and detritus. It was also reported by different authors that a few tropical species feed on plankton, organic matter on rocks, micro-crustaceans, polychaets, nematodes, gastropods, sea-urchin spines, copepods, fish eggs and detritus (Yamanouti, 1939; Trefz, 1958; Frizzell and Excline, 1955; Macnae and Kalk, 1958; Bakus, 1968; 1973; Rao, 1968).

The analysis of food availability in the gut is related to different size groups of H. nobilis in the present study, which indicates that there is no apparent food selection or preference when the animal is growing from younger to adult stage. Hence there is no remarkable variation noticed in the percentage of food items in the size groups of H. nobilis between 20.0 to 22.9 cm and 38.0 - 40.9 cm. But Choe (1963) reported that young individual of S. japonicus feed on micro-algae and detritus and adults on all food items. This type of variation was not noticed in the present study and it may be due to the absence of juveniles or smaller animals in the population of H. nobilis at Minicoy Island.

Though H. nobilis consumes biotic and abiotic food organisms along with sediment, digestion of these food items is not taking place and this was confirmed by careful analysis of faecal matter of H. nobilis which contained immobile micro-organisms similar to that found in the environmental sediment. In the absence of any concrete evidence on undigestability of the food items by H. nobilis, it is very much possible to accept the view of Trefz (1958) who stated that the ingested food items remained viable after passing through the gut of H. atra possibly due to the absence of any masticatory apparatus and weak digestive juice which are required to kill the organisms and masticate and dissolve the food respectively.

Selection of food particles

In the following paragraph the preference and selectivity of sand particle size taken by H. nobilis is discussed. And indepth study on this aspect on H. nobilis clearly indicates that this species does not have any selectivity of sand particle size. This result has also been strengthened by the statistical analysis of data by ANOVA. Powell (1977), who studied the particle size selectivity on Leptosynapta tenuis, S. variegatus and H. atra, Sloan and Von Bodungen (1980) on Isostichopus badionotus have also observed similar results. Yingst (1982) has also found that the particle size found in the digestive tract of P. parvimensis was similar to that available in the environment and he could not point out any particle size preference by P. parvimensis. Levin (1979), Roberts and Bryce (1982) have also opined that H. nobilis is a non-selective feeder and it consumes what are all available in the substratum to meet its requirements. All these observations coincides and strengthens the results and observations of the candidate on H. nobilis from Minicoy Island.

However, a study on comparison of food particles in different regions of the gut of H. nobilis showed slight variation between foregut and midgut. The reason given by Trefz (1958) on H. atra that the action of acidic digestive juice may be causative factor for this difference, may be well suited to this species also.

The observations made on the food particles selectivity in relation to various size groups of H. nobilis showed that there is a marked variation in particle selection between younger and adult stage. The size group belonging to 20.0 - 23.9 cm consumes $<$ 0.5 mm particle size (35.06%), but in the size group 38.0 - 40.9 cm it is only 12.5% and the percentage of consumption of different particle sizes vary and it doesn't show any trend. This may mainly be due to the size of the animal, the digesting capacity and well developed nodule in the animal, as it consumes what are all available in the environmental sediment.

Assimilation efficiency of organic carbon

As most of the tropical holothurians are not digesting biotic and abiotic constituents and food particles available in the substratum, it puzzles the researchers to a greater extent that how these animals are getting energy for their growth and reproduction. It was first presumed by Gardiner (1904) that these holothurians utilizes organic matter from coral reef sand. Glynn (1965) found that Astichopus multifidus consumes sediments containing 0.7% organic matter. Bakus (1968) reported that H. difficialis utilizes about 2% of the dry weight of sediment which contained 4-10% of organic content. All these findings diverted many investigations to pay more attention on assimilation efficiency in holothurians. For this study it is essential to know the quantity of organic matter or organic carbon available in the habitat where these animals are living and how much amount of these matters being observed by gut during digestion.

Availability of organic carbon

The organic carbon is more in the content of foregut region (nearly 0.4 to 0.5%) when compared to substratum and sediment of various other region of the gut. Moriarty (1982) reported an average organic carbon levels of 16 - 34% more in the foregut of H. atra and S. chloronotus in Great Barrier Reef than in the sediment. Hammond (1983) found that organic carbon, organic nitrogen and chlorophyll were more concentrated in the foregut of the species of Aspidochirotide holothurians Isostichopus badionotus, Holothuria mexicana and H. arenicola in the West Indies. Webb et al. (1977) reported the same in H. atra and Hauksson (1979) in S. tremulus. These all researchers attributed the reason for more organic carbon noticed in the foregut is due to selectivity of organic matter, organically rich component of sediment, digestion of micro-organisms and phytobenthos which may contribute some amount of organic carbon. But this view is contrary with present species H. nobilis, because it is not a selective feeder and also not digesting micro-organisms as the candidate has observed in his study.

Assimilation efficiency in relation to month

The results obtained on assimilation efficiency of organic carbon and the rate of assimilation at each region of the gut of H. nobilis during different months in 1990 and 1991 showed only little variation between months and greater variation between different regions of the gut. The variation between months is hard to explain since it is statistically not significant. But the significant variation among the region is possible, because of the assimilation of organic carbon in this species is more in the foregut than rest of the regions. It was also told earlier that the concentration of organic carbon in the foregut was also more. It is quite natural that the assimilation of organic carbon is more in the foregut when the availability of same is more. However, Deming and Colwell (1982) opined that the foregut of holothurian is the place of intra-cellular digestion and mucoid biosynthesis. He has also mentioned that absorption and metobolic activity are believed to occur to greater extend in the hindgut contradicting his won earlier statements. From the finding of Demin and Colwell (1982) and the current observation by the candidate need further detailed studies at the enzymatic level in this group of animal. Further it is concluded from these results that H. nobilis assimilates nearly 36.12% of organic carbon in 1990 and 35.41% in 1991. This is not greatly varied from 40% of assimilation efficiency observed by Bakus (1968) in H. difficialis in sandy sediment of coral reef and 30% noticed in H. tremulus by Hauksson (1979). But Yingst (1979) noticed the assimilation efficiency of Parastichopus parvimensis was nearly 17.2% and further he stated that the variation found among sea-cucumbers is due to the difference in the fractions of organic matter associated with the sediment particle that ingested by these animals. However, Bakus (1973) generally concluded in his review that "the tropical holothurians are relatively efficient in processing sediment since their assimilation efficiency is approximately 50%".

Assimilation efficiency in relation to size groups

The assimilation efficiency related to various size groups showed that from 20.0 - 31.9 cm animals the efficiency was at the range of 21.0 - 32.0% and it steadily increased to 39.53% in the size group of 32.0 - 34.9 cm. But the efficiency again dropped between 30% and 33% in the size group of 35.0 - 40.9 cm. This is giving clue that the reproductive cycle and metabolic activity may have some influence on this efficiency. Hence H. nobilis undergoing sexual maturation from immature to fully mature stage (20.0 - 34.9 cm) the efficiency is increasing. When the animals were in the spawning stage (35.0 - 40.9 cm) the assimilation decreased. This view is strengthened further by the present result that, the assimilation efficiency of organic carbon related to month, showed decrease in June and July in 1990 and July, August and September in 1991, when compared to other months, since these periods are noticed as spawning period of H. nobilis (Chapter III : the reproductive biology of H. nobilis). To support these findings, Hauksson (1979) noticed that the efficiency rate is decreased to 17% from 30% during spawning period of S. tremulus in Norway.

Digestion

The observations on time taken for digestion and analysis of data obtained from various size groups of H. nobilis showed that the retention of food in the gut is longer in larger animals, e.g.

14 hours in 35.0 - 37.9 cm size groups and 8 hours in 20.0 - 22.9 cm. But the estimated average of time taken for digestion in this species is twelve hours. This observation is similar to Crozier's (1918) in S. moebii and he stated that the degree of gut filling varies from locality to locality. Bakus (1968) estimated for H. difficialis at least 15 hours to pass the food. Tanaka (1958) reported that S. japonicus feeds from 1.5 to 5.0 hours and passes food in 30 hours. Yamanouti (1939) observed the digestive process in seven species of Palao Island holothurians as 2.0 - 5.0 hours and the variation between the species in same locality may be due to the animal size, their gut morphology and its function.

Further, this digestive process in H. nobilis gives clear view that it consumed 70.5 gm of dry sediment per day and 18.33 kg per year by one individual. This is greatly different from other holothurians; thus Holothuria atra consumes 70 kg/yr, Holothuria floridana 30 kg/yr and Stichopus moebii 42 kg/yr (Thorson, 1966). Isostichopus badionotus in Bermuda passes the material through the gut in 6-7 kg/m^2 dry weight per year (Crozier, 1918). The variation between sea-cucumbers may be related to their gut capacity, locality and sediment consumed according to their energy requirements during growth and reproduction.

Excretion

Macnae and Kalk (1962) recognised burrow mounds of H. arenicola and H. pervicax by the presence of faeces. Mosher (1980) written that "the identified excretory boluses of H. arenicola in Bahamas have proved a most useful indicator of the population densities and distribution". This is absolutely true to the present study also that the candidate was able to notice accurately the presence and availability of H. nobilis in Minicoy Lagoon by the presence of excretory boluses during skin diving or observing from the boat.

But recent scientific evidence shows that excretory boluses are potential nutrient source for deposit feeders including holothurians (Bakus, 1973; Hauksson, 1979) and they termed this action is Coprophagy. Sloan and Van Bodungen (1980) reported that I. badionotus faeces represent a potential enriched food source for other holothurians. The faeces of H. tubulosa also consistently has a higher organic content than the surrounding sediment (Massin, 1980). Stichopus tremulus selectively feeds on "faecal pellets" and sediment aggregates rich in organic material (Hauksson, 1979). If it so, this H. nobilis also produces 6.0 to 15.0 gm of dry weight of faeces per hour would contribute a potential nutrient to deposit feeders in Minicoy Island and prove the findings by Bakus (1973) and Webb et al. (1977) that "the sea-cucumbers are important reworkers of sediment in coral reef Islands".

SECTION B : ACTINOPYGA MAURITIANA

FEEDING ORGAN

Morphology of tentacles

The mouth of Actinopyga mauritiana is symmetrically surrounded by twenty five oral tentacles in equal size with 0.5 to 1.0 cm long and vary depending on the size of the animal. The stalk of the tentacle is cylindrical with leaf like distal end called frond. The microscopic observations revealed that these fronds are packed with numerous tiny nodules with mucus secretion which is **not seen** in H. nobilis. Each tentacle has an associated tentacular ampulla of the water vascular system located at the base of tentacles (Fig. 32 A, B).

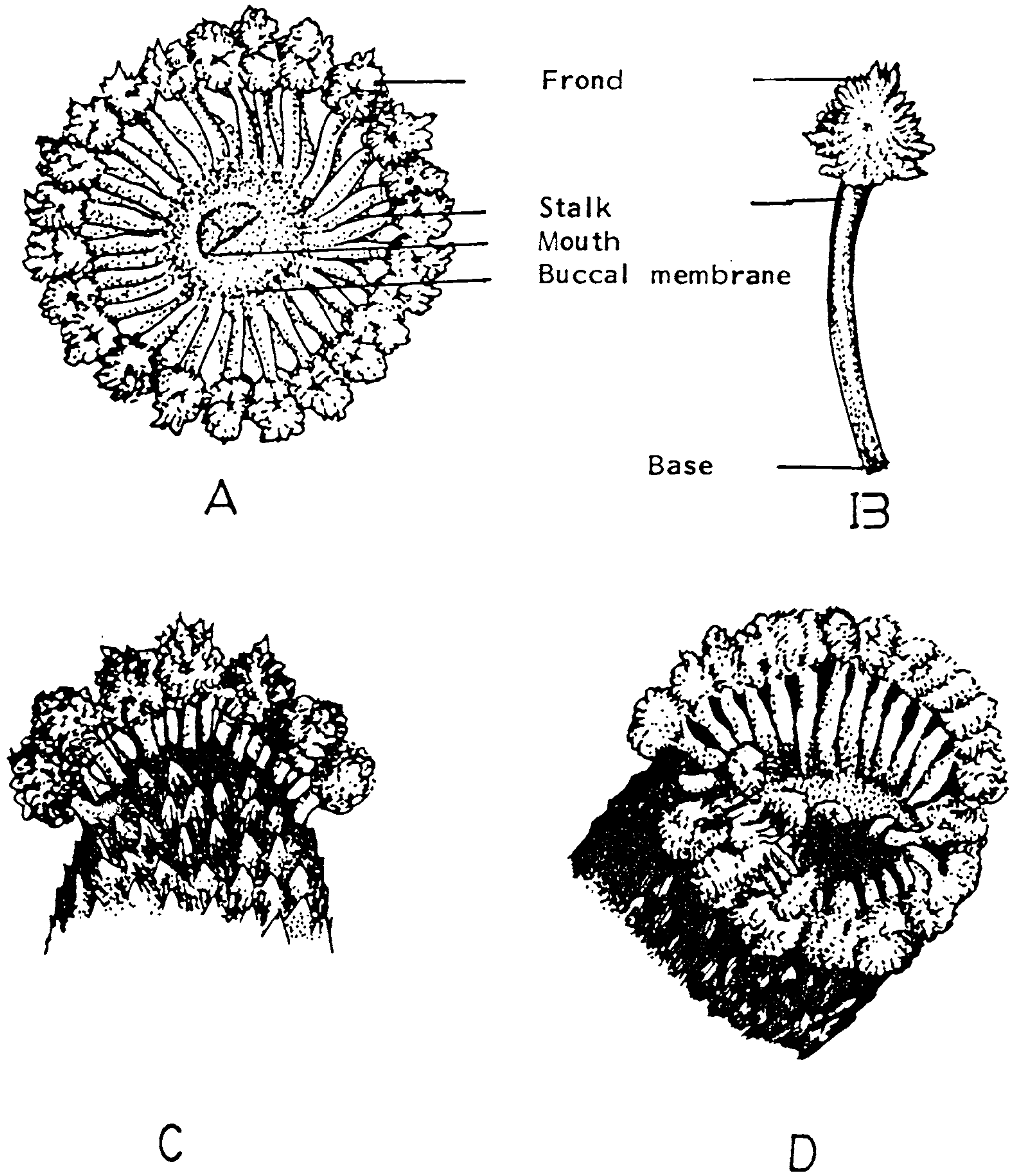


Fig.32. Oral region with associated tentacles in A.*mauritiana* A.Oral View to show the arrangement of tentacles; B. a single tentacle; C. side view of the oral end and D. contraction of tentacles while in rest.

Feeding mechanism

The observations on feeding behaviour of *A. mauritiana* in the laboratory and in their habitat, indicate that this animal feeds selectively on particle size, as it has an adhesive substances secreted by the nodules. This was confirmed further by the observation on the particles obtained from the gut contents, which showed mostly very fine particles. Interestingly, in this species only one or two tentacles are engaged in taking food particles and the rest are at rest. This shows that the function of tentacles in this species seems to be cyclic with special sequence. In favorable conditions the sphincter muscle of mouth opens and closes rhythmically and sands are engulfed, but during low tide, when reef flat exposed to air and dried, the ring of the tentacles are relaxed and the entire oral region is withdrawn from the fleshhood exposing the mouth region (Fig. 32 C,D).

DIGESTIVE ORGAN

Gut structure and related proportions

The details of gut structure and its associated organs have been described in the Chapter - I : Taxonomy of *A. mauritiana*. The gut length, wet weight of the gut with contents and dry weight of the gut sediment related to different size groups are presented in Table 43. In smaller size group *i.e.* 6.0 - 8.9 cm animals, the gut length varied from 20.0 cm to 45.0 cm with mean length of 29.37 ± 5.81 cm. The wet weight of the gut was between 2.0 gm and 15.0 gm with mean weight of 6.68 ± 3.40 gm, while dried weight of the gut sediment was found between 0.2 gm and 2.5 gm with mean weight of 0.90 ± 0.60 gm. In the larger size groups *viz.* 30 - 32.9 cm animals the gut length varied between 93.0 cm and 130.0 cm with mean of 111.46 ± 10.82 cm. The minimum wet weight of the

TABLE 43. The minimum, maximum, mean and standard deviation of gut length in cm (GL), wet weight of gut in gram (WWG) and dried weight of gut sediment in gram (DWGS) in different size groups of *A. mauritiana*

Animal size group (cm)	Number of animals		Minimum	Maximum	Mean		SD
6.0 - 8.9	32	GL	20.0	45.0	29.37	±	5.81
		WWG	2.0	15.0	6.68	±	3.40
		DWGS	0.2	2.5	0.90	±	0.60
9.0 - 11.9	42	GL	30.0	60.0	41.02	±	6.76
		WWG	3.0	20.0	9.46	±	4.12
		DWGS	0.2	5.5	2.06	±	1.28
12.0 - 14.9	40	GL	38.0	68.0	55.93	±	8.20
		WWG	5.0	20.0	11.28	±	3.67
		DWGS	1.0	8.2	2.99	±	1.63
15.0 - 17.9	62	GL	46.0	78.0	68.52	±	10.01
		WWG	8.0	22.0	13.77	±	3.55
		DWGS	1.5	9.0	4.39	±	2.13
18.0 - 20.9	58	GL	63.0	108.0	90.84	±	11.80
		WWG	8.0	30.0	18.78	±	5.15
		DWGS	2.3	12.5	6.46	±	2.90
21.0 - 23.9	45	GL	70.0	115.0	88.58	±	10.62
		WWG	15.0	35.0	21.17	±	4.92
		DWGS	2.8	12.5	7.73	±	2.64
24.0 - 26.9	18	GL	83.0	115.0	98.16	±	10.23
		WWG	15.0	45.0	24.99	±	5.88
		DWGS	3.5	15.5	9.45	±	3.97
27.0 - 29.9	12	GL	83.0	126.0	105.90	±	10.86
		WWG	20.0	60.0	34.49	±	8.60
		DWGS	4.5	19.5	12.34	±	3.97
30.0 - 32.9	15	GL	93.0	130.0	111.46	±	10.82
		WWG	20.0	60.0	41.44	±	8.60
		DWGS	9.5	22.0	15.43	±	3.97

gut in this size was 20.0 gm and maximum was 60.0 gm with mean weight of 41.44 ± 8.60 gm. The dried weight of gut sediment shows a minimum of 9.5 gm and maximum of 22.0 gm with mean weight of 15.43 ± 3.97 gm. These results clearly indicate that when the animal increases in size by 1 cm, the gut length increases 4.0 - 5.0 cm and wet weight of the gut increases by 1.0 - 1.5 gram. The dry weight of the gut sediment was increases only 0.3 to 0.5 gm.

The relationship between these characters by correlation and regression analyses (Table 44 and 45) indicates a very good relationship between body length versus gut length (b = 4.5845, r^2 = 94.3), which is closer to the hypothetical value of b = 3. But relationship with other characters deviates little from the value b = 3.

Condition of the gut

The results of feeding intensity or feeding rhythm of A. mauritiana based on degree of gut fullness studies is given in Table 46. It is clear from this Table that there is not much variation in the consumption between months and the animals were having the fullness of stomach always between 39.02% and 52.38% and 1/2 fullness between 6.46% and 43.48%.

TYPES OF FOOD CONSUMED

Food in the sediment

The percentage of biotic and abiotic organisms available in Reef flat sediment where A. mauritiana were seen, is presented in Table 47. The biotic organisms found in the sediment were polychaetes, nematodes, bivalves, crustacean larvae, tubiculous polychaetes, hermitcrab juveniles, gastropods and sea - weed

TABLE 44. Relationship between body length (BL) and gut length (GL), total gut weight (TGW) and dried weight of the gut sediment (DWGS) of *A. mauritiana*

Characters	df	$y = ax^b$	R^2
Gut length versus Body length	450	$GL = 7.9339\ Bl^{4.5845}$	94.3%
Total gut weight versus Body length	450	$TGW = 0.2705\ Bl^{1.5884}$	96.0%
Dry weight of gut sediment versus Body length	450	$DWGS = 0.0244\ Bl^{2.0289}$	97.5%

TABLE 45. Relationship between gut length (GL) and total gut weight (TGW) and dried weight of the gut sediment (DWGS) of *A. mauritiana*

Characters	df	$y = ax^b$	R^2
Total gut weight versus Gut length	450	$TGW = 0.3337\ Gl^{1.4784}$	88.9%
Dry weight of gut sediment versus Gut length	450	$TGW = 0.1347\ Gl^{1.9425}$	85.6%

TABLE 46. Condition of the gut in *A. mauritiana* in different months during 1990-1991

Month	No. of animals	Degree of fullness: Empty	1/4	1/2	3/4	Full
January 1990	23	4.34	8.70	43.48	-	43.48
February	43	16.28	13.96	25.58	9.30	34.88
March	42	11.63	-	23.25	16.28	48.84
April	28	7.14	17.86	21.43	10.71	42.86
May	21	14.28	14.28	-	28.58	42.86
June	22	9.09	-	13.64	40.91	36.36
July	31	3.23	16.12	6.46	22.58	51.61
August	41	4.88	7.32	7.32	41.46	39.02
September	43	11.63	11.63	9.30	25.58	41.86
October	48	4.08	14.29	18.36	22.45	40.82
November	46	4.5	8.89	11.11	31.11	44.44
December	42	-	23.81	14.29	9.52	52.38
MEAN		8.28±	13.69±	17.66±	23.50±	43.28±
SD		4.57	4.93	10.71	11.53	5.47

Month	No. of animals	Empty	1/4	1/2	3/4	Full
January 1991	48	-	12.77	19.15	21.28	46.80
February	47	2.08	12.50	8.33	29.17	47.92
March	40	7.50	5.00	10.00	35.00	42.50
April	47	2.13	10.64	12.77	34.04	40.42
May	37	-	-	10.81	40.54	48.65
June	34	2.95	-	17.65	32.35	47.05
July	28	6.30	6.30	6.30	37.30	43.80
August	40	22.50	7.50	-	20.00	50.00
September	30	6.67	6.67	6.67	16.66	63.33
October	35	20.00	2.86	5.71	14.29	57.14
November	35	20.00	-	2.86	20.00	57.14
December	42	9.30	-	20.93	27.91	41.86
MEAN		9.94±	8.03±	11.01±	27.34±	48.89±
SD		7.90	3.59	5.96	8.64	7.01

TABLE 47. Food constituents in percentage (biotic and abiotic organisms) in the reef sediment (*A. mauritiana* habitat) of Minicoy Island (25gm wet sediment from the reef flat analysed)

Station	No. of samples	Biotic fauna %								Abiotic fauna %			
		Polychaetes	Nematodes	Bivalves	Crustacean larvae	Turbiculous polychaetes	Hermit crab juveniles	Gastropods	Seaweed fragments	Sea-urchin spines	Molluscan shells	Crustacean moulting skeleton	Unidentified organisms
1	20	6.40	3.82	10.19	5.10	3.81	11.45	7.63	9.54	19.10	11.46	5.10	6.40
2	20	8.53	3.10	12.19	5.81	10.08	12.40	7.75	6.98	10.08	12.02	7.75	3.10
3	20	6.67	3.32	9.12	4.97	8.30	9.13	14.93	12.44	9.13	11.62	6.22	4.15
MEAN ± SD		7.20 ± 1.16	3.41 ± 0.37	10.57 ± 1.67	5.29 ± 0.45	7.40 ± 3.23	10.99 ± 1.68	10.10 ± 4.18	9.65 ± 2.73	12.77 ± 5.50	11.70 ± 0.29	6.36 ± 1.33	4.55 ± 1.69

fragments. The abiotic forms were sea-urchin spines, molluscan shells, crustacean exoskeleton and unidentified organic matters. Among these the dominant forms were polychaetes (7.2 ± 1.16%), bivalves (10.57 ± 1.67%), hermit crab juveniles (10.99 ± 1.68%), gastropodes (10.10 ± 4.18%) and sea-weed fragments (9.65 ± 2.73%). Others were less than 7%. Sea-urchin spines and molluscan shells contributed 12.77 ± 5.50% and 11.7 ± 0.29% respectively in the environment.

Food in the gut

Table 48 shows an interesting result that sponges (5.19 ± 0.95%), foraminiferans (3.69 ± 1.41%) and sea-grass pits (6.58 ± 1.87%) were found in the gut, while these items were absent in the reef sediment. The non-availability of sponges, sea-grass pits and foraminiferans in the sediment and their occurrence in the gut of *A. mauritiana* may be infered that this animal directly bites or collects from the water column or from the boulders found above the water in the reef flat.

Constituents in the faeces

Table 49 shows the percentage composition of food matters (biotic and abiotic organisms) in the faecal castings of *A. mauritiana*. These matters are frequently appeared to be undigested and their availability is all most reflects the quantity and quality available in the gut as well as reef sediment.

Ratio of food items

The ratio between food items available in the sediment of the reef flat, gut and in faeces of *A. mauritiana* are given in Table 50. Nematodes, tubiculous- polychaetes and sea-weed fragments are more in the gut when compared to reef sediment and faeces. In

TABLE 48. Food constituents in percentage (biotic and abiotic organisms) in the gut sediment *A. mauritiana* (25gm wet sediment from the gut analysed)

Station	No. of samples	Biotic fauna %											Abiotic fauna %			
		Polychaetes	Nematodes	Bivalves	Crustacean larvae	Turbiculous polychaetes	Hermit crab juveniles	Gastropods	Sponges	Foraminiferans	Seagrass	Seaweeds	Sea-urchin spines	Molluscan shells	Crustacean moulting skeleton	Unidentified organisms
1	20	6.60	4.20	8.90	3.80	8.60	6.80	5.20	6.00	2.10	5.00	19.15	4.20	6.00	8.00	5.45
2	20	5.65	7.20	6.40	7.46	5.20	5.30	3.30	4.15	4.20	8.65	24.11	4.60	3.40	5.28	5.10
3	20	6.40	8.20	4.38	5.20	8.51	3.18	4.27	5.41	4.78	6.10	26.20	6.30	5.07	3.00	3.00
MEAN ± SD		6.22 ± 0.50	6.53 ± 2.08	6.58 ± 2.26	5.48 ± 1.87	7.44 ± 1.94	5.09 ± 1.82	4.26 ± 0.95	5.19 ± 0.95	3.69 ± 1.41	6.58 ± 1.87	23.15 ± 3.62	6.03 ± 1.12	4.82 ± 1.32	5.43 ± 2.50	4.52 ± 1.33

TABLE 49. Food constituents in percentage (biotic and abiotic organisms) and their percentage composition in the faecal castings of *A. mauritiana* (10gm faecal casting analysed)

		Biotic fauna %											Abiotic fauna %			
Station	No. of samples	Polychaetes	Nematodes	Bivalves	Crustacean larvae	Turbiculous polychaetes	Hermit crab juveniles	Gastropods	Sponges	Foraminiferans	Seagrass	Seaweeds	Sea-urchin spines	Molluscan shells	Crustacean moulting skeleton	Unidentified organisms
1	20	8.20	6.12	8.12	10.15	8.15	10.00	4.12	5.14	2.22	6.18	15.00	3.60	4.00	4.00	5.00
2	20	5.14	5.00	8.22	6.20	8.10	4.17	6.13	6.11	6.10	8.20	12.35	6.00	4.00	5.19	9.09
3	20	5.10	4.40	6.00	5.12	3.08	6.60	4.03	6.07	3.00	6.10	22.60	7.20	8.10	7.60	5.00
MEAN ± SD		6.15± 1.78	5.17± 0.87	7.45± 1.25	7.16± 2.65	6.44± 2.91	6.92± 2.93	4.76± 1.19	5.77± 0.55	3.77± 2.05	6.83± 1.19	16.65± 5.32	5.60± 1.83	5.34± 2.37	5.66± 1.83	6.36± 2.36

TABLE 50. The ratio of food constituents in the environment, gut and faecal matter of A. mauritiana

Species	Sediment			Ratio
	Environment (i)	Gut (ii)	Faecal (iii)	
Biotic fauna				
Polychaetes	7.20	6.22	6.15	1.0:0.86:0.85
Nematodes	3.41	6.53	5.17	1.0:1.91:0.79
Bivalves	10.57	6.56	7.45	1.0:[illegible].62:1.14
Crustacean larvae	5.29	5.48	7.16	1.0:1.04:1.35
Tubiculous polychaetes	7.40	7.44	6.44	1.0:1.01:0.87
Hermit crab juveniles	10.99	5.09	6.92	1.0:0.46:0.63
Gastropods	10.10	4.26	4.76	1.0:0.42:0.47
Sponges	-	5.19	5.77	-
Foraminiferans	-	3.69	3.77	-
Sea grass	-	6.58	6.83	-
Sea weeds	9.65	23.15	16.65	1.0:2.40:1.73
Abiotic fauna				
Sea urchin spines	12.77	5.03	5.60	1.0:0.39:0.44
Molluscan shells	6.36	4.83	5.34	1.0:0.76:0.84
Crustacean moulting skeleton	4.55	5.43	5.60	1.0:1.49:1.23
Unidentified organisms	4.55	4.52	6.36	1.0:0.99:1.40

the faeces, bivalves, crustacean larvae, crustacean exoskeleton and unidentified organisms showed the highest ratio when compared to reef sediment and the gut.

Percentage of food items in the gut in relation to various size groups

Table 51 shows the percentage composition of food items in the gut consumed by various size groups of A. mauritiana. It is seen that there is no selection of food items by this species at any age group. Hence, the percentage was almost same.

Particle size and selectivity

The percentage composition of particle size in reef sediment, foregut, midgut, hindgut and faeces of A. mauritiana (Table 52) studied indicates that the particle size in various region of the gut is entirely varied from that particles available in the substratum. The particle sizes observed in substratum in percentages were 4.0 mm - 15.07%, 2.0 mm - 13.29%, 1.0 mm - 14.93%, 0.7 mm - 17.33%, 0.5 mm - 18.91% and < 0.5 mm - 20.46% and they were almost similar for all size groups. But, within the various regions of the gut, 4.0, 2.0 and 1.0 mm sizes were available less than 7%, 0.7 mm particle size was below 15 to 17% and 0.5 and < 0.5 mm were available between 20 and 22% and 32 and 42% respectively. The comparison made between particles of reef sediment and foregut (Table 53) shows that < 0.5 mm size was more in the gut (42.50%) and other particles sizes varied from 5.78 to 21.61%. Further it is clear from food particle index (Table 54) that 0.5 mm size particles were above 100 as 114.24% in foregut, 113.11% in midgut, 107.90% in hindgut and 104.87% in faeces and < 0.5 mm particles were above 200 as 207.70% in foregut, 200.54% in midgut and 202.25 in hind gut. In faeces the index of < 0.5 mm was reduced to 159.71%.

TABLE 51. Percentage composition of food constituents (biotic and abiotic organisms) in the gut of different size groups of *A. mauritiana* (5gm. wet gut content analysed)

Animal size groups (cm)	No.of animals	Biotic fauna %												Abiotic fauna %		
		Poly-chaetes	Nema-todes	Bi-valves	Crusta-cean larvae	Turbi-culous poly-chaetes	Hermit crab juve-niles	Gastro-pods	Sponges	Forami-nifer-ans	Sea-grass	Sea-weeds	Sea-urchin spines	Mollus-can shells	Crusta-cean moulting skele-ton	Unidenti-fied orga-nisms
6.0- 8.9	8	6.81	3.29	10.05	2.91	8.59	6.48	3.40	3.24	6.65	2.92	25.93	4.86	4.86	6.48	3.58
9.0-11.9	8	11.96	9.36	7.03	4.60	4.29	12.73	4.75	6.13	1.23	3.37	15.34	6.29	2.76	7.36	2.77
12.0-14.9	8	6.52	7.72	5.66	3.77	7.20	10.81	8.91	5.15	0.50	6.03	15.78	5.15	5.14	6.00	5.67
15.0-17.9	8	10.00	4.32	7.26	5.75	6.85	6.58	9.86	6.15	1.78	9.86	16.44	5.20	2.74	4.38	2.34
18.0-20.9	8	8.13	5.24	6.82	9.30	5.24	9.57	4.98	6.68	1.31	7.60	17.04	4.06	5.50	5.90	2.63
21.0-23.9	8	8.96	7.37	5.49	8.67	10.40	10.11	6.94	4.77	2.17	7.36	10.40	2.89	2.89	5.28	5.80
24.0-26.9	8	7.98	9.24	7.07	5.53	3.19	6.61	10.38	7.07	2.51	8.21	13.11	7.07	3.42	6.84	3.77
27.0-29.9	8	9.34	11.71	5.50	8.36	7.76	9.80	6.33	8.12	1.43	4.90	10.99	3.82	5.02	3.94	2.98
30.0-32.9	8	7.76	4.92	5.17	6.47	3.88	11.77	8.02	6.47	4.14	9.06	17.08	5.43	2.72	4.52	2.59
MEAN		8.64±	7.03±	6.67±	6.15	6.38±	9.38±	7.06±	6.02±	2.41±	6.59±	15.79±	4.59±	3.90±	5.63±	3.57±
SD		1.69	2.77	1.50	2.25	2.40	2.34	2.42	1.44	1.89	2.45	4.55	1.27	1.20	1.18	1.31

TABLE 52. **Percentage composition of food particle size in the environment substratum, foregut, midgut, hindgut and faeces of A. mauritiana by seive analysis (Number of sample 50)**

Graine size (mm)	Environment Substratum	Foregut	Midgut	Hindgut	Faeces
4.0	15.07	6.39	7.47	6.78	6.53
2.0	13.29	5.78	6.05	6.63	7.58
1.0	14.93	7.57	7.33	7.59	6.36
0.7	17.33	16.15	16.73	17.30	15.91
0.5	18.91	21.61	21.39	20.31	19.83
< 0.5	20.46	42.50	41.03	41.39	32.68

TABLE 53. **Comparison of food particles in substratum and foregut of A. mauritiana**

Parts	Food particle size (mm)					
	4.0	2.0	1.0	0.7	0.5	<0.5
Environmental substratum	15.07	13.29	14.43	17.33	18.91	20.46
Foregut	6.39	5.78	7.57	16.15	21.61	42.50
Difference	8.68	7.51	6.86	1.18	-2.7	-22.04

TABLE 54. Food particle size relative index (as substratum 100) of *A. mauritiana*

Graine size (mm)	Environment Substratum	Foregut	Midgut	Hindgut	Faeces
4.0	100	42.42	49.54	45.00	43.36
2.0	100	43.49	45.53	49.87	57.00
1.0	100	50.70	49.07	50.80	42.60
0.7	100	93.20	96.52	99.82	91.78
0.5	100	114.24	113.11	107.40	104.87
< 0.5	100	207.70	200.54	202.25	159.71

TABLE 55. Comparison of ingested food particles in different gut regions of *A. mauritiana*

Various regions of the gut	Food particle size (mm)					
	4.0	2.0	1.0	0.7	0.5	<0.5
Foregut (FG)	6.39	5.78	7.57	16.15	21.61	42.50
Midgut (MG)	7.47	6.05	7.33	16.73	21.39	41.03
Difference (~ FG and MG)	-0.08	- 0.27	0.24	- 0.58	0.22	1.47
Hindgut (FG)	6.78	6.63	7.59	17.30	20.30	41.39
Difference (~ FG and MG)	- 0.39	-1.35	- 0.02	-1.15	1.31	1.11
Faeces (F)	6.53	7.58	6.36	15.91	19.83	32.68
Difference (~ FG and MG)	- 0.14	-2.30	1.21	0.24	1.78	9.82

Food particles in different regions of the gut

The food particles size (Table 55) in various regions of the gut did not show any marked variation. This was further strengthened by ANOVA II that the level of variation between the particle size of various regions of the gut is insignificant (F = 0.17) and is significant between particle size (F = 24.08) at 1% level (Table 56).

Food particle selection in relation to animal size

There was no particle size selection in different size groups of *A. mauritiana*. From Table 57 it is confirmed that they consume more quantity of 0.5 to 0.7 mm particle size. However, their consumption varied from 70 to 80% in 6 cm - 14 cm (smaller) animals, 35 to 42% in 15 cm - 23 cm (medium) animals and 20 to 30% in 27 cm - 29 cm (larger) animals.

ASSIMILATION EFFICIENCY

Assimilation of organic carbon by A. mauritiana in different months

Organic carbon in bottom sediment

Organic carbon was the highest with 0.55% in April 1990 and the lowest with 0.45% in July, August and November 1990, and the same was 0.54% in March 1991 and 0.44% in July 1991. The annual mean of organic carbon was 0.49 ± 0.03% for both 1990 and 1991. Hence there was not much variation in organic carbon in the sediment between years (Table 58).

Organic carbon in the gut

Foregut : Organic carbon in the foregut was the highest with 0.59%

TABLE 56. Level of variation in food particle percentage between different regions of the gut and between particle size of *A. mauritiana*, analysed by ANOVA II

Source	df	SS	MSS	F.value	Remarks
Treatment	3	16.452	5.484	0.17	Non Significant
Replication	5	2898.458	579.692	24.08	Significant

TABLE 57. Selection of food particles in relation to different size groups of _A. mauritiana_ in an average of 50gm of gut content (n = number)

Grain size (mm)	Size groups (cm)								
	6.0-8.9 (n-20)	9.0-11.9 (n-20)	12.0-14.9 (n-15)	15.0-17.9 (n-15)	18.0-20.9 (n-15)	21.0-23.9 (n-10)	24.0-26.9 (n-10)	27.0-29.9 (n-10)	30.0-32.9 (n-10)
4.0	3.36	4.00	4.00	8.00	7.00	4.20	7.12	6.24	7.64
2.0	4.40	6.24	7.20	12.24	4.36	2.30	11.64	9.20	8.00
1.0	3.66	4.20	7.96	11.26	4.30	9.26	12.84	12.24	12.00
0.7	8.30	12.24	12.10	10.24	7.20	16.24	21.26	20.30	20.20
0.5	20.40	24.60	20.24	16.20	31.00	32.64	21.60	26.04	24.00
<0.5	59.88	48.72	48.50	42.06	36.14	35.46	25.54	25.98	28.16

TABLE 58. Average monthly percentage of organic carbon in the food from substratum, foregut, midgut, hindugt and faeces of *A. mauritiana* during 1990–1991

Month	No. of observ-ations	Environment Subst-ratum	Foregut	Midgut	Hindgut	Faeces
January 1990	6	0.50	0.54	0.45	0.40	0.38
February	6	0.47	0.50	0.42	0.38	0.36
March	10	0.53	0.58	0.52	0.48	0.45
April	8	0.55	0.57	0.50	0.47	0.44
May	10	0.51	0.59	0.50	0.45	0.44
June	6	0.46	0.57	0.50	0.44	0.42
July	6	0.45	0.50	0.44	0.41	0.37
August	12	0.45	0.49	0.44	0.40	0.35
September	8	0.51	0.54	0.46	0.43	0.40
October	10	0.50	0.53	0.46	0.44	0.39
November	10	0.45	0.50	0.43	0.39	0.35
December	12	0.48	0.50	0.43	0.39	0.35
MEAN SD	8.66± 2.31	0.49± 0.03	0.53± 0.04	0.46± 0.03	0.42± 0.03	0.39± 0.04

January 1991	8	0.51	0.54	0.45	0.42	0.39
February	10	0.48	0.50	0.42	0.39	0.35
March	7	0.54	0.56	0.47	0.43	0.39
April	10	0.50	0.51	0.42	0.39	0.36
May	7	0.50	0.53	0.42	0.40	0.37
June	6	0.45	0.47	0.41	0.40	0.36
July	6	0.44	0.50	0.43	0.40	0.37
August	8	0.50	0.51	0.45	0.42	0.32
September	9	0.50	0.55	0.48	0.46	0.41
October	10	0.51	0.53	0.45	0.41	0.38
November	12	0.48	0.50	0.42	0.38	0.36
December	7	0.50	0.51	0.43	0.40	0.36
MEAN SD	8.33± 1.87	0.49± 0.03	0.52± 0.03	0.44± 0.02	0.41± 0.02	0.37± 0.02

in May 1990 and the lowest with 0.49% in August 1990. The same was 0.56% in March 1991 and 0.47% in June 1991. The annual average of organic carbon in the foregut were 0.53 ± 0.04% in 1990 and 0.52 ± 0.03% in 1991 and the variation is only 0.1% (Table 58).

Midgut : Organic carbon in the midgut was the highest with 0.52% in March 1990 and lowest with 0.42% in February 1990. The same was 0.48% in September 1991 and 0.41% in June. The annual average of organic carbon in the midgut was 0.46 ± 0.03% in 1990 and 0.44 ± 0.02% in 1991, and the variation in average between years is only 0.2% (Table 58).

Hindgut : Organic carbon in the hindgut was the highest with 0.48% in March 1990 and the lowest with 0.38% in February 1990. The same was 0.46% in September 1991 and 0.38% in November 1991. The average of annual organic carbon in the hindgut were 0.42 ± 0.03% in 1990 and 0.41 ± 0.02% in 1991 (Table 58). In general there was not much variation in organic carbon percentage between years.

Faeces : Organic carbon in the faeces was the highest with 0.45% in March 1990 and the lowest with 0.35% in August, November and December 1990. The same was 0.41% in September 1991 and 0.32% in August 1991. The average annual organic carbon in the faeces were 0.39 ± 0.04% in 1990 and 0.37 ± 0.02% in 1991. The difference in percentage of organic carbon between the maximum of two years was 0.4% and in the minimum was 0.3% (Table 58).

The ANOVA showed a highly significant variation in organic carbon between the various regions of the gut (F = 205.16) and between months (F = 30.56) in 1990 and (F = 223.0) between various regions of the gut (F = 26.5) between months in 1991 (Table 59, 60).

TABLE 59. **Level of significance in variation of organic carbon between months and other sources such as substratum, foregut, midgut, hindgut and faeces of *A. mauritiana* during 1990, analysed by ANOVA II**

Source	df	SS	MSS	F-value	Remarks
Coloumn	4	0.1477	0.0369	205.16	Highly Significant
Row	11	0.0602	0.0055	30.56	Significant
Error	44	0.0077	0.0002		
Total	59	0.2156			

TABLE 60. **Level of significance in variation of organic carbon between months and other sources such as substratum, foregut, midgut, hindgut and faeces of *A. mauritiana* during 1991, analysed by ANOVA II**

Source	df	SS	MSS	F-value	Remarks
Coloum	4	0.1782	0.0446	223.0	Highly Significant
Row	11	0.0578	0.0053	26.5	Significant
Error	44	0.0085	0.0002		
Total	59	0.2445			

Assimilation efficiency of organic carbon in the gut

The assimilation efficiency at various regions of the gut (Table 61) in *A. mauritiana* is follows :

In foregut : In this region the assimilation was maximum with 16.45 ± 6.26% in January 1990 and minimum with 10.94 ± 3.55% in August 1990. The same was 21.33 ± 7.02% in May 1991 and 12.27 ± 3.57% in June 1991.

In midgut : In this region the assimilation was maximum with 25.92 ± 9.00% in January 1990 and the lowest with 17.00 ± 8.95% in October 1990. The same was 25.96 ± 10.20% in May 1991 and 15.39 ± 4.10% in June 1991.

In hindgut : The assimilation was maximum in hindgut with 29.14 ± 7.80% in November 1990 and the lowest with 22.47 ± 2.85% in March 1990. The same was 29.87 ± 11.48% in December 1991 and 23.77 ± 6.40% in June 1991.

The ANOVA showed significant variation between various regions of the gut (F = 236.23) and months (F = 4.86) in 1990 and the same was (F = 449.44) between various parts of the gut and (F = 21.83) between months in 1991 (Table 62, 63).

Rate of assimilation at each region of the gut

The annual rate of assimilation in the foregut region was 13.42 ± 1.91% in 1990 and 15.57 ± 2.63% in 1991, in midgut it was 7.46 ± 1.92% in 1990 and 5.98 ± 1.73% in 1991 and in the hindgut it was 5.88 ± 2.42% in 1990 and 6.93 ± 1.71% in 1991 (Table 64). Further these results show the highest assimilation which was taking place in the foregut and it was less in other regions of the gut. In addition, it is also concluded that *A. mauritiana* assimilates organic

TABLE 61. Average monthly assimilation efficiency (%) of organic carbon in various regions of the gut of A. mauritiana during 1990-1991

Month	No. of obser-vations	Foregut to midgut	Foregut to hindgut	Foregut to faeces
January 1990	6	16.45 ± 3.93	25.92 ± 9.00	29.09 ± 6.38
February	6	15.58 ± 6.26	24.54 ± 7.41	27.76 ± 4.79
March	10	10.63 ± 3.86	17.15 ± 5.39	22.47 ± 2.85
April	8	12.47 ± 3.50	17.69 ± 7.11	22.93 ± 5.17
May	10	12.46 ± 5.01	23.07 ± 4.57	26.02 ± 5.45
June	6	13.66 ± 3.06	22.88 ± 6.54	26.86 ± 5.32
July	6	11.90 ± 3.88	18.69 ± 5.96	26.72 ± 5.33
August	12	10.94 ± 3.55	17.91 ± 3.55	28.39 ± 4.35
September	8	14.20 ± 6.36	21.12 ± 8.00	26.75 ± 8.53
October	10	12.90 ± 3.84	17.00 ± 8.95	25.86 ± 8.90
November	10	16.18 ± 5.62	22.25 ± 6.05	29.14 ± 7.80
December	12	13.59 ± 3.30	22.20 ± 4.71	29.09 ± 6.08
January 1991	8	15.52 ± 8.24	22.74 ± 10.12	28.56 ± 13.50
February	10	16.85 ± 7.70	23.18 ± 10.50	29.87 ± 12.20
March	7	16.28 ± 5.32	23.25 ± 7.52	29.12 ± 10.20
April	10	18.33 ± 4.31	23.01 ± 6.51	29.80 ± 10.15
May	7	21.33 ± 7.02	25.96 ± 10.20	29.35 ± 11.10
June	6	12.27 ± 3.57	15.39 ± 4.10	23.77 ± 6.40
July	6	14.06 ± 7.02	20.35 ± 8.12	27.23 ± 10.58
August	8	12.48 ± 3.24	17.05 ± 4.64	24.79 ± 4.03
September	9	12.55 ± 3.15	16.55 ± 3.98	25.68 ± 4.57
October	10	15.28 ± 5.62	23.67 ± 8.32	29.03 ± 13.63
November	12	16.63 ± 6.78	24.87 ± 7.84	28.65 ± 10.50
December	7	15.22 ± 6.63	22.50 ± 8.28	29.87 ± 11.48

TABLE 62. **Level of significance in variation of assimilation efficiency of organic carbon between months and various regions of the gut of *A. mauritiana* during 1990, analysed by ANOVA II.**

Source	df	SS	MSS	F-value	Remarks
Coloumn	2	1072.41	536.21	236.23	Highly Significant
Row	11	154.42	11.04	4.86	Significant
Error	22	49.84	2.27		
Total	35	1276.67			

TABLE 63. **Level of significance in variation of assimilation efficiency of organic carbon between months and various regions of the gut of *A. mauritiana* during 1991, analysed by ANOVA - II**

Source	df	SS	MSS	F-value	Remarks
Coloumn	2	924.46	462.23	449.49	Highly Significant
Row	11	222.15	20.20	21.83	Significant
Error	22	32.39	0.93		
Total	35	1179.00			

TABLE 64. Average monthly rate of assimilation (%) in various regions of the gut of *A. mauritiana* during 1990–1991

Month	No. of observations	Rate of assimilation Foregut	Midgut	Hindgut
January 1990	6	16.45	9.47	3.11
February	6	15.58	8.96	3.22
March	10	10.63	6.52	5.32
April	8	12.47	5.22	5.24
May	10	12.46	10.61	2.95
June	6	13.66	9.22	3.98
July	6	11.96	6.79	8.03
August	12	10.94	6.97	10.48
September	8	14.20	6.92	5.63
October	10	12.90	4.10	8.86
November	10	16.18	6.07	6.89
December	12	13.59	8.61	6.89
MEAN ± SD		13.42 ± 1.91	7.46 ± 1.92	5.88 ± 2.42
Total assimilation				26.76%

January 1991	8	15.52	7.22	5.82
February	10	16.85	6.33	6.69
March	7	16.28	6.97	5.87
April	10	18.33	4.68	6.79
May	7	21.33	4.63	3.39
June	6	12.27	3.12	8.38
July	6	14.08	6.29	6.88
August	8	12.48	4.57	7.74
September	9	12.55	4.00	9.13
October	10	15.28	8.39	5.36
November	12	16.63	8.24	3.78
December	7	15.22	7.28	7.37
MEAN ± SD		15.57 ± 2.63	5.98 ± 1.73	6.43 ± 1.71
Total assimilation				27.98%

carbon nearly 26 to 28%, since the total annual assimilation was 26.76% in 1990 and 27.98% in 1991. The two-way ANOVA also showed that in 1990 and 1991 there was significant variation in the rate of assimilation between various regions of the gut while insignificant between months (Table 65, 66).

Percentage of organic carbon and assimilation efficiency in relation to animal size

The availability of organic carbon in the foregut, midgut, hindgut, and faeces and the assimilation efficiency in these regions in various size groups of *A. mauritiana* (Table 67) shows that in all size groups studied, from 6-8.9 cm (smaller) to 30.0 - 32.9 cm (larger) the organic carbon was not showing any remarkable variation when size increases. The percentage of availability of organic carbon in foregut was 0.46% to 0.58%, in midgut 0.41% to 0.48%, in hindgut (0.37% to 0.44%) and in faeces (0.32% to 0.41%). But the ANOVA showed that the variation in organic carbon is highly significant (F = 119.33) between various regions of the gut and significant (F = 8.00) between various size groups (Table 68).

The assimilation efficiency of organic carbon in animals mainly depends on the availability in the gut content of all sizes and it does not have any relation to the animal sizes. The ANOVA analysis (Table 69) proved that the variation in assimilation efficiency is significant between various regions of the gut of various size groups (F = 5.62) and it is insignificant between size groups (F = 0.20).

DIGESTION

Time taken for digestion in various size groups

Table 70 gives the average time required from ingestion to egestion of *A. mauritiana* in relation to various size groups. The

TABLE 65. Level of significance in variation of assimilation ratio between months and various regions of the gut of *A. mauritiana* during 1990, by ANOVA II

Source	df	SS	MSS	F-value	Remarks
Coloumn	2	378.62	189.31	32.53	Highly Significant
Row	11	16.33	1.48	0.25	Not Significant
Error	22	127.98	5.82		
Total	35	522.93			

TABLE 66. Level of significance in variation of assimilation rate between months and various regions of the gut of *A. mauritiana* during 1991, by ANOVA - II

Source	df	SS	MSS	F-value	Remarks
Coloumn	2	702.56	351.28	61.74	Significant
Row	11	15.92	1.45	0.25	Not Significant
Error	22	125.14	5.70		
Total	35	843.62			

TABLE 67. The percentage of organic carbon available and assimilation efficiency in various regions of the gut at different size groups of *A. mauritiana*

Animal size groups (cm)	% of organic carbon					Assimilation efficiency						
	No. of animals	Foregut	Midgut	Hindgut	Faeces	Foregut to midgut	Foregut to hindgut	Foregut to faeces	Midgut to hindgut	Midgut to faeces	Hindgut to faeces	Substratum to faeces
6.0- 8.9	10	0.51	0.43	0.40	0.39	15.69	21.57	23.57	6.98	9.30	2.5	13.33
9.0-11.9	10	0.48	0.44	0.38	0.35	8.33	20.83	27.09	13.63	20.45	7.89	18.60
12.0-14.9	10	0.52	0.46	0.43	0.38	11.54	17.31	26.92	6.52	17.39	11.63	25.49
15.0-17.9	10	0.55	0.48	0.44	0.41	12.72	20.00	25.45	8.33	14.58	6.81	14.58
18.0-20.9	10	0.51	0.45	0.41	0.38	11.76	19.61	25.49	8.89	15.55	7.32	15.56
21.0-23.9	10	0.58	0.51	0.42	0.36	12.03	27.58	37.93	17.65	29.41	14.29	33.33
24.0-26.9	10	0.53	0.44	0.41	0.38	16.98	22.64	28.30	6.82	13.63	7.32	24.00
27.0-29.9	10	0.50	0.44	0.40	0.32	12.00	20.00	36.00	9.09	27.27	20.00	30.43
30.0-32.9	10	0.46	0.41	0.37	0.35	10.87	19.57	23.91	9.76	14.63	5.41	18.60

TABLE 68. Level of significance in variation of organic carbon between size groups and various gut regions of *A. mauritiana*, by ANOVA II

Source	df	SS	MSS	F-value	Remarks
Coloum	3	0.1073	0.0358	119.33	Highly Significant
Row	8	0.0193	0.0024	8.00	Significant
Error	24	0.0075	0.0003		
Total	35	0.1341			

TABLE 69. Level of significance in variation of assimilation efficiency between size groups and various gut regions of *A. mauritiana*, by ANOVA - II

Source	df	SS	MSS	F-value	Remarks
Coloumn	2	1134.44	567.22	5.62	Significant
Row	8	161.60	20.20	0.20	Noto Significant
Error	16	1613.65	100.855		
Total	26	2909.79			

TABLE 70. The average time from ingestion to egestion of A. mauritiana in relation to various size groups.

Animal size groups (cm)	Rate of egestion														
	No. of animals per experiment	Time (hours)	Rate of egestion (%)	Time Hours	Rate of egestion (%)	Time Hours	Rate of egestion (%)	Time Hours	Rate of egestion (%)	Time Hours	Rate of egestion (%)	Time Hours	Rate of egestion (%)	Time Hours	Rate of egestion (%)
6.0- 8.9	14	2	40.00	4	20.00	6	-	8	-	10	100.00	-	-	-	-
9.0-11.9	14	2	43.50	4	30.60	6	-	8	-	10	100.00	-	-	-	-
12.0-14.9	14	2	60.15	4	15.10	6	10.50	8	-	10	5.00	12	100.00	-	-
15.0-17.9	14	2	50.00	4	10.15	6	20.00	8	-	10	-	12	100.00	-	-
18.0-20.9	14	2	8.00	4	20.00	6	40.00	8	-	10	-	12	100.00	-	-
21.0-23.9	14	2	10.00	4	15.00	6	20.00	8	-	10	-	12	20.15	14	100.00
24.0-26.9	14	2	15.00	4	30.00	6	-	8	-	10	-	12	40.15	14	100.00

results obtained from 7 size groups shows that in the larger animals, the time for digestion increases. However, it is interesting to note that the animals in 6.0 - 11.9 cm and 12.0 - 20.9 cm sizes, there was ceasation of digestion or retension of food for about 2 to 3 hours in a digestion cycle of 8 to 12 hours.

Quantity of sediment ingested by various size groups

When the size of the animal increases the consumption of the sediment (dry weight) per day and per year also increases gradually in smaller size groups and sudden increase in bigger size groups, but the cycle of digestion decreases (Table 71). In the size group 6.0 - 8.9 cm and 9.0 - 11.9 cm, the cycle of digestion was 1.8/day and consumes 1.68 gm and 3.71 gm of sediment per day and 591 .30 gm and 1354.15 gm per year respectively by one individual. In the size group 21.0 - 23.9 and 24.0 - 26.9 cm the cycle of digestion was 1.2/day and consumes 9.97 and 12.19 gm sediment per day and 3634.05 and 4449.35 gm per year respectively. These results indicate the average cycle of digestion per day is 1.5 and consumes 6.89 gm of sediment per day and 2517.12 per year by one individual of A. mauritiana.

EXCRETION

Production of excretory boluses by A. mauritiana

A. mauritiana excretes the faeces as a string of beads with mucus substance. This is measured as 0.1 to 0.3 cm long with dry weight of 200 mg to 600 mg per bead. The quantity of excreta may vary depending upon the size of the animal and its gut characteristics. It is also noticed that the wave action does not disturb the faecal matter in the study areas. Hence it formed of plant material like minute sea-weed fragments with fine sediment particles.

TABLE 71. The amount of sand eaten by different size groups of *A. mauritiana* per day and year

Animal Size groups (cm)	A in hour	B in hour	C per day	D gram	E gram	F gram
6.0- 8.9	18	10	1.80	0.90	1.68	591.30
9.0-11.9	18	10	1.80	2.06	3.71	1,354.15
12.0-14.9	18	12	1.50	2.99	4.49	1,638.85
15.0-17.9	18	12	1.50	4.39	6.59	2,405.35
18.0-20.9	18	12	1.50	6.46	9.69	3,536.85
21.0-23.9	18	14	1.29	7.73	9.97	3,634.05
24.0-26.9	18	14	1.29	9.45	12.19	4,449.35

A - Time in which the gut is actually full in a day
B - One cycle of diagestion
C - Number of digestic cycle in a day calculated by dividing A and by B
D - Average amount of gut content, referred from Table 46
E - Average amount of sand eaten by one individual per day (C x D)
F - The same amount per year (E x 365)

The quantity of faeces and the organic carbon uptake by A. mauritiana in various size groups (Table 72) indicate that the quantity of excreta and organic carbon uptake has direct proportion to the length of the animal. For example, 6.0 - 8.9 cm excrete 2.8 gm of faeces and uptake 8.06% of organic carbon and 30.0 - 32.9 cm excrete 11.10 gm of faeces and uptake 29.30% of organic carbon.

DISCUSSION

Tentacle structure and feeding mechanism

The tentacle structure of Actinopyga mauritiana represents the peltate type as in other aspidochirotes holothurians reported by Hyman (1955), Trefz (1958), Cameron and Fankboner (1980) and as in H. nobilis of the present study. But the number of tentacles was found to be twenty five. The frond of the tentacle is leaflike and it expands greatly to scoop the food particles from the environment. It also helps to hold the substratum firmly to withstand the rough weather particularly wave action and water current in the Minicoy Reef flat as observed during the collections.

As in many of the aspidochirotes holothurians, in A. mauritiana also the nodules in the tentacle's frond act as a functional surface to scoop the food stuffs from the substratum. But this species is different from aspidochirotes, because of the secretion of an adhesive substance in the nodules, which is characteristic feature of dendrochirotes holothurians as observed by Fish (1967) and Fankboner (1978). However, there are reports that the possibility of adhesive secretion in aspidochirote holothurians too (Hyman, 1955; Hammond, 1982; Cameron and Fankboner, 1984). Hyman (1955) reported that some aspidochirotes have mucus glands in the pharyngeal wall, which keeps tentacles with mucus coating. Hammond (1982)

TABLE 72. Percentage of organic carbon uptake by *A. mauritiana* in relation to different size groups

Animal size groups (cm)	No. of animals	Average weight of faeces (gm)	Average percentage or oganic carbon in sediments	Average percentage of organic carbon in faeces	Organic carbon removal (sediment-faces)	% organic carbon up-take (animal/day)
6.0- 8.9	10	2.8	0.50	0.38	0.12	8.06
9.0-11.9	10	4.5	0.48	0.36	0.12	12.96
12.0-14.9	10	5.03	0.53	0.41	0.12	14.49
15.0-17.9	10	5.78	0.51	0.42	0.09	12.48
18.0-20.9	10	7.20	0.50	0.40	0.10	17.28
21.0-23.9	10	8.60	0.49	0.36	0.10	20.04
24.0-26.9	10	10.05	0.50	0.42	0.08	19.30
27.0-29.9	10	10.90	0.53	0.43	0.10	26.16
30.0-32.9	10	11.10	0.53	0.42	0.11	29.30

through SEM observations noticed an apparent coating of mucus on the tentacles of I. badionotus, H. mexicana and A. agassizi all belong to Aspidochirotes. Cameron and Fankboner (1984) reported that the secretion of an adhesive substance at the surface of the nodule is the most important character in the food collection by P. californicus, an another aspidochirote species which forms a significant sea-cucumber fishery in the Pacific Coast of North America.

In addition, Fankboner (1978) reported that this adhesive substance protects the nodules from abration or damage while consuming sharp edged food items, as observed in a dendrochirotes holothurian Psolues echitinoids. This view is certainly accepted by Roberts and Bryce (1982) and stated "as surface friction is likely to be much greater in aspidochirotes than in dendrochirotes, the presence of a protective 'cuticle' coating of the tentacle epithelium is not surprising". If it so, this finding also well suited to A. mauritiana, which is an inhabitant of rough environment and where sharp edged food items such as seaurchin spines, molluscan shells, coral pits, etc. are available.

Gut structure and its related characters

The gut in A. mauritiana is coiled with ascending and descending loops. The gut wall is very thin and sometimes sharp food items like molluscan shells and crustacean appendages discerned causing damage to the gut wall. Hyman (1955) reported that the intestine of some holothurian is typically very long, two to three or several times coiled than the body length. Further it seems that the gut of A. mauritiana environmentally adapted for digesting fine particles and some algal matters.

The length of the animal to the length of the gut is in the ratio 1:4 with isometric relationships while other relationships such as body length to wet weight of the gut contents and body length to dry weight of the gut content showed a ratio of 1.0:1.5 and 1.0:0.5 respectively.

with allometric relationship. This is similar to H. nobilis of the present study also and the reason given by Crozier (1918) on S. moebii that "the total length of the gut increases rapidly with the size of the body and the maximal capacity is less than proportional to the cube of this length. Further a slight deviation from the cubic relationship noticed between these characters may be attributed to the fact that in most of the time the stomach is never entirely filled with sand, but always contain a fair volume of digestive juices. Hence, with the fullgut content individuals show fair and accurate relationship". But the dry weight of the gut content of A. mauritiana is very low when compared to H. nobilis and it may be due to selection of fine sediment particles.

The feeding rhythm of A. mauritiana based on degree of gut fullness showed nearly 50% of the gut were full and 30% gut were 1/2 full in every month during study period. It gives a clue that this species is continuously eating sediment without any eastivation in summer or stops feeding activity after spawning as reported by Tokuhisa (1915) and Choe (1963) in S. japonicus. However, it is observed here that the species was found more than 2 to 3 hours exposed during low tide on the reef flat. During this time the tentacles were found fully withdrawn from the muscle hood of mouth. In such conditions the animal was dissected and gut condition was observed and found that no digestion was taking place. Again they feed and excrete only when high tide begins and water flows over the reef flat.

Food consumed

The analysis of gut content shows that this species consumes various items such as polychaetes, nematodes, bivalves, crustacean larvae, tubiculous– polychaetes, hermit crab juveniles, gastropods, sponges, foraminiferans, sea-weeds, sea-urchin spines, molluscan shells, crustacean endoskeleton and unidentified organisms as in the case of H. nobilis. These all organisms and their percentages in the gut is almost reflecting the same to that available in the environmental sediment, but sponge, foraminifers and sea-grass pits were found only in the gut. These items would have been obtained by this animal from the coral boulders or rubbles of the reef flat area, but not from sediments.

Further, from the gut content analyses in various size groups, nearly 25.93% of sea-weeds and other plant fragments were noticed in younger animals and in larger animals it was less and only 17.08%. The preference of plant fragments and sea-weeds by younger A. mauritiana may be attributed to the finding of Yingst (1976) in Parastichopus parvimmensis that the younger animals require plant matters, because it has dissolved colloidal organic and inorganic compound, which serve as nutrients in younger developing stages of this species.

However, as noticed in H. nobilis in the present study and reported by Trefz (1958) in H. atra, this A. mauritiana also not digesting any of these biotic and abiotic organisms. Hence the faecal pellet analysis showed almost similar organisms as it was available in the gut. This may be of weak acidic action of digestive juice available in the gut of this species, which is required to kill or digest these food items in the absence of grinding mastigatory apparatus in the alimentary system.

Selection of food particles

The observation on the particle size selection by A. mauritiana showed that this species prefers mostly particles measured 0.5 mm and < 0.5 mm size, while sediment contains all the particles measured 4.0, 2.0, 1.0, 0.7, 0.5 and < 0.5 mm with equal proportions. So, it clearly indicates this species is a selective feeder of smaller (0.5 and < 0.5 m) particle sizes. This view is further strengthened by the comparison made between environment sediment and contents of foregut region which contained 40% of particles $<$ 0.5 mm. The observation of Yamanouti (1939) on Actinopyga spp. in Palao Island, which consumes fine sediments adhering to macrophytes in the field, is acceptable and coincides with present observations. Further the present result shows that there is no degradation of food sediment particles when it undergoes digestion at various region of the gut of A. mauritiana.

Assimilation efficiency of organic carbon

The assimilation efficiency of A. mauritiana has been estimated by using organic carbon as a source of nutirent. The monthwise estimation of the organic carbon by percentage in the substratum, foregut, midgut, hindgut and faeces showed significant variation between months as well as various regions of the gut. The monthwise variation in organic carbon in the reef sediment is possible, because it serves as a "bio-filters" due to accumulation of organic matters by waves from different sources such as decay of plant matters and animals which are all habitat in the reef flat. This varies depending upon the environmental condition prevailing in this area. But the variation found between the gut regions may be related to availability of organic carbon of the consumed sediment at each region of the gut.

Availability of organic carbon

It is evident from the present observations that the organic carbon is more in the content of the foregut when compared to other regions. This type of observation was well noticed in many holothurians by various authors, such as H. atra and S. chloronotus (Moriarity, 1982); I. badionotus, H. mexicana and H. arenicola (Hammond, 1983); H. atra (Webb et al., 1977) and S. tremulus (Hauksson, 1979). These investigators have attributed the reason that the more availability of organic carbon in the foregut is due to selectivity of organic matter, rich organic carbon component of sediment, digestion of micro-organisms, which contribute some amount of organic carbon. This may be true and comparable to A. mauritiana also, since it consume very fine particle along with plant matters.

Assimilation efficiency in relation to month

The assimilation efficiency and rate of assimilation of organic carbon in various region of the gut of A. mauritiana show only little variation in between months. This may be related to the capability of assimilation by different region of the gut. Further, in this species also the assimilation was higher in the foregut as in the case of H. nobilis, when compared to other regions. Foregut is the first place to receive the food, it is quite natural that the organic carbon is more in this region resulting higher assimilation.

The assimilation efficiency of A. mauritiana was found 26.76% in 1990 and 27.98% in 1991, which is lower than 40% of assimilation efficiency found by Bakus (1968) in H. difficilis in study sediments of coral reef and concluded that the assimilation efficiency in the tropical holothurian is approximately 50%. These variations between the candidate's observation and Bakus' view may be related to the variation in the fraction of organic matter available in the environment or difference in the fraction of organic matter associated with the sediment particle ingested by these two holothurians. Hence A. mauritiana of present study, consumes very fine sediment, while H. difficilis (Bakus, 1968) feeds on medium sized sand grains.

Assimilation efficiency in relation to size groups

The organic carbon assimilation related to different size groups of A. mauritiana found to be statistically insignificant ($F = 0.20$) and it indicates the assimilation efficiency is similar in all the size groups.

Digestion

The time required for digestion from ingestion to egestion in *A. mauritiana* in relation to the size of the animals indicates that when the size increases, the time for digestion also increases which is 10 hours in 6 to 11 cm animals and 14 hours in 21 cm to 26.0 cm animals. This may be related to the gut length and consumption of food in relation to animal length. However, the observation made from reef flat area and experiment conducted at the laboratory to observe the period of ceasation during digestion in *A. mauritiana* revealed hereby that the animals stops digestion for two hours when they are exposed to atmosphere during low tide. This two hours ceasation was also observed in the laboratory experiments, which coincides to the reef flat animal during the low tide time. The ceasation in digestion during low tide at reef flat may be attributed to the exposure of the animals to the atmosphere and inactiveness of the animal. However, the reason for ceasation of digestion for about 2 hours in the laboratory are yet to be studied in detail.

The cycle of digestion and the amount of environmental sediment consumed per day and per year showed remarkable variations depending upon the size of *A. mauritiana*. This may be related to their gut characteristics and metabolic efficiency. It is also confirmed from the present study that *A. mauritiana* consumed 6.89 gm sediment per day and 2517.12 gm per year by one individual. This is lower when compared to other deposit feeding holothurians, *H. atra* consumes 70 kg/yr, *H. floridana* 30 kg/yr and *S. moebii* 42 kg/yr (Thorson, 1966). This variation may be due to micro-habitat selection by *A. mauritiana* since it consumes very fine sediment particles.

Excretion

The excretory boluses or faeces of *A. mauritiana* is very useful tool to locate the population and density in the reef flat, when the animals are under the coral boulders. This boluses are capable of withstanding the rough wave action and water current without any damage, because it packed with fine sediments and minute plant matters.. These are found as a string of beads with mucus substances. The faeces production by this species also depends upon the size of the animal.

Part 2 : Reproductive biology of *Holothuria nobilis* and *Actinopyga mauritiana*

INTRODUCTION

The information on the reproduction and population of many tropical holothurian is very little, eventhough these animals are economically important from 1000 AD (James, 1994). The earlier reports available on reproduction of holothurians by Hyman (1955), Tanaka (1958) and Choe (1963) give only basic knowledge on reproductive system of certain species of holothurians. A greater knowledge is required still on the structural modifications of the reproductive system, spawning behaviours, fecundity, embryology, larval developments, juveniles and recruitment to the population. During the last two decades considerable attention has been paid on the aspects of reproductive biology of holothurians. From the literature available, it is understood that the holothurians are very adaptive to their environment and food available, and their reproduction mainly depends on the habitat. Most of the tropical species are known to spawn and their fertilization takes place in the environmental media. Some of the species are also known for their asexual reproduction by transverse fission as in the case of *A. difficialis* and *A. mauritiana*. In some of the species particularly in *H. atra* the reproduction is by both sexual and asexual. A few species are known to brood their larvae e.g. *Cucumaria lubrica*. Recent investigations by Tyler and Gage (1991) indicates that there is hermophroditism too, as in the case of sea holothurian *Paroriza pallens*. As it really interesting to know that the animals belonging to same Phylum having different methods of reproduction, the researchers in recent time inspired to study in depth about sex organs, spawning behaviour, reproductive efforts, fecundity, etc. of the holothurian all over the world particularly in tropical regions, where economically important holothurians are available. Accordingly

Conand (1983, 1990, 1993) from Pacific Islands; Harriot (1982, 1985) from Great Barrier Reef, Australia; Shelley (1981, 1985) from New Guinea; Rutherford (1973), Green (1978) and Engstrom (1980) from North American continent have studied the reproductive biology of many holothurians in detail, which has brought to light some information to fill the gap in the reproductive biology.

But in India, more than 100 species, of holothurians are known only to H. scabra from the Gulf of Mannar has been studied in detail (Krishnaswamy and Krishnan, 1967; Krishnan, 1968; Baskar, 1994). Jayashree and Bhavanarayana (1994) studied the reproduction of H. leucospilota from Anjuna, Goa. Due to lack of detailed information on the reproduction of economically important holothurians particularly H. nobilis and A. mauritiana from the Minicoy Island, the candidate carried out investigations on reproductive biology such as sex organ and stages, reproductive cycle, reproductive efforts, ecological factor that influence reproduction on H. nobilis and asexual method of reproduction on A. mauritiana from Minicoy Island, Lakshadweep.

MATERIALS AND METHODS

As Actinopyga mauritiana reproduces asexually by transverse fission, the description given here is only for Holothuria nobilis which reproduces sexually.

Morphology of gonad and stages

In holothurians the gonad is comprised of tufts of tubules and not lobe-like. Since the histological study was considered to be time consuming (Conand, 1981) macroscopic observations of the fresh gonad such as colour, size, shape and number of tubules were recorded and classified corresponding to different stages of maturity based on earlier works (Choe, 1963; Rutherford, 1973; Harriot, 1980; Conand, 1990).

Sex ratio and maturity stages

Based on the visual observations, sexes and maturity stages were noted every month and calculated the individual percentage of sexes and maturity stages available in the population.

Gonad Index (GI)

The simplest indicator of reproductive stage is the gonad index (Grant and Tyler, 1983). This index can be derived from the following calculation.

$$GI = \frac{\text{Weight of the gonad}}{\text{Weight of the animal}} \times 100$$

From the fortnightly samples of Holothuria nobilis, gonad (Testis and Ovary) weight were taken to nearest 1 gm along with total weight, drained weight and gutted weight of the animal. But the GI was computed to the drained weight of the animal as it gives better and reliable result as suggested by Conand (1981).

$$GI = \frac{\text{Wet weight of the gonad}}{\text{Total drained weight of the animal}} \times 100$$

Oocyte - Relative proportion frequency profile

Oocyte size is a good indicator of maturation and gonadal cycle. For this study, in every sampling, fresh pieces of ovary of H. nobilis from different tubules belonging to different maturity stages, were teased in a drop of 1% formalin on a glass slide and the eggs were observed through microscope and measured along the horizontal axis using ocular micrometer precalibrated with stage micrometer. Based on this observation, oocyte size frequency in relation to different stages of maturity and monthwise oocyte developments were calculated.

Size at first sexual maturity

The size at first sexual maturity or size at which an individual may reproduce for the first time is an important parameter for stock management (Choe, 1963; Rutherford, 1973; Conand, 1981). In Holothuria nobilis the percentage of individuals in maturity stages III, IV and V were recorded in classes of total weight (TW) and drained weight (DW) using the sample excluded the resting period as adopted by Conand (1990). Probit analysis and regression were done to find out, when 50% of the size classes are sexually matured in relation to total weight and drained weight.

Fecundity

Fecundity is one of the parameter with potential influence on recruitment (Conand, 1990). One gram of mature ovary was taken from the mid part of a tubule, drained, weighed and placed in a Gilson fixative which helps disintegrate the ovarian stroma and harden the oocytes (Conand, 1990). The eggs were teased in 10 ml of 1% formalin in a graduated 10 ml capacity measuring jar and subsamples of 1.0 ml were taken using a pipette and the eggs counted. The following formula was employed to estimate the relative fecundity of H. nobilis

$$Rf = n \times G/W$$

Where

Rf = Relative fecundity

n = number of oocytes counted in the sub samples

GW = weight of the gonad

Reproductive cycle in relation to environment

Environmental parameters such as salinity, dissolved oxygen and temperature from 9 stations and rainfall data for Minicoy Island (from the Indian Metriological Department, Minicoy) were collected from January 1990 to December 1991. These parameters were correlated with mean value of gonad index of the species by multiple regression analysis to find out the influence of these parameters on reproductive cycle of this species.

SECTION A : HOLOTHURIA NOBILIS

Description of gonad

In Holothuria nobilis sexes are separate. The gonad consists of single tuft of tubules with gonad base attachment near to the dorsal mesentary. In mature animal at the free end the tubules are dichotomously branched into smaller branches and extend some where as far as posterior part of the coelomic body cavity. The gonoduct runs along the dorsal mesentary and opens to the exterior through gonopore on the mid-dorsal inter-radius about 1.5 cm above the tentacles, which is generally not visible. There is no distinct papilla or any marked protrusion of the body wall associated with the gonopore. The appearence of the testis and ovary are anatomically same, but differentiated by their colour, length and weight according to their stages of maturation. Tubules of the testis in the adult male is purely white and in an average 17.0 cm in length with 180.0 gm of wet weight. The tubules in the ovary in the adult female is slightly cream in colour with an average length of 19.0 cm and wet weight 250.0 gm. The number of tubules vary between 30 to 43.

Reproductive stages

In male and female six stages were distinguished based on macroscopic observations namely 1. immature 2. maturing 3. mature 4. spawning 5. spent and 6. resting. (Fig. 33 & 34).

Male

Immature : The colour of the testis is bright cream. The tubules are thread-like and very thin measuring 2.0 to 5.8 cm with an average length of 2.9 cm and wet weight from 20.0 to 40.0 gm. When these tubules are pressed by microslide they tend to break into small pieces, which means spermatozoa are not formed. The sperms could have been attached to lumen of tubules in this stage.

Maturing stage : The colour is light cream. The tubules are slightly thicker than in stage 1 and the free end is pointed. It measured 8.0 to 12.0 cm with a mean length of 9.12 cm weighing 50.0 to 70.0 gm. The microscopic observations show active spermatogenesis, as some motile spermatozoa are noticed.

Mature stage : The colour of the testis at this stage is pure white and tubules become thick with mature spermatozoa. The tubules slightly longer compared to earlier two stages, and branched at tips. The tubules extend to mid-portion of body cavity. It varies 11.0 cm to 17.0 cm with a mean of 13.50 cm with wet weight from 120.0 to 220.0 gm. The number of tubules are more than 25 and in microscopic observations the spermatozoa are very active with well developed tail.

Spawning stage : The colour is white or slightly brownish white. Most of the tubules found empty since spermatozoa were released. The rest of the tubules were fully packed with active spermatozoa for release. The wall of the tubule is very thin and transparent

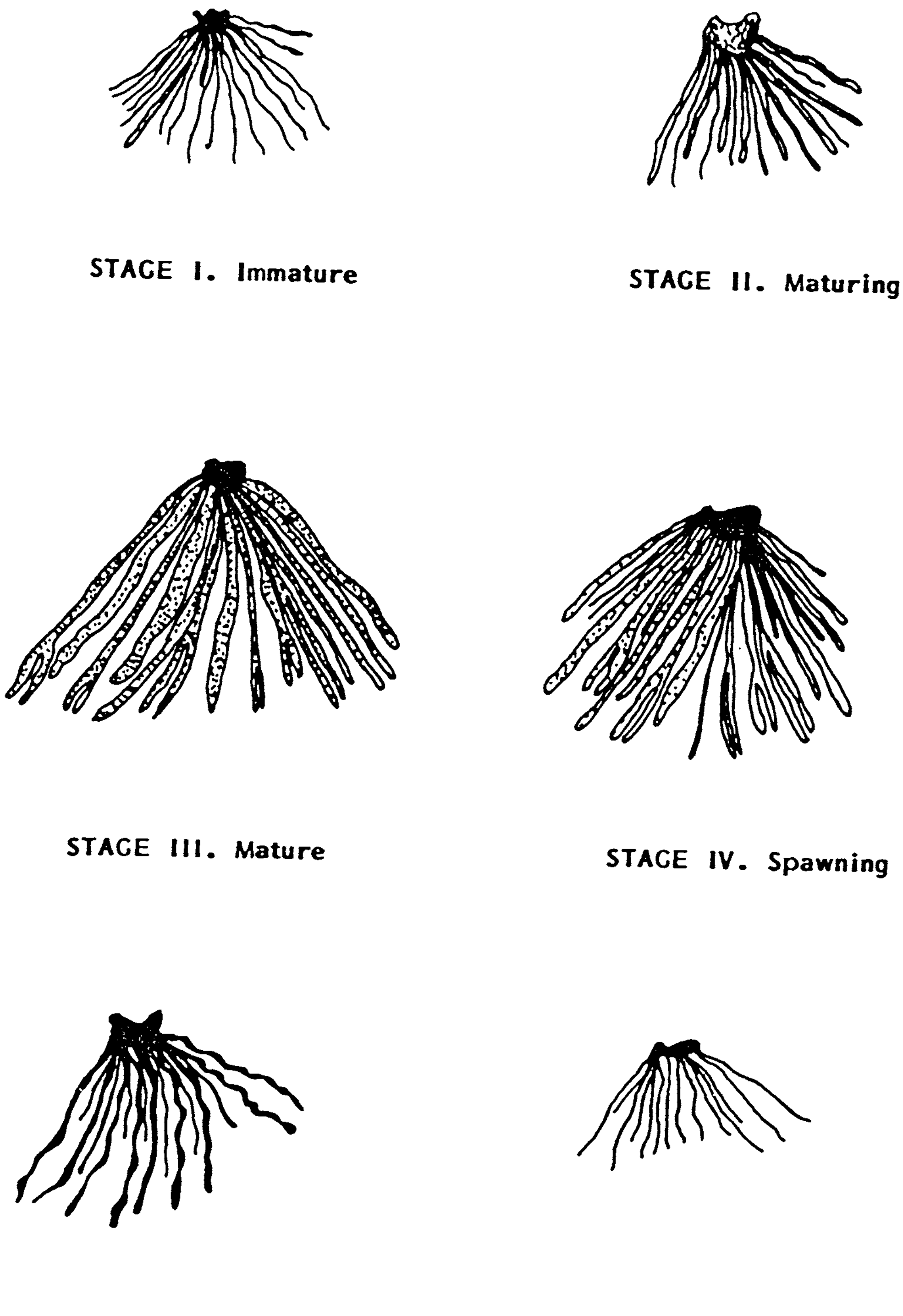
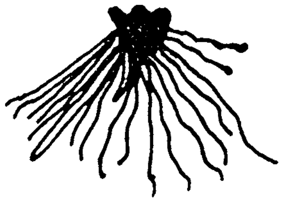
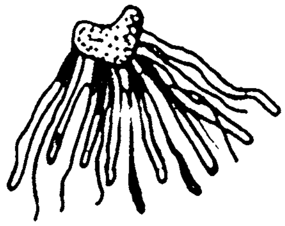


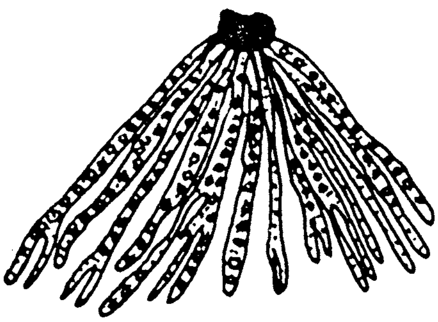
Fig.33. Reproductive Stages of male H.nobilis



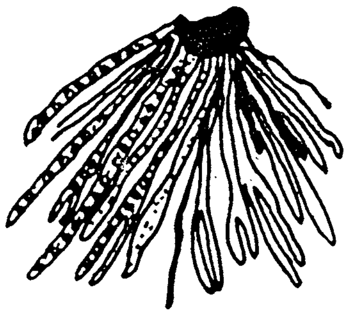
STAGE I. Immature



STAGE II. Maturing

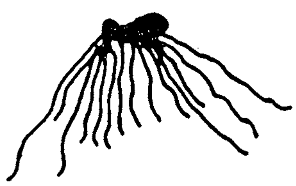


STAGE III. Mature



STAGE IV. Spawning

STAGE V. Spent



STAGE VI. Rest

Fig.34. Reproductive Stages of female *H. nobilis*.

and is very long when compared to earlier stages. They measure 10.0 to 20.0 cm with mean of 16.20 cm with wet weight of 150.0 to 200.0gm. The squash preparation of this stage showed that sperm was moving very fast using its long tail whiping for propulsion.

Spent stage : The colour at this stage is light grey and tubules are very thin with bead-like tips. It measured 3.5 to 8.0 cm with a mean of 6.10 cm weighing 20.0 to 40.0 gm. In this stage, the spermato-genesis is absent or much reduced and the tubules show constriction in many places.

Resting stage : The colour at this stage is very deep grey and the tubules are very minute and thin comparable to that in stage 1. No spermatozoa found in this stage.

Female

Immature : The colour of ovary at this stage is bright yellowish and tubules are very short measuring 2.0 to 6.5 cm with a mean of 3.79 cm length.

The number of tubules are varying between 13 and 15 according to size of the animal. The squash preparation between microslides shows that eggs are attached with gonadal wall and distinctly round in shape without nucleus. The egg measured from 18.0 μm (13.82%) to 54.0 μm (5.54%) with highest percentage of 36.0 um egg (33.18%).

Maturing stage : The colour at this stage is light yellow and tubules are increasing in their length and extent towards the coelomic body cavity. Tubules measured from 8.0 cm to 14.0 cm with a mean of 10.92 cm length and weighed from 100.0 to 130.0 gm. The microscopic observation shows that the egg is slightly bigger when compared to earlier stage. This egg contains small yolk granules

TABLE 73. Variation in the length of gonad tubules of male and female *H. nobilis* in relation to various stages of maturity

Sex	Stage	Number of animals	Length of gonad tubules		
			Minimum (cm)	Maximum (cm)	Mean and SD (cm)
Female	Immature	33	2.0	6.5	3.79 ± 1.69
	Maturing	54	8.0	14.0	10.92 ± 1.70
	Mature	52	10.0	19.0	10.57 ± 2.05
	Spawning	30	10.0	22.0	15.67 ± 2.30
	Spent	22	4.0	10.0	6.62 ± 1.49
Male	Immature	28	2.0	5.8	2.90 ± 1.60
	Maturing	40	8.0	12.0	9.12 ± 1.40
	Mature	32	11.0	17.0	13.50 ± 2.30
	Spawning	30	10.0	20.0	16.20 ± 2.78
	Spent	33	3.5	8.0	6.10 ± 1.70
	Resting	5	-	-	-

\- Nil

TABLE 74. Chart of egg diameter (μm) in various maturity stages of *H. nobilis* at Minicoy Island

Egg diameter (um)	Immature %	Maturing %	Mature %	Spawning %	Spent %
18	13.82				
27	18.43				
36	33.18				
45	29.03	1.99			
54	5.54	4.48			
63		5.47			
72		14.43			
81		16.41			
90		34.33			
99		6.97			
108		11.44			
117		4.48			
126			3.92		
135			11.75		
144			8.36		
153			18.54		
162			26.89	18.49	
171			17.49	12.61	19.86
180			13.05	24.37	23.40
189				34.54	36.88
198				10.00	19.86

without nucleus. The eggs of this stage measured from 45.0 (1.99%) to 177.0 µm (4.48%) with highest percentage of 90.0 µm egg (34.33%).

Mature stage : The colour of the ovary at this stage is light cream and tubules are fully packed with mature eggs. The tubules are very long and tips bifurcated with thin branches at the free end. The tubules measure 10.0 to 19.0 cm with a mean of 15.57 cm, weighing 170 to 250 gm. Mature eggs are of different shape with one prominent nucleus. Egg is freely moving into lumen of tubules and not attached on gonad tubules. The size is from 126.0 µm (3.92%) to 180.0 µm (13.05%) with highest percentage of 162.0 µm egg (26.89%).

Spawning stage : The colour of this stage is in white and length of the tubules increases when compared to former stages. Tubules measure 10.0 cm to 22.0 cm with a mean of 15.67 cm weighing 100.0 to 170.0 gm. Eggs are freely moving in the lumen and measure 162.0 µm (188.49%) to 198.0 µm (10.0 %) with highest percentage of 180.0 µm egg (34.53%). This stage is ready to spawn and in the spawning stage.

Spent stage : The colour at this stage is grey. Since spawning comes to end almost all eggs are exhausted and the tubules shrink, slightly brick red in colour. The tubule length is also reduced with size of 4.0 cm to 10.0 cm and mean of 6.62 cm weighing 20.0 to 30.0 gm. The eggs measure 171.0 µm (18.86%) to 198.0 µm (19.86%) with highest percentage of 189.0 µm egg (36.88%). The new and young gonad tubules at one attachment base begin to grow and prepare for maturing to begin with the next spawning cycle.

Resting stage : In this stage only pigmented and shrunken tubules of the ovary are found at the base.

Sex ratio

The proportion of male, female and indeterminate animals collected from Minicoy Island are given in Figure 35. Among 500 animals identified for sex only 12 animals were indeterminates due to more shrunken state or as they are in resting stage. In January 1990, 0.07% of animals and in April 1991, 0.09% of animals could not be identified for their sex. For male and female the frequency distribution calculated based on the assumption 1:1 ratio by x^2 analysis for 1990 and 1991 showed (Table 75) that observed distribution of sex ratio was not significantly different from the expected distribution of sex ratio, since the monthly values are low level when compared to Table value.

REPRODUCTIVE CYCLE

Maturity chart

Male : In January 1990, I, II, III, V and VI were found and highest animals were in stage VI (40%). In February, except stage IV and VI all other stages were found with highest animal in stage I (45.45%). In March, except stage IV and V, all other stages were noticed and maximum was stage I (57.4%). In April stage II was dominant (44.44%) among stage I to III. In May, stage II and III was observed with high percentage of stage II (55.56%). In June, only stages II and III were noticed and the highest was stage III (55.56%). In July and August, 100% of animals were in stage III (mature). In September, stage III and IV were noticed and the same continued in October also. In November, stage III, IV and V were noticed and stage V (58.33%) was dominant. In December, stage III to VI were noticed and stage V (63.64%) was dominant (Fig. 36).

TABLE 75. Relative proportion and x^2 analysis of sex ratio (male: female) in *H. nobilis* in Minicoy Island during 1990-1991

Month	Total	Male	Female	Undetermined sex	Relative	x^2
January 1990	17	10	7		0.59 . 0.41	0.52
February	24	11	13		0.46 . 0.54	0.16
March	28	14	14		0.50 . 0.50	0.00
April	16	9	7		0.56 . 0.54	0.26
May	19	9	10		0.47 . 0.53	0.06
June	14	9	5		0.64 . 0.36	1.14
July	12	7	5		0.58 . 0.42	0.34
August	17	9	8		0.53 . 0.47	0.16
September	28	14	12	2	0.50 . 0.43 . 0.07	0.16
October	23	12	11		0.52 . 0.48	0.04
November	22	12	10		0.55 . 0.45	0.18
December	19	11	8		0.58 . 0.42	0.48
MEAN			8.28±	13.69±	17.66± 23.50±	43.28±
SD			4.57	4.93	10.71 11.53	5.47
January 1991	22	11	9	2	0.50 . 0.41 . 0.09	0.2
February	25	12	10	3	0.48 . 0.40 . 0.12	0.18
March	23	11	9	3	0.48 . 0.39 . 0.13	0.20
April	22	13	7	2	0.59 . 0.32 . 0.09	0.80
May	22	12	10		0.55 . 0.45	0.18
June	17	9	8		0.52 . 0.48	0.06
July	19	10	9		0.52 . 0.48	0.05
August	24	12	12		0.50 . 0.50	0.0
September	22	11	11		0.50 . 0.50	0.0
October	17	10	7		0.58 . 0.42	0.05
November	26	15	11		0.58 . 0.42	0.06
December	22	11	11		0.50 . 0.50	0.0

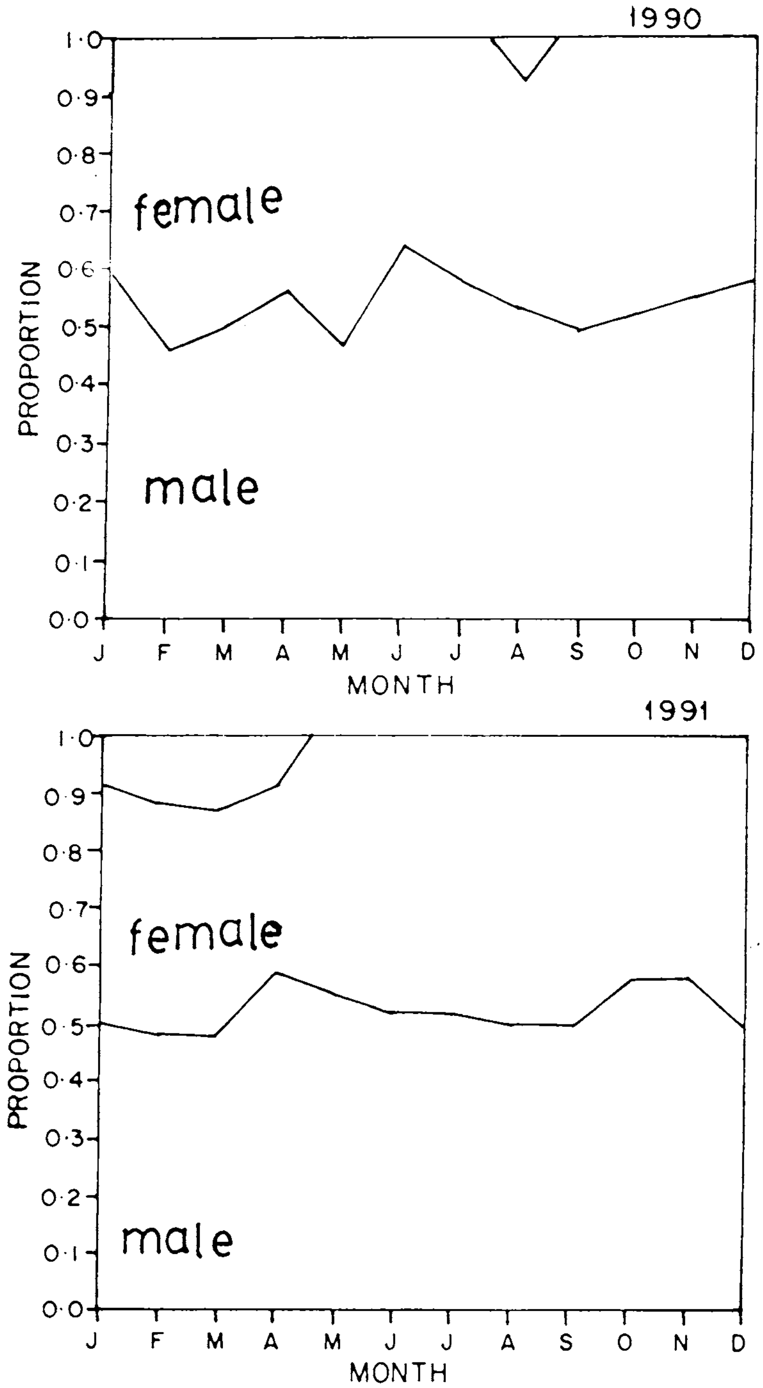


Fig.35. Relative abundance of male, female and sex unknown of *H.nobilis* in Minicoy Island during 1990 - 1991.

In January 1991, stages from III to VI were noticed with maximum animals were in stage VI (63.64%). In February, stage I, II, V and VI were noticed and maximum animals (41.67%) were in the stage I. In March, stage I to III were noticed and maximum animals were in the stage I (45.45%). In April, among the first three stages noticed, stage II (53.86%) was maximum. In May, stage II and III were equaly represented (50%). In June, stage II and III noticed, stage III was maximum (66.67%). During July-September, 100% animals were in stage III (mature). In October, stage III (60%) and IV (40%) were noticed and in November stage V (13.33%) was noticed along with stage III (40%) and IV (46.67%). In December, stage IV, V and VI were noticed and maximum (63.64%) seen was stage V (Fig. 36).

Female : In January 1990, stage I, III, V and VI were found and maximum (42.86%) was stage VI. In February, stage I was dominant (53.86%) along with other stages of II, III, V and VI. In March, stages I to III were found with maximum (50%) in stage I. In April only the first three stages were occurred with maximum animals (42.86%) in stage II. In May, stage II and III were occurred with maximum (60%) in stage III. From June to August, animals were mainly (100%) in stage III (mature). In Semptember, stage III and IV were found and same continued to occur in October also. In November, stage III, IV and V were occurred with maximum in stage V. In December, among stages III to VI found, 62.50% were in stage V (Fig. 37).

In January 1991, stage III, and VI were found and maximum (66.67%) was stage VI. In February, except stage IV and V and in March except stage IV , V and VI, all other stages were occurred with maximum in stage I. In April and May, stage I, II and III were found and maximum (57.14%) in April and 50.0% in May were noticed. Stages II and III were seen equally in June. From July to September, 100% animals were in stage III (Mature), while other

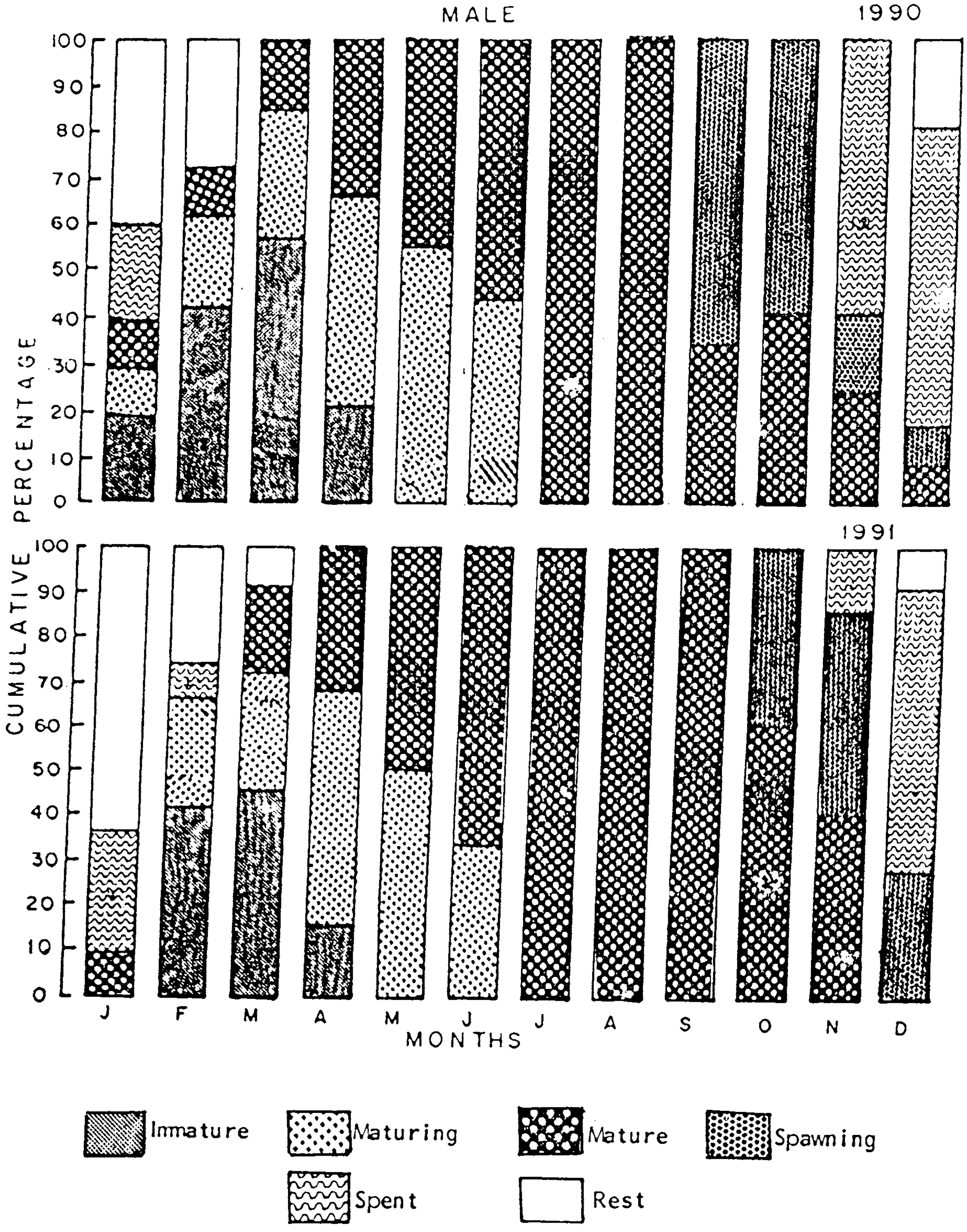


Fig.36. Maturity Chart of male H.nobilis showing the monthly percentages of stages of maturity during 1990 - 1991.

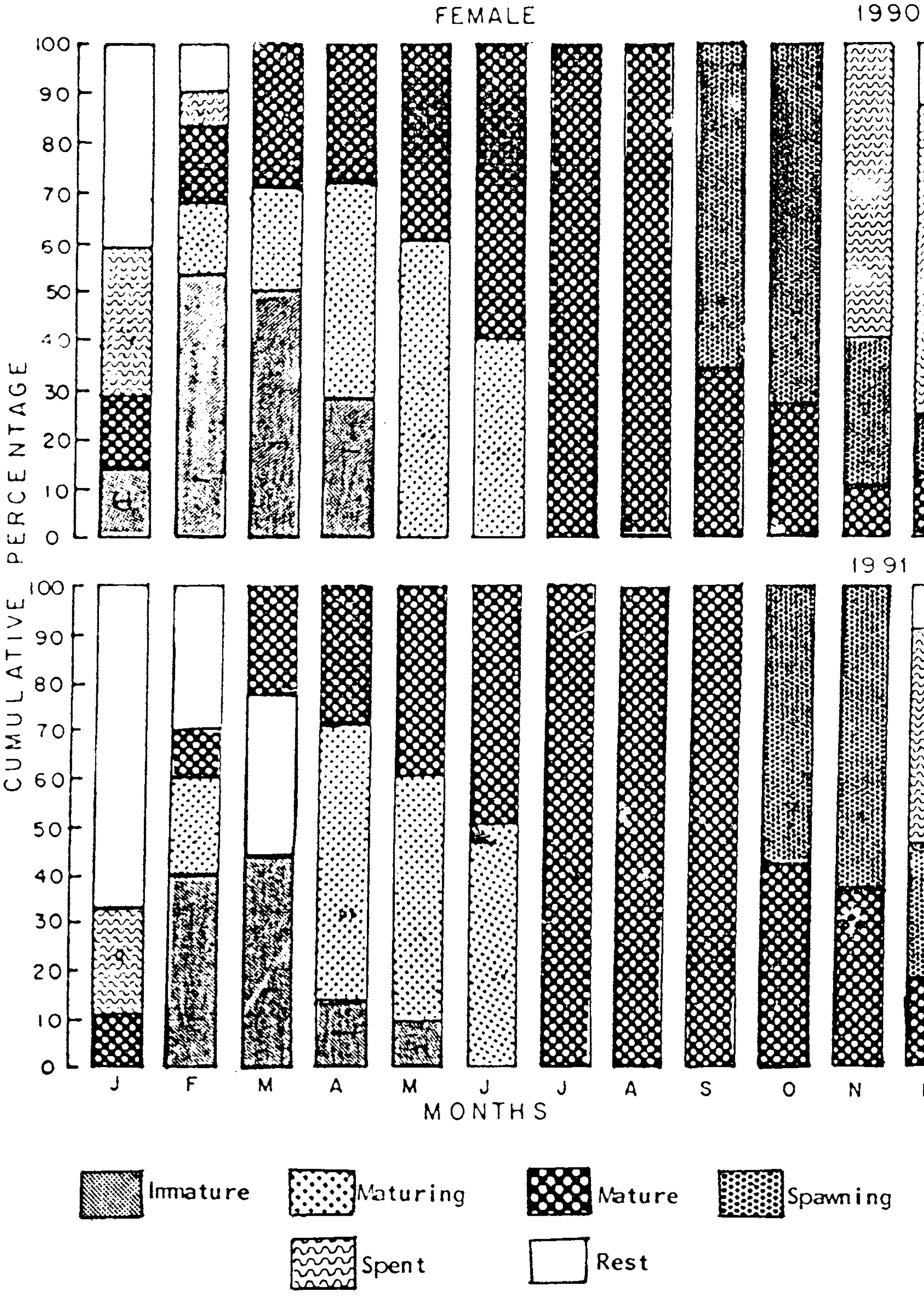


Fig.37. Maturity Chart of female H.nobilis showing monthly percentages of stages of maturity during 1990 - 1991.

stages were absent. In October and November, stages III and IV were occured with domination of stage IV. In December, stages from III to VI were occurred with maximum animals (45.45%) in stage V (Fig. 37).

Gonad weight and index in relation to maturity of sex

Male : The weight of testis was found 25.77 ± 11.5 gm from stage I (immature) to 172.22 ± 32.32 gm in stage III (mature). After spawning, from 143.33 ± 20.10 gm in stage IV and reduced remarkably to 65.56 ± 18.65 gm in stage V (spent) and 12.66 ± 6.12 gm in stage VI (resting) (Fig. 38 E). The gonad index also showed similar pattern. It is increased from 4.07 ± 1.46 in stage I to 12.60 ± 4.28 in stage III and slowly decreasing to 10.55 ± 6.72 in stage IV and values are suddenly dropping to 6.12 ± 5.10 in stage V and 2.19 ± 2.12 in stage VI (Fig. 38 A,C).

Female : The ovary weight increased from 30.12 ± 10.15 gm from stage I (immature) to 196.65 ± 30.10 gm in stage III (mature). A spawner (stage IV) weighs 150.00 ± 18.12 gm, the same weighs after spawning (stage V) 82.50 ± 9.60 gm and at the resting (stage VI) 14.65 ± 4.10 gm (Fig. 38 F, H). The gonad index also showed similar trend. It increased from 6.12 ± 1.75 in stage I to 13.50 ± 2.85 in stage III and decrease from 3.15 ± 4.65 in stage IV to 6.40 ± 2.20 in stage V and 4.50 ± 2.00 in stage VI (Fig. 38 B, D).

Spawning period

The gonad index of both male and female *H. nobilis*, with respect to different months in 1990 and 1991 **clearly showed that July and August in 1990 and extented to September in 1991 were the period of spawning.** The index value decreased due to spawning. From September in 1990 and October in 1991.

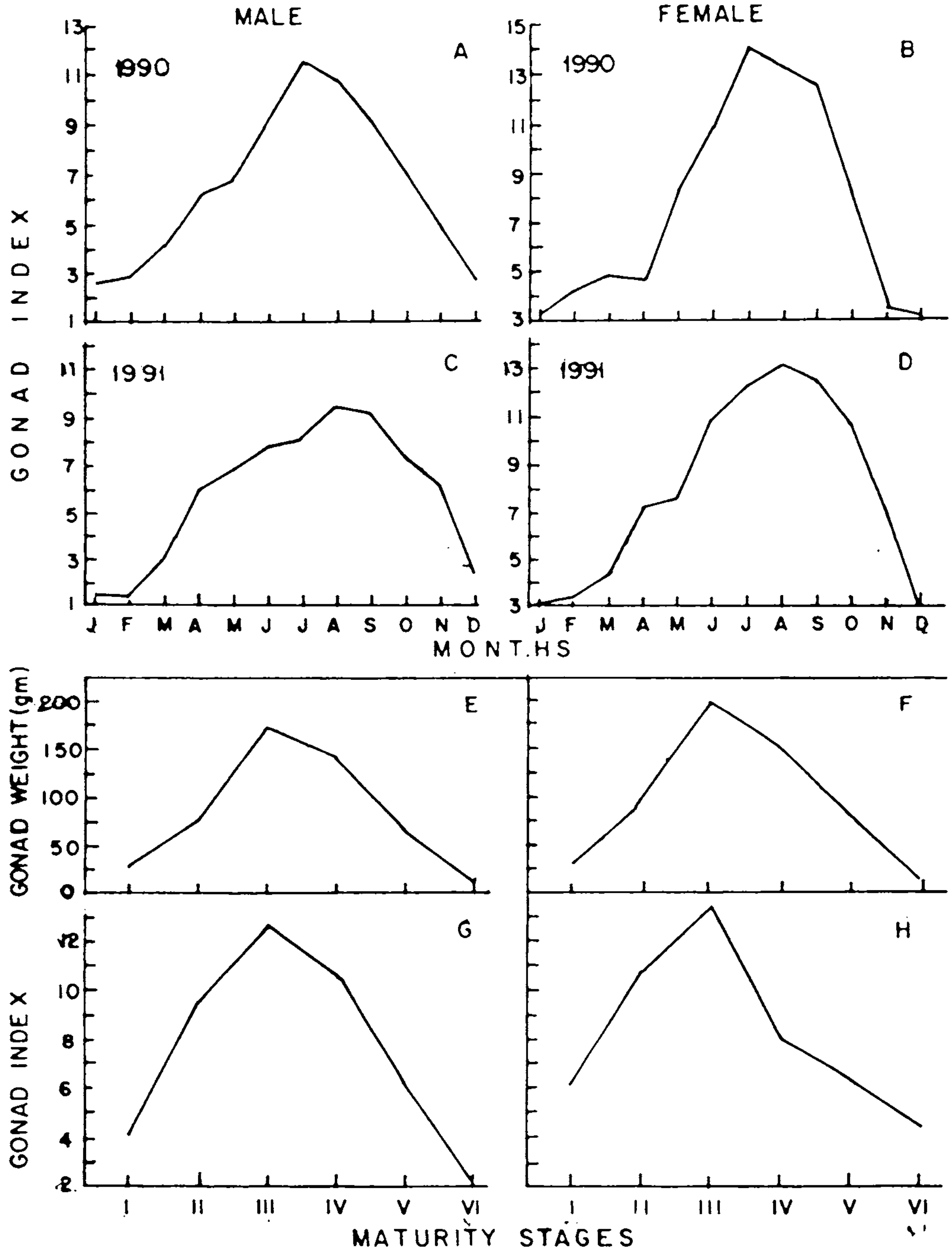


Fig.38. A-D. Mean gonad index for adult male and female H.nobilis at Minicoy Island during 1990-1991 and E-H mean gonad index and gonad weight relation to maturity stages.

Oocyte - Relative proportion frequency profile

The oocyte frequency profile (Fig. 39) undoubtedly gives the annual reproductive cycle. For both the years 1990 and 1991, during January to March all oocytes ranging from 20.0 µm to 180.0 µm were noticed. This could be a mixed oocytes of various sizes, as various maturity stages available during these period. From April to June distinct oocyte sizes measuring 100.0 µm to 180.0 µm were observed with peak of 150.0 µm oocytes in 1990 and 170.0 µm oocytes in 1991. These oocytes further developed to 120.0 to 210.0 µm during July to September in 1990 and August to October in 1991 with high peak of oocytes with 180.0 µm, when H. nobilis exactly began to spawn their oocytes in Minicoy Lagoon. During October to December in 1990 and November and December in 1991 the oocytes were measured between 120.0 µm and 200.00 µm with peak of 150.0 µm size. It is very clear from the observations that H. nobilis in Minicoy has only one reproductive cycle and they spawn oocytes measuring 180.0 µm size.

REPRODUCTIVE EFFORTS

Size at first maturity

Male : It is seen from the data on size and maturity stages that collected from January 1990 to December 1991, all male species in 22.0 - 23.9 cm size were in immature condition (Stage I). In 24.0 - 25.9 cm size group, 43.33% animals were in maturing (Stage II) and 50% of animals were in mature condition (Stage III). The rest of the animals of 6.66% in 24.0 - 25.9 cm size were in immature condition (Stage I). Mature animals were noticed from 24.0 - 25.9 cm size group to 38.0 - 39.9 cm size group with highest 69.23% in 26.0 - 27.9 cm size group. Stage IV (spawning) was first noticed in 30.0 - 31.9 cm size group with 42.56% and the percentage decreased from 41.67% in 32.0 - 33.9 cm size to 35.90% in 34.0 - 35.9 cm, 28.88%

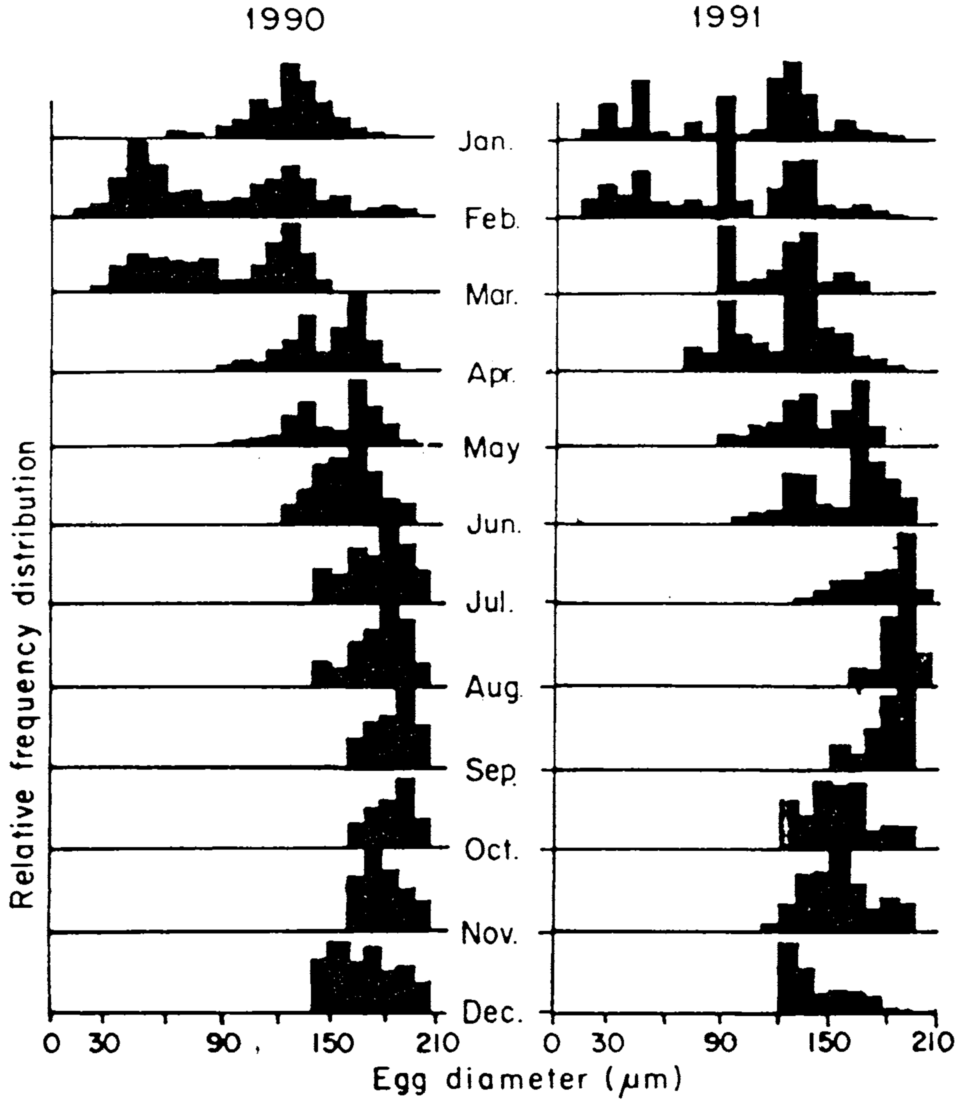


Fig.39. Relative frequency distribution of egg (oocyte) of *H.nobilis* in different months during 1990 - 1991.

in 36.0 - 37.9 cm and 22.86% in 38.0 - 39.9 cm size groups. The peak spawning was in 30.0 - 31.9 cm size group. Resting Stage VI (16.42%) was noticed in 36.0 - 37.0 cm and in 38.0 - 39.9 cm size group (20.0%). It is clear that **this species matures at 24.0 - 25.9 cm size only with 50% matured animal** (Table 76).

Female : From the pooled data made from the collection, it can be stated that 100% of the animals in size 22.0 - 23.9 cm and 10% in 24.0 - 25.9 cm were immature, 37.93% in size group 24.0 - 25.9, 33.3% in size group 26.0 - 27.9 and 28.0 - 29.9 were maturing. However, the matured animals were seen from 24.0 - 25.9 cm size group (51.73%) with an increase to 66.67% in size groups 26.0 - 27.9 and 28.0 - 29.9 cm. However, the reason for only 33.33% in size group 30.0 - 31.9 cm observed during the study in mature condition did not give any reason for reduction in percentage. The matured animal from size 32.0 - 38.9 cm with 38.39% decreased to 33.33% in 34.0 - 35.9 cm and 35.30% in size group 36.0 - 37.9 cm. A slight increase in the percentage (43.48%), in the largest size group 38.0 - 39.9 cm is significant. The actual spawning started in size 31.0 - 32.9 cm (36.33%) which reduced gradually to 13.04% in 38.0 - 39.9 cm size group. The spent Stage (V) was seen between the size groups 30.0 - 31.9 cm and 38.0 - 39.0 cm. The resting Stage (VI) with 10.70% at 36.0 - 37.9 size group and 29.4% in 38.0 - 39.0 cm size group was prominent. From the above observations and results it is clear that the animal mature at 24.0 - 25.9 cm with 51.73% and spawns at 30.0 - 31.9 cm size group with 66.67%. Simultaneously the reduction (13.33%) in maturing stage clearly indicates the peak spawning in size group 30.0 - 31.9 cm (Table 76).

Fecundity

The fecundity of 50 sea-cucumbers examined are presented in (Table 77) along with total length, total weight, drained weight, gutted weight and fecundity in whole ovary. This shows when length and other body characters are increasing, the fecundity also increases

TABLE 76. Details of size at first maturity in male and female of *H. nobilis* in relation to length

Male

Length	Total weight	Drained weight	Immature %	Maturing %	Mature %	Spawning %	Spent %	Resting stage
22.0-23.9	500- 600	300- 400	100.00	-	-	-	-	-
24.0-25.9	700- 800	500- 600	6.66	43.33	50.00	-	-	-
26.0-27.9	900-1000	700- 800	7.69	23.08	69.23	-	-	-
28.0-29.9	1100-1200	900-1000	-	33.33	66.67	-	-	-
30.0-31.9	1300-1400	1100-1200	-	-	28.57	42.86	28.57	-
32.0-33.9	1500-1600	1300-1400	-	-	25.00	41.67	33.33	-
34.0-35.9	1700-1800	1500-1600	-	-	38.46	35.20	25.64	-
36.0-37.9	1900-2000	1700-1800	-	-	29.85	23.88	29.85	16.42
38.0-39.9	2100-2200	1900-2000	-	-	42.86	22.86	14.28	20.00

Female

Length	Total weight	Drained weight	Immature %	Maturing %	Mature %	Spawning %	Spent %	Resting stage
22.0-23.9	500- 600	300- 400	100.00	-	-	-	-	-
24.0-25.9	700- 800	500- 600	10.34	37.93	51.73	-	-	-
26.0-27.9	900-1000	700- 800	-	33.33	66.67	-	-	-
28.0-29.9	1100-1200	900-1000	-	33.33	66.67	-	-	-
30.0-31.9	1300-1400	1100-1200	-	-	13.33	66.67	20.00	-
32.0-33.9	1500-1600	1300-1400	-	-	38.89	33.33	27.78	-
34.0-35.9	1700-1800	1500-1600	-	-	33.33	16.67	50.00	-
36.0-37.9	1900-2000	1700-1800	-	-	35.38	18.46	35.38	10.78
38.0-39.9	2100-2200	1900-2000	-	-	43.48	13.04	21.74	21.74

\- Nil

TABLE 77. Estimation of absolute fecundity in *H. nobilis* in relation to total length (cm), total weight (gm), drained weight (gm), gutted weight (gm) and gonad weight (gm)

Total length	No. of animals	Average Total weight	Drained weight	Gutted weight	Gonad weight	Fecundity ($10x10^4$)
28	5	895	760	550	116	279533
29	5	1005	850	650	119	315000
30	5	1180	1065	780	125	426080
31	5	1315	1165	900	150	631800
32	5	1385	1240	1015	160	713430
33	5	1435	1295	1040	180	826680
34	5	1560	1320	1110	190	1135600
35	5	1620	1450	1160	230	1330610
36	5	1790	1500	1160	240	1672000
37	5	1810	1690	1210	250	1800000
Mean value		1399.50	1236.50	960.50	175.80	9,13,073.30

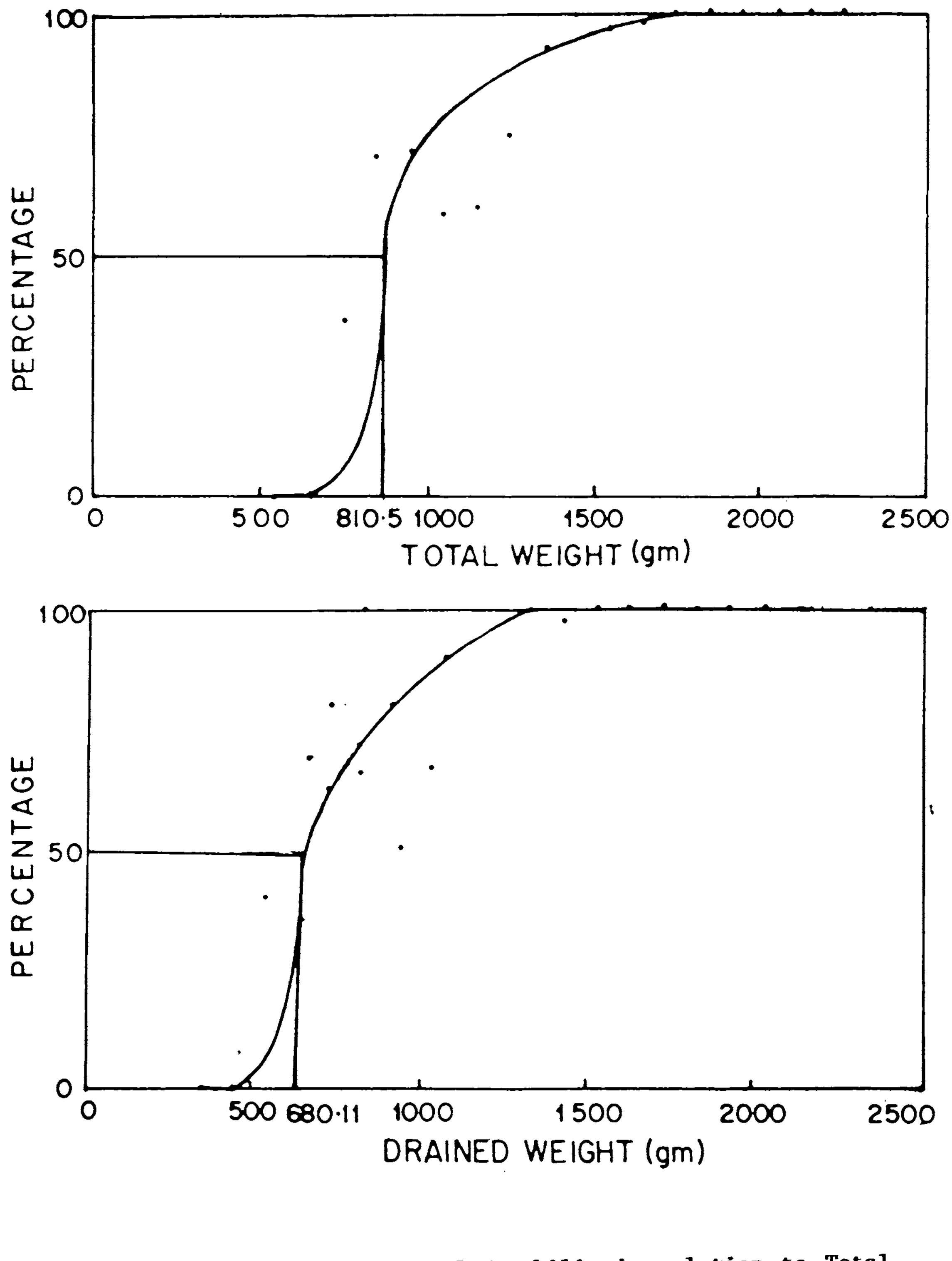


Fig.40. Size at first maturity of H.nobilis in relation to Total Weight and Drained Weight.

considerably. The highest fecundity (18,00,000) was observed in a sea-cucumber measuring 37.0 cm length, 1810 gram of total weight, 1690 gram of drained weight, 1210 gram of gutted weight and 250 gram of gonad weight. The lowest fecundity (2,79,533) was observed in a sea-cucumber measuring 28.0 cm length, 895 gram of total weight, 760 gram of drained weight, 550 gram of gutted weight and 116 gram of gonad weight. The average fecundity was estimated at 9,13,074 eggs measured animal 32.5 cm length, with 1399.5 gm total weight, 1236.5 gram drained weight, 960.5 gram gutted weight and 175.80 gram of ovary weight. The relationship between total length (1), total weight (2), drained weight (3) and gutted weight (4) shows curvelinear relationship with fecundity, while ovary weight (5) shows linear relationship with fecundity. The values are as follows :

1. $\log F = -4.52094 + 6.875099441 \log L;\ r = 0.99$
2. $\log F = -2.29719 + 2.618174277 \log W;\ r = 0.93$
3. $\log F = -1.54901 + 2.433514764 \log DW;\ r = 0.94$
4. $\log F = -0.72299 + 2.211733809 \log GW;\ r = 0.83$
5. $\log F = 1.49216 + 1.963437689 \log OW;\ r = 0.96$

where,

F = fecundity; L = total length; W = total weight; DW = Drained weight; GW = Gutted weight; OW = ovary weight.

The correlation coefficient (r) was significant ($P \leq 0.01$) for all these relationship confirming fairly good relationship between fecundity and all characters. Scatter diagram and fitted lines are shown in figure 41.

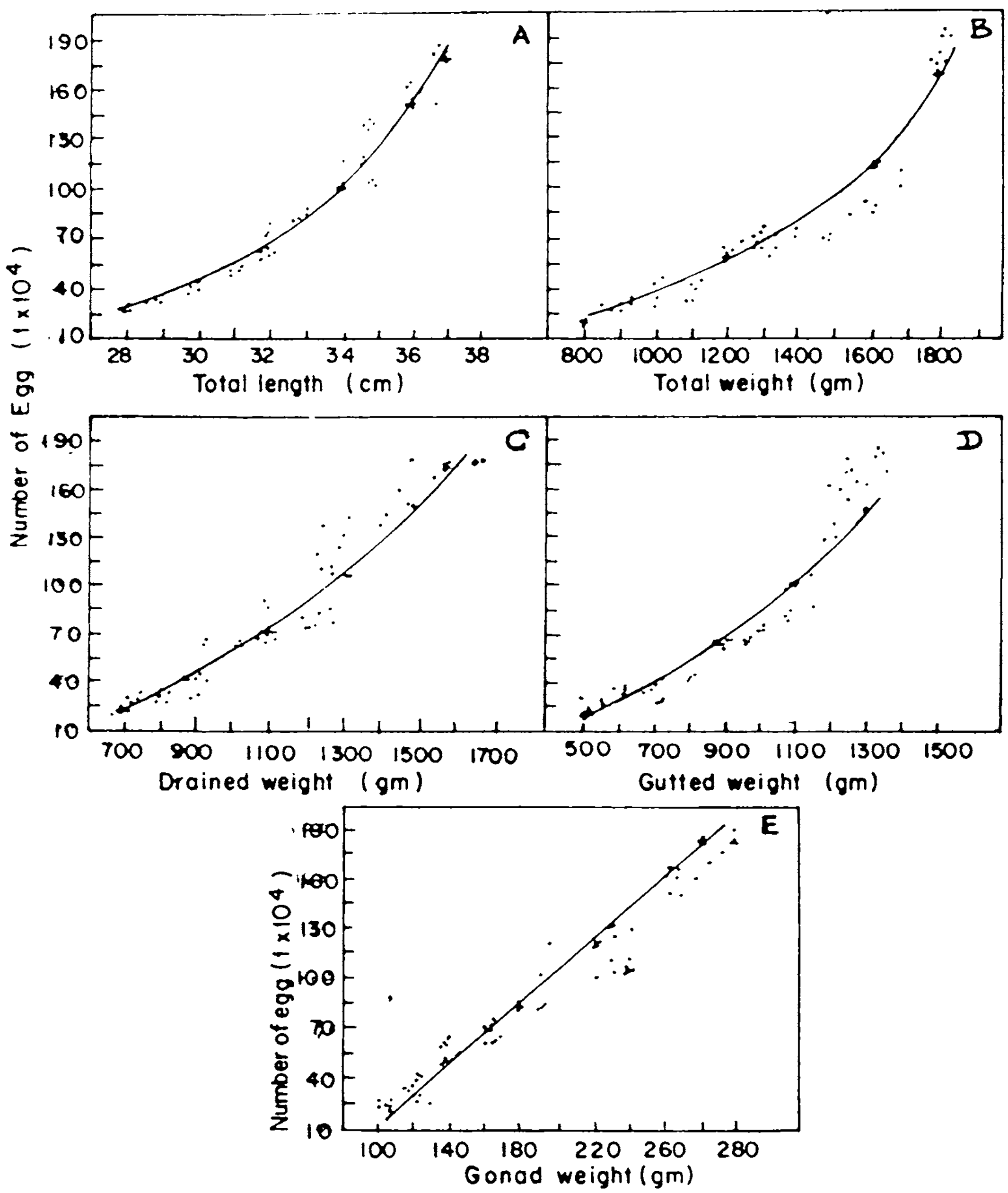


Fig.41. The relationship of the potential annual fecundity of H.nobilis from Minicoy Island to (a) total length, (b) total weight (c) drained weight (d) gutted weight and (e) Gonad weight.

EFFECT OF ENVIRONMENTAL FACTORS ON REPRODUCTION

Based on the reproductive stages, gonad index and percentage of different stages in population during different months in 1990 and 1991 for male and female *H. nobilis*, the annual cycle is divided into 6 reproductive phases as stated earlier. The ecological parameters are related to the 6 reproductive phases to observe any ecological effects on reproductive cycle of this species (Fig. 42).

Resting phase (Stage VI) : The observation on animals during December and January with maximum of 70% in January indicates that the month January is considered as resting phase. During January 1990 and 1991 the ecological parameters were: temperature was 31.28°C and 31.10°C, the salinity was 34.50 ppt and 35.0 ppt, dissolved oxygen was 5.56 ml/l and 6.03 ml/l and rainfall was 0.0 and 0.8 mm respectively. The mean gonad index value of this phase showed the range 1.0% to 2.0% for both sex.

Immature phase (Stage I) : The availability of animals during January to April in 1990 and extended to May in 1991 with 40.0 - 60.0% animals at immature stage in February and March indicates that this duration was dominant with immature phase. The ecological parameters in February and March were : temperature - 30.94°C and 29.95°C in 1990 and 31.36°C and 30.78°C in 1991, the salinity - 34.75 ppt, 34.84 ppt in 1990 and 35.66 ppt, 34.26 ppt in 1991, the dissolved oxygen - 5.44 ml/l and 5.19 ml/l in 1990 and 5.68 ml/l and 6.03 ml/l in 1991, the rainfall 2.2 mm in March 1991. The mean gonad index showed the range between 2.0% and 5.0% for both sex.

Maturity Phase (Stage II) : The observations during February to June with 50.0 to 60.0% in April and May indicates the period of maturing phase. The ecological parameters were : temperature - 31.48°C, 30.80°C in 1990 and 30.17°C, 30.63°C in 1991, salinity - 34.98 ppt, 34.67 ppt in 1990 and 35.64 ppt, 34.80 ppt in 1991, the

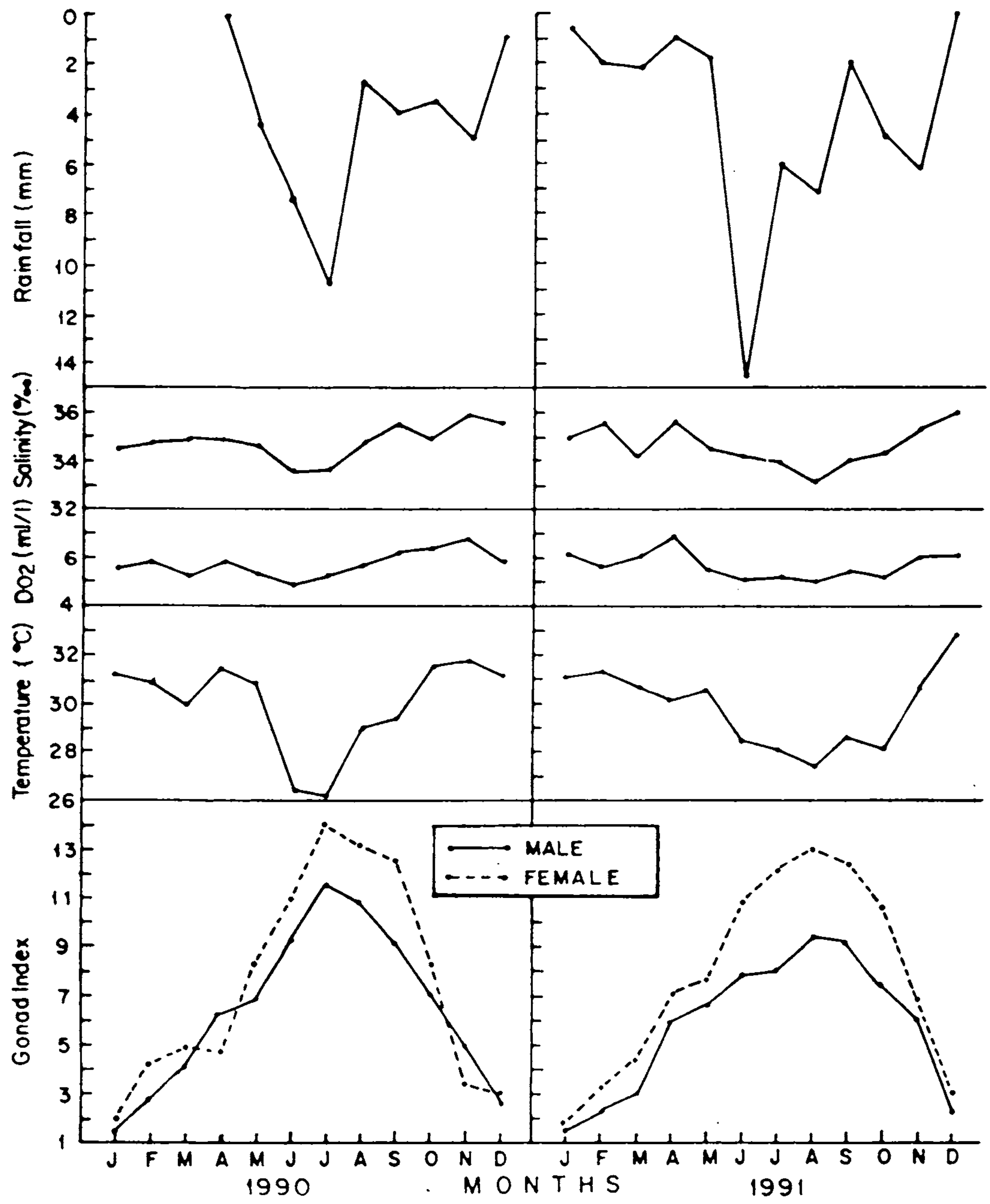


Fig.42. Effect of temperature, dissolved oxygen, salinity and rainfall on H.nobilis reproduction (gonad index).

dissolved oxygen - 5.88 ml/l, 5.26 ml/l in 1990 and 5.80 ml/l and 5.45 ml/l in 1991, the rainfall - 0.0, 4.6 mm in 1990 and 1.0, 1.8 mm in 1991. During April and May the mean gonad index showed the range betwen 6.0% and 11.0% for both sex.

Mature Phase (Stage III) : The animals during January to December with above 50.0% to 100.0% in June, July and August were observed. So this period is considered as mature phase. The ecological parameters were : temperature - 26.36, 26.12 and 28.96°C in 1990 and 28.49, 28.06 and 27.37°C in 1991, the salinity - 33.64, 35.69 and 34.76 ppt in 1990 and 34.13, 34.05 and 32.22 ppt in 1991, the dissolved oxygen - 4.93, 5.26 and 5.69 ml/l in 1990 and 5.02, 5.12 and 5.0 ml/l in 1991, the rainfall - 7.4, 10.8 and 2.8 mm in 1990 and 14.6, 6.2 and 7.2 mm in 1991. The mean gonad index showed the range between 8.0 and 14.0 % for both sex.

Spawning Phase (Stage IV) : The observations on animals during September to December with 40.0 to 50.0% in September and October indicates that these two months are contemplated as spawning phase. The ecological parameters were : temperature - 29.31°C, 31.89°C in 1990 and 28.81°C, 28.07°C in 1991, the salinity - 34.80 ppt, 34.97 ppt in 1990 and 34.05 ppt, 34.32 ppt in 1991, the dissolved oxygen - 6.15 ml/l, 6.32 ml/l in 1990 and 5.33 ml/l, 5.14 ml/l in 1991, the rainfall - 4.0 mm, 3.6 mm in 1990 and 2.1 mm, 5.0 mm in 1991. The gonad index showed the range between 7.0 to 9.5% in male and 8.0 to 12.5 in female.

Spent Phase (Stage V) : The observations on animals during November to January with 40.0 to 60.0% in November and December indicates that these two months are considered as spent phase. The ecological parameters were : the temperature - 31.70°C, 31.19°C in 1990 and 30.62°C, 32.80°C in 1991, the salinity - 35.99 ppt, 35.69 ppt in 1990 and 35.99 ppt, 35.96 ppt in 1991, the dissolved oxygen - 6.76 ml/l, 5.76 ml/l in 1990 and 6.00 ml/l, 5.76 ml/l in 1991, the rainfall

- 1.0 mm, 5.0 mm in 1990 6.2 mm, 0.0 mm in 1991. The mean gonad index showed the range between 2.0% to 6.5% for both sex.

Relationship between ecological parameters and gonad index

The relationship between ecological factors such as temperature, salinity, dissolved oxygen and rainfall and gonad index of male, female and both combined sex showed correlation co-efficient (r) as 81.5% for male, 81.6% for female and 83.5% for combined sex (Table 78).

DISCUSSION

Sex and reproductive stages

In *Holothuria nobilis*, sexes are separate and the gross morphology of the ovary and testis was very simple consisting of 20 to 30 tubules which arise from the base of a single thick fleshy attachment and distal free ends in the coelomic body cavity. There is no distinct papillae or any mark on the body wall to indicate the gonopore. All characters are almost similar as observed in many aspidochirotes as tabulated below :

Holothurians	Place	Authors
Stichopus japonicus	Indo-Pacific region	Hyman, 1955
Holothuria floridana	Southern Florida	Engstrom, 1980
Holothuria mexicana	Southern Florida	Engstrom, 1980
Holothuria nobilis	New Caledonia	Conand, 1981
Stichopus californicus	Friday Harbour Laboratory	Smiley and Cloney, 1985
Stichopus variegatus	New Caledonia	Conand, 1993

TABLE 78. Relationship between gonad index of *H. nobilis* in relation to ecological parameters

Relationship between gonad index and ecological parameters						df	r^2
Male							
GIM	=	24.9215	T	-	1.8973	23	81.5%
			D	+	2.0835		
			S	+	0.7481		
			R		0.01845		
Female							
GIF	=	32.3781	T	-	2.4043	23	81.6%
			D	+	1.2423		
			S	-	1.1421		
			R		2.8867		
Both Sex							
GIC	=	28.2797	T	-	2.1232	47	83.5%
			D	+	2.3489		
			S	+	8.2338		
			R		5.0350		

GIM = Gonad index male, GIF = gonad index female, GIC = gonad index of both sex, T = temperature, D = dissolved oxygen, S = salinity and R = rainfall, df = degree of freedom, and r^2 = correlation coefficient.

In order to classify the reproductive stages in sea-cucumbers, different criteria such as colour, length, weight and position of gonad, squash mounts and histological observations of gonads were used by various authors in different tropical holothurians as follows :

Holothurians	Criteria	Stage	Authors
Stichopus japonicus	ripeness of gamete	11	Kinosita, 1938
Leptosynapta teneuis	histology	5	Green, 1978
Stichopus japonicus	histology	5	Tanaka, 1958
Holothuria scabra	histology	4	Krishnaswamy & Krishnan, 1967
Holothuria mexicana	histology	5	Engstrom, 1980
Holothuria floridana	histology	5	Engstrom, 1980
Theleonata ananas Holothuria nobilis	macroscopic and microscopic	5	Conand, 1981, 1982 1990
Holothuria fuscogilva	"	"	"
Actinopyga echinities	"	"	"
Parastichopus californicus	histology	4	Cameron & Fankboner, 1986
Stichopus variegatus	microscopic and macroscopic	5	Conand, 1993

From the above references it is clear that different authors have identified and used varying number of stages in different species. However, the candidate has, based on his first hand information, experience and knowledge and also based on visual observations on gonad namely colour, size and microscope observation on developing gametes particularly the eggs and their diameter, identified and adapted only 6 stages in this Thesis as clearly mentioned in a previous section in reproductive biology. The candidate's observations on gonad stages are almost coincided with that observations and statements of Giese (1959) and Boolootian (1966) who said "the most of the echinoderms has six distinct phases such as activation, gametogenesis, growth, spawning, recession and resting gonad". But Conand (1990) reported that generally 5 stages are available in holothurians at Pacific Island countries in which H. nobilis also one of the species. She has distinctly excluded spawning stage. It is well clear that when H. nobilis matures, subsequently starts spawning, but it is not completely oozing out all spermatozoa or oocyte at one time. It is observed that in most of the time, half of the tubules were shrunked and half of the tubules were packed with sperm or ova. So in this study it is treated as a separate stage. However, Boolootian (1966) reported that spawning is another term much confused in the literature as well as researchers and spawning means the shedding of gametes where it occur once or more than once in a cycle, which support the candidate's view in the present study.

The length, weight and position of the gonad tubules and ova diameter observed in the present study on H. nobilis from Minicoy Island is slightly different from what reported by Conand (1981) for H. nobilis from New Caledonia. The possible reason may be related to the number of animals observed for characters by the candidate.

The sex-ratio of H. nobilis over to the successive years (January 1990-December 1991) in the present work showed a slight preponderence of the male in most of the months, eventhough the sex ratio was statistically not different from 1:1. Similar results were observed and reported by various authors in many holothurians also.

Holothurians	Authors
Stichopus tremulus	Jesperson and Lutzen, 1971
Holothuria mexicana	Mosher, 1982
Cucumaria Lubrica	Engstrom, 1982
Parastichopus californicus	Cameron and Fankboner, 1986
Holothuria scabra	Conand, 1990

However, Cameron and Fankboner (1986) reported based on their observation in P. californicus that "this 1:1 sex ratio within a randomly diffusing population should disperse the sexes in such a manner that a relatively even mixure of sexes would occur. This behaviour should enhance the probability for successful mixing of the spawned gametes, especially in a species when there is no aggregation of animals during spawning". Further, few H. nobilis in the present study was not representing any sex or stage. This may be due to degeneration of gonad tubules after spawning or this is an indication of resting stage.

Reproductive cycle

In the present study, to confirm reproductive cycle and spawning period, maturing chart, gonad index and ova size frequency profile related to months were studied very carefully.

According to maturing chart, 100% matured animals were found in the population during June to August for both sexes indicating H. nobilis having only one reproductive cycle in an year and spawning takes place from September onwards. Boolootian (1966) reported that the restricted and single reproductive cycle is characteristic to the most tropical and sub-tropical echinoderms including holothurian.

Further, the maturing chart showed January to April - immature animals, January to June - maturing animals, January to December - matured animals, September to December - Spawning, November to January - spent animals and December to February - resting animals were noticed in both the sexes with fair degree of similarity in this species H. nobilis. This well coincides with Conand's (1990) observation on H. nobilis in New Caledonia, but she has not included first two stages (immature and maturing) in her maturity chart.

In addition, it is interesting to note that the mature animals were recorded from January to December with varying percentages, while other stages were available only in a particular month during 1990 and 1991 in Minicoy Island. The presence of few matured animals after the peak periods may possible due to the influence of the environmental factors. Barnes (1975) stated that "in marine invertebrates the onset of spawning is depended upon some exogenous environmental events for stimulation, one might expect that the animals to be mature over an extented period of time. This would ensure that the reproductive effort of the particular population has the greatest probability of success".

But the availability of matured H. nobilis during January to June in both the years really amusing and it gives a clue that the early spawned animals or spawned animals of the previous year would have produced again gametes after going through resting stage for next reproductive season. Hence during these period eventhough gonad contains mature gametes it contributes little weight to the animal as observed by the candidate. Similar observation were reported by Sewell (1990), in Stichopus mollis an aspidochirotes holothurian, the regrowth of the gonad begins before the actual annual cyclic period and it was evident at first as small thread-like tubules extending from the gonad base. These grew by branching and lengthening of the tubules until early in the summer for the next reproductive season. Further, from the maturity chart of the present study, it was noticed that peak season was extended to September in 1991 in both male and female, while it was upto August in 1990. This may be of some ecological influence as reported by Tanaka (1958) that the extending of gonadal activity in Stichopus japonicus is in relation to local environmental conditions.

Cameron and Fankboner (1986) reported that gonad volume is dependent on body size and therefore the gonad index is an accurate measure of the seasonal reproductive effort. This is well suited for H. nobilis of the present study. The data related to the stages and gonad weight showed that gonad weight increases 9 to 10 fold from immature to mature animals and decreases to 5 to 3 fold after spawning. For example, 25.77 gm of mean testis weight at immature animal increases to 177.22 gm in matured animal and decreases to 143.33 gm during spawning and 65.50 gm in spent animals. Boolootian (1966) reported that during sexual maturation the gonad tubules in holothurians may undergo 12 to 35 fold increase in volume. Tanaka (1958) observed 12 to 15 fold volume increase in the gonads during the annual reproductive cycle of S. japonicus. Rutherford (1973) noticed 9 fold increase in the weight of the gonads of Cucumaria pseudocurata and hence it could be said that many individuals virtually double or triple their weight in a period of 6 to 8 months before spawning putting so much effort for reproduction and probably reducing considerable energy to somatic growth.

Further, the gonad index analyses of H. nobilis in the present study showed highest index unit for both sex in July (11.43% - male, 14.0% - females) 1990 and in August (9.40% - male, 13.0% - female) 1991. This clearly indicates and confirms the finding that H. nobilis at Minicoy Island has **only one reproductive cycle in an year.** This type of single reproductive cycle has been reported by various authors as given below, based on gonad index studies in most of the aspidochirotes holothurians from different regions of the world such as Temperature, Tropical and Atlantic region.

From Temperate region	Authors
Stichopus japonicus	Mitsukuri, 1903
Stichopus japonicus	Tanaka, 1958
Stichopus japonicus	Choe, 1963
Parastichopus parvimensis	Muscat, 1983
Parastichopus californicus	Cameron and Fankboner, 1986
From Tropical region	
Holothuria impatiens	Harriott, 1985
Holothuria nobilis	Conand, 1981
Stichopus variegatus	Conand, 1993
From Atlantic region	
Holothuria mexicana	Engstrom, 1980
Holothuria floridana	Engstrom, 1980

However, it is important to mention here that, though the above mentioned species have single annual reproductive cycle the month of maturation varies from species to species. This is most probably due to the environmental condition prevailing from these regions (Boolootian, 1966).

Eventhough male and female H. nobilis showed maturity of gonads almost in the same period or month, there was slight difference in the gonad index (male 11.3%; female 14.0%) in 1990 (male 9.2%; female 13.0%) in 1991. This may perhaps be due to female animals having larger gonads than male with more tubules and slightly or prolonged maturity time. Cameron and Fankboner (1986) reported that female P. californicus have a significantly larger gonad index at maturing than males indicating a greater reproductive effort for the female than the male.

Grant and Tyler (1983) reported that the gonad index has long been used to assess the reproductive cycles in holothurians, but at the same time, it can be traced in much greater detail by the size of oocytes over a period of time. In the present study the diameter frequency polygone for H. nobilis clearly indicates the availability of all sizes (20 to 180 µm) of oocytes from January to March, with a peak in 130 um size. This may probably be due to population consisting different maturity stages. These oocytes (20 to 200 µm) grow from March onwards and it reaches a maximum size (between 180 µm and 210 µm) during June to August in 1990 and extended to September in 1991. Based on this observation, it is inferred that H. nobilis spawns with oocytes measuring between 180 um and 190 µm and has only one reproductive cycle in a year. Conand (1990) reported "in general the oocyte diameter in mature holothurians are polymodal distribution with principal mode approximately 150-200 microns, while in growing condition the oocytes measured 20 to 120 microns approximately".

Reproductive efforts

Conand (1981) stated that the size at first sexual maturity or size at which an individual may reproduce for the first time is an important parameters for stock management. In the present study, the analysis of reproductive stages at various size groups showed that the male and female H. nobilis measuring 24.0-25.9 cm was attained 50% matured condition in the population. The graphical representation (Fig. 40) also strengthened this finding that 50% of animals matured at 810.5 gm of total weight which represents the size group 24.0-25.9 cm. These results are almost strengthened by the observation of Conand (1990) that H. nobilis was in New

Caledonia in 50% matured condition at 26.0 cm total length, 800.0 gm of total weight and 580.0 gm of drained weight. Many workers have also calculated size at first maturity for various species as follows :

Size of different species at first maturity

Holothurians	Total length	Total weight	Drained weight	Authors
Stichopus japonicus		39 gm and 58-60 gm		Choe, 1963
Cucumaria pseudocurata		3 gm		Rutherford, 1973
Holothuria atra		100 gm		Harriot, 1980
Holothuria scabra	16 cm	184 gm	140 gm	Conand, 1990
Holothuria versicolor	22 cm	490 gm	320 gm	Conand, 1990
Holothuria fuscogilva	32 cm	1175 gm	900 gm	Conand, 1990
Actinopyga echinites	12 cm	90 gm	75 gm	Conand, 1990
Thelenota ananas	30 cm	1230 gm	1150 gm	Conand, 1990
Holothuria nobilis	26 cm	800 gm	380 gm	Conand, 1990
Holothuria mexicana-				
male	9.0 cm	57.9gm		Engstrom, 1980
female	10.5 cm	75.7 gm		Engstrom, 1980
Holothuria floridana				
male	8.8 cm	28.5 gm		Engstrom, 1980
female	8.7 cm	22.0 gm		Engstrom, 1980
Holothuria hybrids				
male	9.9 cm	52.4 gm		Engstrom, 1980
female	0.4 cm	80.1 gm		Engstrom, 1980
Holothuria nobilis				
male	24.0-25.9 cm	700-800 gm		By the candidate
female	24.0-25.9 cm	700-800 gm		

However, Conand (1989) noticed that the size at first maturity calculated for various species by different authors by various methods like including or excluding the immature and resting animals for this purpose is not giving any concrete conclusion especially in sea-cucumbers.

Fecundity is one parameter very helpful to understand the potential, influence and recruitment (Conand, 1990). In the present study the fecundity of *H. nobilis* shows remarkable variation with their total length and weight. The average fecundity was estimated 9,13,074 eggs per gonad weighing 175.8 gm, animal measured 32.5 cm, 1399.5 gm total weight, 1236.5 gm drained weight, 960.5 gm gutted weight. Conand (1990) estimated the fecundity range as 13 to 78 million oocytes in *H. nobilis* at New Caledonia. The variation may be related to sampling measures that not covered or calculated the fecundity each of the various group. Hence the fecundity shows remarkable variation with body characters and ovary weight as the fecundity varied from 2,79,553 to 18,00,000 in individual measured in total length 28.0 cm to 37.0 cm. Fecundity for other species estimated by various authors are :

Holothurians	fecundity	Author
Holothuria nobilis	13 to 18 $\times 10^{6}$	Conand, 1990
Holothuria scabra	9 to 12 $\times 10^{6}$	Conand, 1990
Holothuria fuscogilva	8 to 14 $\times 10^{6}$	Conand, 1990
Actinopyga echinites	4 to 25 $\times 10^{6}$	Conand, 1990
Stichopus variegatus	7 to 12 $\times 10^{3}$	Conand, 1993
Cucumaria pseudocurata (by brooding)	1 to 340	Rutherford, 1973
Holothuria atra	6000	Harriot, 1985
Holothuria edulis	2800	Harriot, 1985
Holothuria impatiens	300	Harriot, 1985
Holothuria nobilis	90 $\times 10^{4}$	By the candidate

The relationship established between fecundity and body characters showed curvilinear relationship, while fecundity and gonad weight showed linear relationship. High correlation coefficient was noticed in all relationship for H. nobilis in the present study. But Shelley (1981) and Harriot (1980) reported that there is no significant correlation between animal weight and gonad weight in H. scabra. But there is very good correlation noticed in H. atra and H. edulis by Harriot (1980). However, Conand (1990) stated that the relationship established between a size parameter (length and weight) and the weight of matured gonad is variable depending on the species and method used. Further Conand suggested that for this type of study sampling has to cover each of the various size groups.

Effect of environmental factors on reproduction

The factors that specifically regulate reproductive seasonality and stimulate spawning in invertebrates are generally unknown very much (Giese and Pierse, 1974; Barnes, 1975; Todd and Doyle, 1981). But temperature, salinity, abundance of food and photoperiod have all been cited as factors regulating reproductive cycle in invertebrates (Orton, 1920; Boolootian, 1966). Boolootian (1966) stated that specific breeding seasons are either established or have been indicated for many sea-cucumbers and also suggested that environmental parameters are the entertainment mechanisms facilitating these patterns. However, many reports show that in holothurian, various of environmental factors including temperature (Tanaka, 1958), light (Conand, 1982; Cameron and Fankboner, 1986), salinity (Krishnaswamy and Krishnan, 1967), water current and crowded condition (Engstrom, 1980) have been reported to influence the reproductive cycle.

In the present study, the gonad index of H. nobilis in relation to ecological parameters showed that during January to May and October to December gonad index was low due to presence of resting, immature, maturing and spent animals. The temperature was ranging from 28.0°C to 33.0°C the salinity between 34 and 36 ppt, the dissolved oxygen between 5 and 7 ml/l, rainfall range 0-5.0 mm. During June to September, the gonad index was high due to availability of mature and some spawning animals. The temperature ranged between 27.0°C and 29.0°C, salinity between 33.0 and 34.0 ppt, dissolved oxygen between 4.0 and 6.8 ml/l and rainfall between 2.0 and 15.0 mm during 1990 and 1991. These results give clear evidence that, **the lower temperature and lower salinity are the main factors for maturation and spawning in** H. nobilis during June to September when rainfall was more by southwest monsoon in Minicoy. Ambient environmental conditions especially in temperature and salinity were prevailing during other seasons when gametogenesis and resting stages were observed.

To support the present observation that the low temperature is responsible for breeding season, Conand (1990) reported that the breeding season for H. nobilis in New Caledonia noticed when water temperature was very low and cool during July to August. Costelloe (1988) observed and reported that the low temperature combined with relatively high oxygen in water resulted in increased gametogenesis in Aslia lefevrei. Krishnaswamy and Krishnan (1967) reported the lower salinity is the cause for breeding season in H. scabra in the Gulf of Mannar region. Hence influence of water from Indian Ocean during the southwest monsoon and from the Bay of Bengal during northeast monsoon changing the salinity in this region, induce breeding in H. scabra. Boolootian (1966) reported that the temperature coupled with rainfall is also play a vital role in gonadal development, gametogenesis and spawning in holothurians. However, he has no evidence to support his views in this aspect. In the present study on H. nobilis the environmental factors such as temperature, salinity, dissolved oxygen and rainfall showed a positive relationship with gonad index of male, female and pooled together.

Further, the results showed that the maximum gonad index was noticed during June to August in 1990 and it was seen continued to September in 1991. The continuation of maturation of H. nobilis in September 1991 is mainly attributed to the cool environment due to the continuation of rainfall from September to November in 1991 compared to that of 1990. Sewell (1990) reported that due to lower water temperature, the reproductive season of Stichopus mollis extended in 1987 when the study was conducted during 1985 to 1987 in northeast coast of New Zealand.

However, all these present observations are contradicting or deviating from the statements of Colwin (1948), Nyholm (1951) and Tanaka (1958) that warm water is one of the most important factor stimulates spawning in most of the holothurians. For example, Colwin (1948) kept one set of Thyone briareus at room temperature 20.0°C-22.0°C and an another set of the same species at temperature 16.5°C-18.0°C and found that the shedding was occurred among the animals in warm water. But no change in animals kept in cool water.

Recently in India, James et al. (1988) conducted experiments on H. scabra to spawn at the laboratory by thermal stimulation by raising the temperature from 30.0°C to 34.0°C. He succeeded in the experiment and found that the male H. scabra spawned first which stimulated the female to release the eggs. He has also maintained the developed eggs to metamorphoses and they reached the juveniles through different respective larval stages.

From the spawning studies on H. nobilis by Conand (1990) the present observations by the candidate from Minicoy Island have well established that H. nobilis prefers cool water for its spawning. However the statements by Chia and Sickell (1983) that the lower sea-water temperature have certain effect on gametogenesis and spawning in certain echinoderms and other marine invertebrates needs further assessment in a broder context by the combination of controlled laboratory experiments and field observations and similar observations on Thyone briareus by Colwin (1948) and in other holothurians by Nyholm (1951) and Tanaka (1958 b) can not be totally neglected.

SECTION B : ACTINOPYGA MAURITIANA

Reproduction

A. mauritiana was collected from Reef Flat of Minicoy Island in an average 40 every month. All animals were carefully dissected to findout the sex and gonad stages. Surprising, no sex organ or sexual dimorphism either morphologically or anatomically was found in A. mauritiana. The absence of any gonad indicated that these animals multiply by asexual method by transverse fission. This transverse fission was confirmed from the collections made by the candidate during his regular observations. A specimen with only posterior portion of the adult living condition (Fig. 43 A) and an another specimen with a budding of young one from the posterior portion of the adult of A. mauritiana (Fig. 43 B) from the Minicoy Reef Flat. These two specimens were dissected carefully and examined for their anatomy (Fig. 43, A & B). The former animal showed only half of the gut with food content, respiratory tree and Cuvierian tubules. There was no other organs like polian vesicles, water canal system, tentacle base, etc. In the latter specimen, it was interesting to note that no internal organs were found in the bud and all organs were present in the main animal only.

Besides these two, few more animals with 2 or 3 anal teeth instead of normal 5 with this body wall were also collected. Most probably these animals with lesser number of anal teeth, would have been the young and developing juveniles after budding.

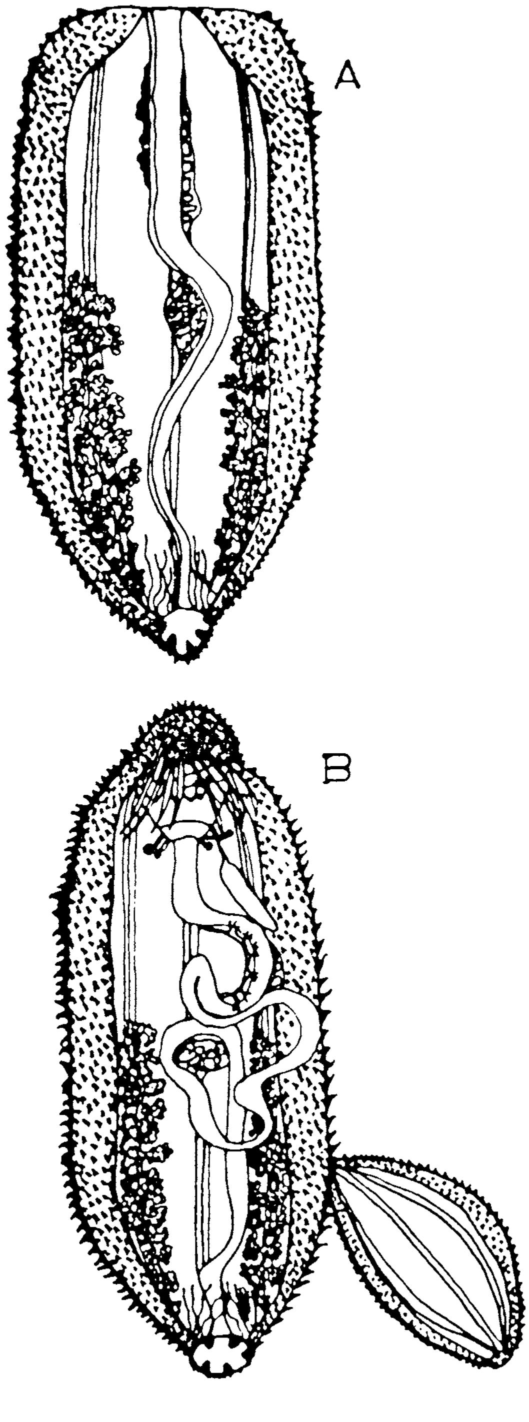


Fig.43. Asexual reproduction in A.mauritiana: A. Specimen with posterior part. B. Specimen with a budding young one from its posterior part of the body.

Influence of environment on asexual reproduction in A. mauritiana

The environmental parameters such as water and atmospheric temperature, dissolved oxygen, salinity and rainfall recorded during January 1990 to December 1991 from Minicoy Reef Flat were related to the monthwise mean progression of length and total weight of A. mauritiana (Fig. 44) to find out the impact of ecological parameters on the growth and asexual reproduction.

It is seen that the values of different parameters were low during June to October in 1990. The water temperature varied between 28.2°C (June) and 30.8°C (October), atmospheric temperature was 30.4°C (August) to 32.8°C (October), dissolved oxygen was 5.6 ml/l (May) to 6.2 ml (July), salinity was 32.8 ppt (June) to 35.8 ppt (October) and rainfall was 2.8 mm (August) to 10.4 mm (July). The mean length of animal showed progression from 18.0 cm (June) to 21.5 cm (October) and it is found that the parameters were low during these months. But when these parameters were high during January to May, November and December in 1990 as water temperature varied from 30.8°C (April) and 32.8°C (March), atmospheric temperature was 31.0°C (January) to 33.0°C (May), dissolved oxygen was 5.6 ml/l (May) to 6.8 ml/l (January, November and December), salinity was 34.0 ppt (May) to 36.6 ppt (December) and the rain fall was 0.0 mm (January to April) to 4.8 mm (May), the mean length of animal was not shown any clear progression in growth.

During January to August in 1991, when environmental parameters were low: water temperature varied between 26.2°C (July) and 31.2°C (January), atmospheric temperature was 30.2°C (July) to 32.0°C (April), dissolved oxygen was 6.0 ml/l (July) to 7.0 ml/l (May), salinity was 32.6 ppt (May to July) to 36.2 ppt (February) and rainfall was 0.4 mm (January) to 14.4 mm (July), the mean length was progressing from 14.0 cm to 22.0 cm. But during September to December 1991, when these parameters were high as

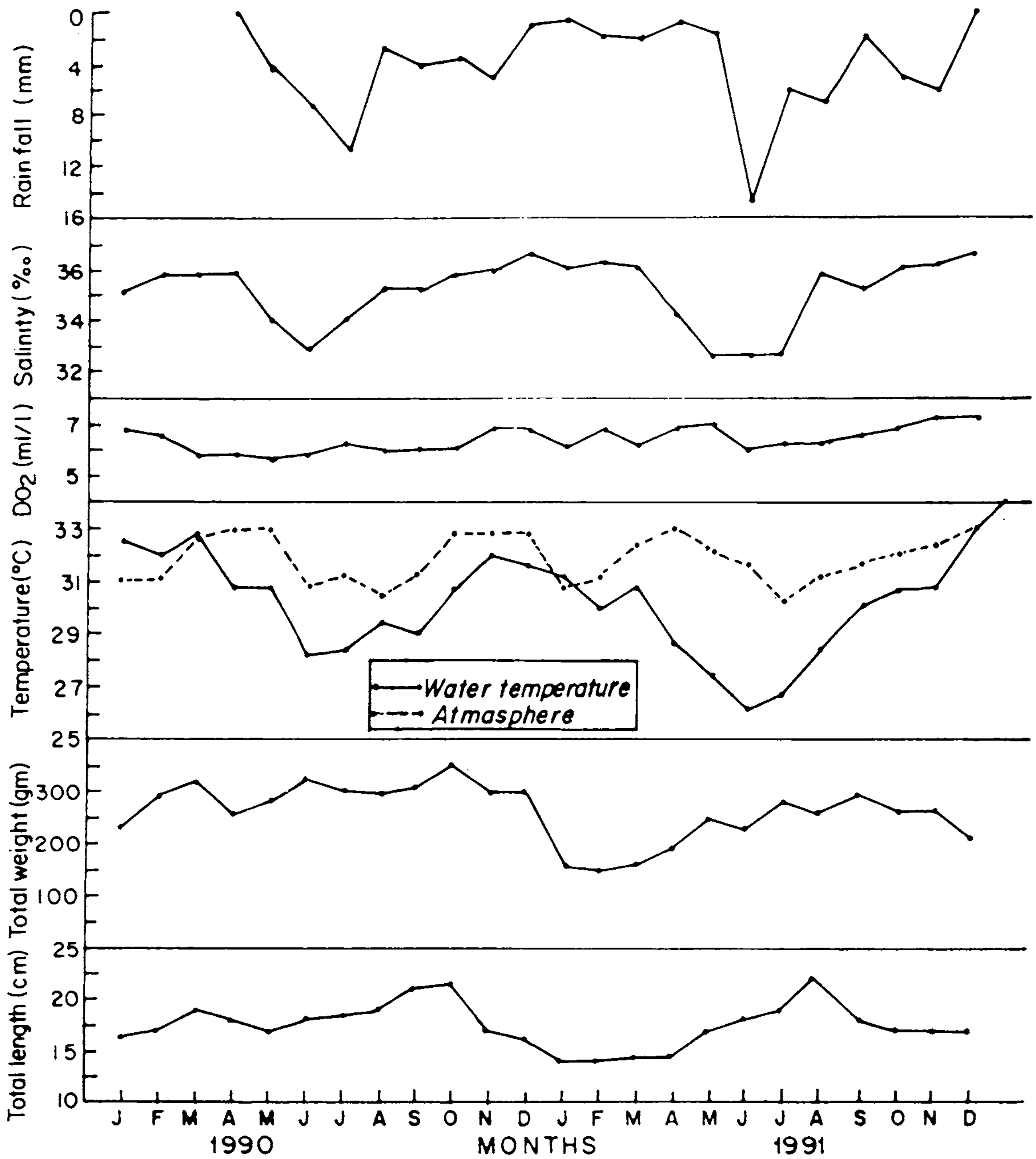


Fig.44. Effect of environmental parameters temperature, dissolved oxygen, Salinity and rainfall on a sexual reproduction in *A.mauritiana*.

water temperature varied between 30.0°C (September) and 33.0°C (December), atmospheric temperature was 31.2°C (September) to 33.0°C (December), dissolved oxygen was 6.2 ml/l (August) and 7.2 ml/l (December), salinity was 35.2 ppt (September) to 36.4 ppt (December) and rainfall was 0.4 mm (December) to 6.8 mm (August), but the mean length of the animal was not shown any clear progression in growth.

The effect of environmental parameters on the growth and reproduction of A. mauritiana is very clear. This animal prefers low values, particularly temperature and salinity for their growth and higher values for asexual reproduction. However, the dissolved oxygen was found not to have any influence.

DISCUSSION

It is well known that echinoderms particularly the holothurians have remarkable capability of regeneration of lost parts and for asexual reproduction. Though many authors have stated that certain holothurians reproduces asexually, but at the same time they have not answered to some of the serious questions and the baffling aspects of asexual reproduction. "What causes fission? What restricts the fission plane to a point approximately midway between the oral and anal end ? How is the fission achieved?" (Emson and Miadenov, 1987). These are some of the questions remain unanswered. Further investigations to answer these questions are to be taken up seriously by the echinodermologists. Emson and Wilkie (1980) stated "the fission is a asexual process in which an animal divides into two parts and each part is then capable of regenerating the whole animal". Particularly in holothurian, body divide with anterior and posterior part by transverse fission and it is a normal part of the life cycle in Holothuria spp. This statement well coincides with present observation on A. mauritiana which reproduces asexually. Many authors from different parts of the world have also reported that this asexual reproduction is a common event in many holothurians:

Species	Percentage of fission	Geographical distribution	Habitat	References
Ocnus planci	-	Channel, Atlantic	Shallow water on muddy bottom	Dalyell, 1851
Ocnus lactea	-	Channel, Atlantic	Stony or shelly bottom	Dalyell, 1851
Holothuria surinamensis	11%	Bermuda	Rocky shores	Crozier, 1917
H. parvula	65%	Bermuda, West Indies	Low water rock under coral reef slabs	Deichmann, 1921
H. difficilis	50%	Hawaii	Rock pools	Deichmann, 1921
Cucumaria lactea	-	Tropics	Rock pools	Frizzell and Exline, 1955
H. difficilis	-	Tropics	Rock pools	Frizzell and Exline, 1955
H. atra	-	Pacific	Shallow pools	Bonham and Held, 1963
H. atra	-	Eniwetak Atoll	Shallow water	Bakus, 1973
H. parvula	-	Great Barrier Reef	Shallow water	Kille, 1942
H. atra	6 to 70%	Great Barrier Reef	Shallow water	Harriot, 1982
H. parvula	43 to 83%	Bermuda	Underside of the boulder	Emson and Mladenov, 1987
A. mauritiana	100%	Minicoy Island	Reef flat	Present observation by the Candidate.

Most of the above authors have ruled out the sexual reproduction too in these species. In the present investigation of A. mauritiana at Minicoy Island has clearly shown that **there is no sexual animals which strongly leads to the assumption that these animals reproduces only by asexual means. It is interesting to understand that such an unique feature was not noted anywhere.** As the fact remains as above in the case of Minicoy Island, contradictory to this, James et al. (1993) collected three males and one females from the Oceanic water of Andaman & Nicobar Islands, maintained in the aquarium of the FORV Sagar Sampada. Surprisingly the higher temperature at the aquarium stimulated the male to spawn and released the sperms. This triggered the female to release their eggs. They were able to observe the fertilized and developed eggs up to 4 cell stage. It may be mentioned here that A. mauritiana is purely a coral reef dweller and it reproduces asexually to maintain its population in the Minicoy Reef Flat area, as observed by the candidate. It is evident from the absence of sexual animals from the study area. The observations of James et al. (1993) and by the candidate are entirely different. Hence, it needs a thorough study in this aspect. However, Harriot (1982) reported from the Great Barrier Reef that H. atra was showing 70% fission. Emson and Mladenov (1987) reported that a maximum of 83% in H. parvula at Bermuda Island undergoes fission. Emson and Wilkie (1980) have never seen gonads in the starfish Stephanasterias albula from Off Lubec Maine, U.S.A. and confirmed that this species reproduces only by asexual fission, as observed in A. mauritiana from Minicoy Island in the present study by the candidate.

The collection of A. mauritiana with a budding young one from its posterior part of the body (Fig. 43 B) and a number of specimen with posterior part (Fig. 43 A) with varying number of anal teeth clearly shows that this species separates the posterior part by transverse fission and multiplies. Bakus (1973) has also collected a specimen of H. atra from Enewetak Atoll with a bud. Clark (1896) and Ohshima (1915) noticed in certain holothurians with (i) double posterior end, (ii) individuals with five sets of tentacles and (iii) four digestive tracts. Bonham and Held (1963) noticed in a warm pool of Southwest shore of Burok Island two short specimens of H. atra encountered lying end to end.

The candidate has also conducted experiments to stimulate asexual fission in A. mauritiana. The animals were tied with nylon thread at the middle of the body in some animals and at three places in some animals. Interestingly, the animals with three tyings successfully reduced their body thickness and shed the nylon thread/loops at both ends of the body without damage to the animal. The animals with only central tying showed peculiar behaviour and tried to loosen the tie and shed the thread. They either enlarge the anterior portion or posterior portion as shown in Fig. 45. But they never split their body into two animals. The candidate could not get any bifurcated young A. mauritiana form this experiment.

To conclude, it can be said that the reproduction in A. mauritiana especially to asexual multiplication is still a mystery and further investigation with determination and continuous efforts are to be done.

Further the present study showed that, the environmental parameters particularly temperature and salinity have influence on asexual reproduction of A. mauritiana. When these parameters were low in the Reef Flat at Minicoy A. mauritiana grew considerably and these parameters were high, the animal undergo fission.

Emson and Mladenov (1987) analysed mean value progression of length and weight of H. pervula over a period of time at Bermuda and reported that the individual which split in summer with high

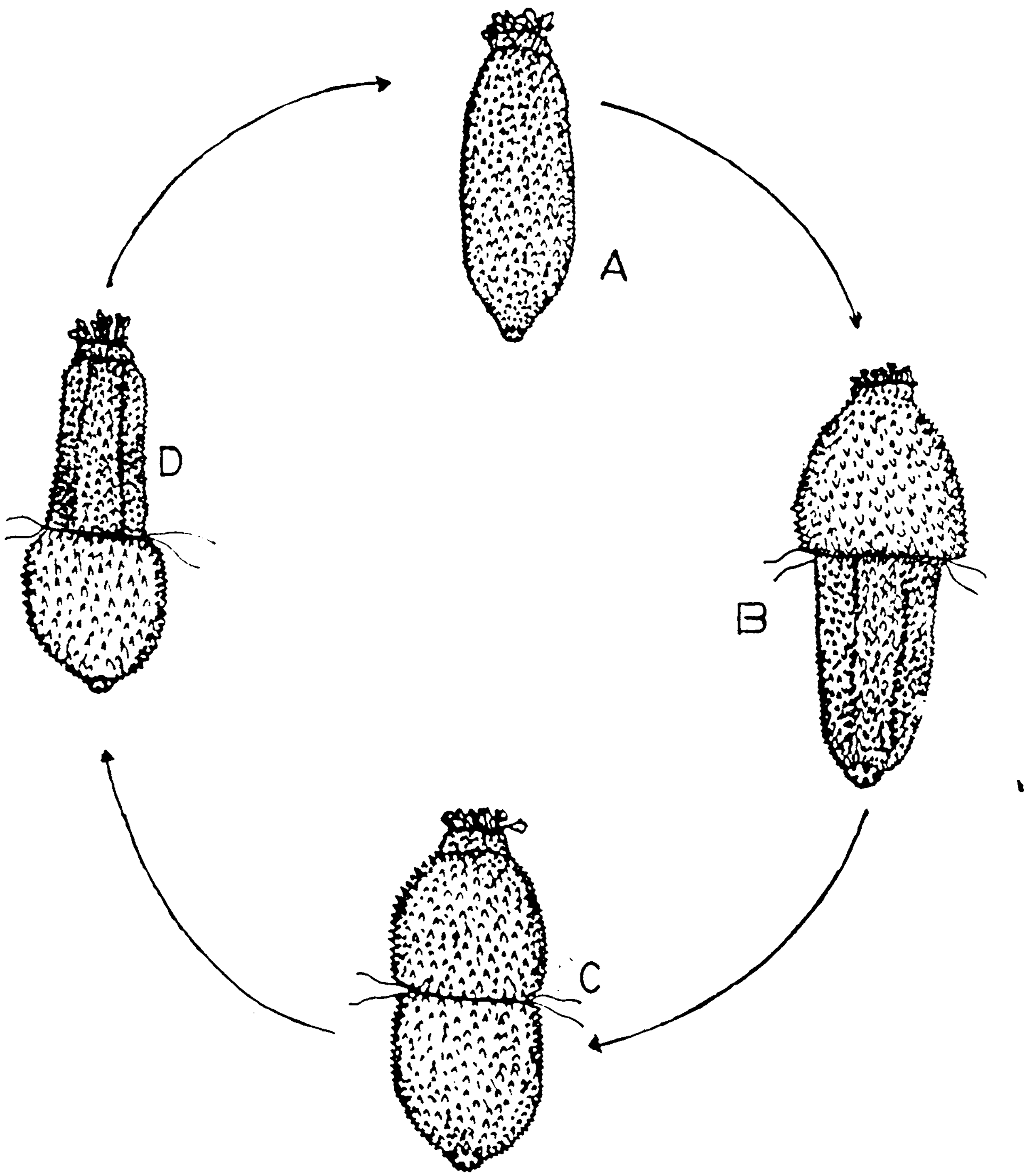


Fig.45. Experiment to stimulate asexual fissioning in A.mauritiana: A. normal A.mauritiana; B. stretching of posterior part of the body; C. regaining normal condition; D. stretching anterior part of the body.

temperature and physical disturbance at low tide appear to be regenerated sufficiently to be capable of feeding by autumn. This finding well coinsides to the candidate results and view on *A. mauritiana*. Bonham and Held (1963) also noticed that *H. atra* splits its body when water temperature was 37°C. This reports also further strengthen the present observations.

However, Emson and Wilkie (1980) reported air and high water temperature are major causes for fission in most of the holothurians, since these animals are living in intertidal and reef flat area, where these parameters were highly fluctuating and they are exposed to higher temperature. This is also one of the factor for asexual reproduction in *A. mauritiana* of the present study, as the reef flat of Minicoy Island is subjected to exposure to hot air and temperature for about 2 to 3 hours during low tide and it again would be more during summer period.

Part 3 : Age and growth of *Holothuria nobilis* and *Actinopyga mauritiana*

INTRODUCTION

The greater demand for *Beche-de-mer* in the world market and also involvement of more fisherfolk in fishing and processing industry, have made this *Beche-de-mer* industry a profitable and viable foreign exchange earner. This has led to the over-exploitation of the resources including the undersized ones. This over-exploitation has created a serious threat to natural population by depleting majority of holothurians from the Indo-Pacific regions. To overcome this problem FAO and South Pacific Commission imposed various control measures for judicial and rational exploitation and management of this resource, such as regulation of 'fishery season' and 'fishing ground' and 'ban to collect specimens below a particular size' (Conand, 1990). But all these measures created some problems to export industry and to the researchers not only in South Pacific countries, but also throughout the world to find out suitable remedies in a more scientific way using some mathematical modelling related to population parameters such as age, growth and mortality, etc. (Conand, 1990).

Based on this, Harriot (1980), Conand (1983) and Shelley (1985) carried out detailed investigations on age and growth of certain important holothurians from Pacific Island countries and from the Great Barrier Reef in Australia. All these authors applied various methods such as (i) tagging (ii) observing individuals in cages or in the aquarium for certain period of time, (iii) 'size modal progression' over a period of time (iv) counting growth rings in spicules, etc. But the results obtained by these authors were not satisfactory, since each methods had its own limitations on holothurians which are subject to shrinkage due to external stimuli.

In India, no attempt has been made on the age and growth of any species of sea-cucumbers. So in the present study, the candidate attempted and carried out investigations on age and growth of Holothuria nobilis and Actinopyga mauritiana from Minicoy Island by (i) tagging (ii) growing the animals in aquarium tank and (iii) 'size modal progression method' over the period of time as suggested and followed by Conand (1983, 1990). However, the first two methods have not yielded any encouraging results. Only the size modal progression method has given good results on age and growth.

MATERIALS AND METHODS

It is extremely difficult to study the growth of sea-cucumber due to its capability of contraction and water content in the body (Conand, 1990). Total length (TL), total weight (TW), drained weight (DW) gutted weight (GW) and gut length (GL) of the animals were taken every month for all the samples as described in the chapter II.

The gut length is important as it is not showing any remarkable change or contraction in their gut length, compared to other characters such as body length and weight.

In Holothuria nobilis, due to less number of adult and lack of juveniles in the population the age and growth have been described based on monthly trend in mode value of these characters as suggested by Conand (1990) and Shelley (1985). In Actinopyga mauritiana, besides these monthly trend in modal value, the gut length was taken for growth study using Von-Bertallanfy Growth formula :

$$L_t = L_{oo} (1-e^{-k} (t-t_o)$$

as suggested by Shepherd (1987).

Section A : Age and growth by monthly modal progression of total length and gut length

Only modal progression of total length and gut length (Table 79, 80) were taken to find out the age and growth of _H. nobilis_ and _A. mauritiana_ from the collection, as the total weight, drained weight and gutted weight were not showing any clear modal progression. The results are presented in Table 79 for _H. nobilis_ and Table 80 for _A. mauritiana_.

Calculation of age by total length in 1990

Growth in total length (April-December) in 1990 = 6.5 cm

Growth rate in total length per month $\frac{6.5 \text{ cm}}{9 \text{ months}}$ = 0.72 cm/month

Annual increment in length 0.72 cm/month x 12 months = 8.67 cm/year

If it is considered the annual growth in _H. nobilis_ as 8.67 cm, the animal age at first maturity would be

$$\frac{\text{Size at first maturity (25.0 cm) (as arrived at in the reproductive biology)}}{\text{Annual increment in size (8.67 cm)}} = 2.9 \text{ years}$$

Age of the animal at maximum size

$$\frac{\text{Maximum size of H. nobilis (38.0 cm) (as recorded in the present study)}}{\text{Annual increment in length (8.67 cm)}} = 4.4 \text{ years}$$

Holothuria nobilis

Total length : The monthly modal progression of total length was seen from April (28.5 cm in 1990 and 26.0 cm in 1991) to December (35.0 cm in 1990 and 34.5 cm in 1991).

The growth of total length in 1990 and 1991 was 6.5 cm and 8.5 cm respectively. The calculated annual increment was 8.67

TABLE 79. Total length (cm) and gut length (cm) of *H. nobilis* collected from Minicoy Island during 1990-1991

Month	No. of animals observed	Total length (cm)			Gut length (cm)		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean
January 1990	17	20.0	34.0	31.0	50.0	80.0	65.0
February	24	20.0	34.0	29.5	48.0	80.0	60.0
March	28	24.0	36.0	29.0	52.0	100.0	62.0
April	16	24.0	33.0	28.5	60.0	80.0	65.0
May	19	27.0	35.0	30.5	72.0	90.0	65.0
June	14	30.0	36.0	30.5	80.0	95.0	72.0
July	12	33.0	38.0	33.0	70.0	95.0	73.0
August	17	32.0	38.0	33.5	73.0	90.0	75.0
September	28	32.0	38.0	33.5	80.0	100.0	79.0
October	23	32.0	36.0	33.5	80.0	100.0	83.0
November	22	33.0	38.0	34.5	82.0	106.0	85.0
December	19	32.0	36.0	35.0	75.0	110.0	85.0
January 1991	20	33.0	38.0	34.0	80.0	103.0	90.0
February	23	24.0	36.0	34.0	53.0	90.0	82.0
March	21	26.0	33.0	29.0	75.0	83.0	64.0
April	20	20.0	34.0	26.0	50.0	85.0	62.0
May	18	24.0	31.0	30.0	65.0	85.0	68.0
June	14	28.0	34.0	31.0	61.0	90.0	69.0
July	17	30.0	34.0	31.0	65.0	96.0	73.0
August	22	33.0	36.0	32.5	80.0	100.0	73.0
September	20	33.0	36.0	33.0	80.0	100.0	77.0
October	15	35.0	38.0	34.0	90.0	102.0	80.0
November	24	35.0	38.0	34.5	95.0	110.0	83.0
December	20	33.0	38.0	34.5	85.0	110.0	83.0

TABLE 80. Total length (cm) and gut length (cm) of _A. mauritiana_ collected from Minicoy reef flat during 1990-1991

Month	No. of animals observed	Total length (cm)			Gut length (cm)		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean
January 1990	48	8.0	27.0	16.5	40.0	110.0	77.0
February	47	12.0	30.0	17.5	53.0	135.0	83.0
March	40	11.0	26.0	19.0	50.0	123.0	89.0
April	47	10.0	25.0	18.0	43.0	120.0	85.0
May	37	6.0	29.0	5.0	23.0	135.0	85.0
June	34	12.0	26.0	18.0	60.0	130.0	88.0
July	28	10.0	30.0	18.5	42.0	130.0	91.0
August	40	6.0	27.0	19.0	26.0	133.0	95.0
September	30	4.0	30.0	21.0	23.0	130.0	96.0
October	35	7.0	26.0	21.5	33.0	120.0	102.0
November	35	10.0	25.0	17.0	45.0	120.0	89.0
December	42	6.0	30.0	16.0	33.0	130.0	85.0
January 1991	23	6.0	25.0	14.0	30.0	130.0	64.0
February	43	7.0	27.0	14.0	28.0	120.0	64.0
March	42	6.5	22.0	14.5	30.0	90.0	68.0
April	28	4.0	21.0	14.5	20.0	83.0	72.0
May	21	11.0	23.0	17.0	55.0	120.0	80.0
June	22	7.0	22.0	18.0	32.0	96.0	85.0
July	31	12.0	29.0	19.0	54.0	130.0	91.0
August	41	8.0	29.0	22.0	36.0	120.0	96.0
September	43	9.0	24.0	18.0	40.0	100.0	95.0
October	48	8.0	25.0	17.0	43.0	120.0	92.0
November	46	9.0	24.0	17.0	52.0	93.0	86.0
December	42	4.0	22.0	17.0	23.0	105.0	73.0

cm in 1990 and 11.33 cm in 1991. Based on this annual increment, the age at first maturity calculated was 2.9 years and age at maximum size was 4.4 years in 1990. The same was 2.2 years and 3.4 years in 1991 (Table 81).

Gut length : The monthly modal progression of gut length was (seen during April) 65.0 cm in 1990 and 62.0 cm in 1991 to December 85.0 cm in 1990 and 83.0 cm in 1991.

In 1990 and 1991, the growth of gut length was noticed in April-December with 20.0 cm and 21.0 cm respectively. The calculated annual increment was 26.40 cm in 1990 and 28.00 cm in 1991. Based on this annual growth increment the age at first maturity calculated was 2.6 years in 1990 and 2.4 years in 1991. The age at maximum size of *H. nobilis* was 4.2 years and 3.8 years in 1990 and 1991 respectively (Table 81).

Actinopyga mauritiana

Total length : The monthly modal progression of total length was seen from June (18.0 cm) to October (21.5 cm) in 1990 and January (14.0 cm) to August (22.0 cm) in 1991.

In 1990 and 1991, the growth of total length was noticed from June to December at the rate of 3.5 cm and 8.0 cm respectively. The calculated annual increment was 8.4 cm in 1990 and 12.0 cm in 1991. Based on this annual increment, the age at minimum size was 0.7 years (1990) and 0.5 years (1991). The age at maximum size was 3.6 years (1990) and 2.5 years (1991) (Table 82).

Gut length : The monthly modal progression of gut length was seen during April (85.0 cm) to October (102.0 cm) in 1990 and January (64.0 cm) to August (96.0 cm) in 1991.

TABLE 81. Estimation of age and growth of *H. nobilis* using modal progression of total length and gut length during 1990-1991

Year	Character (cm)	Growth period (month)	Growth rate (cm)	Growth/month (cm)	Annual increment in growth (cm)	Animal length at first maturity (cm)	Age at first maturity	Animal length at maximum size (cm)	Age at maximum size (years)
1990	Total length	April-December (9 months)	6.5	0.72	8.67	25.0*	2.9	38.0**	4.4
1991	Total length	April-December (9 months)	8.5	0.94	11.33	25.0	2.2	38.0**	3.4
1990	Gut length	April-December (9 months)	20.0	2.20	26.40	68.0***	2.6	108.0***	4.2
1991	Gut length	April-December (9 months)	21.0	2.33	28.00	68.0***	2.4	108.0***	3.8

* as arrived at in the reproductive biology
** as recorded in the present study period
*** the length of 25.0 cm. *H. nobilis*

TABLE 82. Estimation of age and growth of *A. mauritiana* using modal progression of total length and gut length during 1990–1991

Year	Character (cm)	Growth period (month)	Growth rate (cm)	Growth/month (cm)	Annual increment in growth (cm)	Animal length at minimum size (cm)	Age at minimum size	Animal length at maximum size (cm)	Age at maximum size (years)
1990	Total length	June - October (5 months)	3.5	0.7	8.7	6.0	0.7	30.0	3.6
1991	Total length	January - August (8 months)	8.0	1.0	12.0	6.0	0.5	30.0	2.5
1990	Gut length	April - October (7 months)	17.0	2.4	28.8	23.0	0.8	106.0	2.2
1991	Gut length	January - August (8 months)	32.0	4.0	48.0	23.0	0.5	106.0	2.2

In 1990 and 1991, the growth of gut length was noticed from April to October at the rate of 17.0 cm and 32.0 cm respectively. The calculated annual increment was 28.8 cm in 1990 and 48.0 cm in 1991. Based on this annual increment, the age at minimum size was 0.8 years (1990) and 0.5 years (1991). The age at maximum size was 3.7 years in 1990 and 2.2 years in 1991 (Table 82).

SECTION B : Age and growth estimation by Von-Bertallanfy Growth formula

In *A. mauritiana* the growth in animal by means of gut growth has been analysed by Van Bertallanfy Growth Formula (VBGF) assuming there is absence of any contrary evidence or method to analyse these parameters.

$$L_t = L_{\infty} \; (1-e^{-k} \; (t-t_o\;)$$

where L_t = gut length at time (age) t

L_{oo} = asymptotic gut length

k = Brody's growth coefficient

t_o = starting value of the line when gut length is zero

The parameter L_{oo} and k are estimated by using SRLC method described by Shepherd (1987).

Based on this, the gut length data collected for the year 1990 and 1991 were analysed separately and the score values are given in Table 83. From this Table there is a wide range of almost equally good pairs of related values of k and L_{oo} lying between k = 0.55 t0 0.75 and L_{oo} = 160 to 180 for 1990 and k = 0.60 to 0.75 and L_{oo} = 160 to 180 for 1991.

TABLE 83. Estimated score value of gut length (cm) to calculate growth in *H. nobilis* during 1990–1991

1990

Loc/K	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85
160.0	57.2	68.4	81.3	92.6	98.5	98.8	94.9	88.4
165.0	61.3	77.0	90.6	97.9	98.9	94.7	86.9	77.7
170.0	69.7	86.4	96.8	99.5	95.3	86.2	75.2	65.9
175.0	79.1	93.9	100.0	96.9	86.9	74.0	63.2	59.4
180.0	88.0	99.3	99.0	89.2	74.6	61.7	57.2	63.3

1991

Loc/K	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85
160.0	29.9	28.4	68.9	84.8	85.0	86.4	91.7	95.0
165.0	28.8	61.2	71.2	81.4	93.7	99.6	96.8	87.8
170.0	47.5	62.4	82.4	97.2	100.0	93.5	82.8	71.7
175.0	52.4	79.4	96.4	98.6	91.4	81.0	71.3	63.5
180.0	70.8	92.8	97.2	91.0	81.6	72.9	65.6	59.5

The statistical properties of the score function are not known, so it is not possible to determine proper confidence region for the parameter values (Shepherd, 1987). As a rough approximation, it may be guessed that the score function relative to its maximum is probably analogous to a variance ratio and that the contour corresponding to half the maximum is associated with something like 1 95% confidence level (Shepherd, 1987).

In the present study, the score function of the gut length of A. mauritiana for both years (1990 and 1991) the confidence region lies between k = 0.55 to 0.75 per year with L_{oo} for 160 to 180 cm, thus a parametric pair of L_{oo} = 170 cm and k = 0.65 has been chosen to be estimated the L_{oo} and k per year respectively.

The variation in score values over the difference in k/year for each of L_{oo} are dipicted in (Fig. 46 and 47) for both years. From these Figures also we can see the scores in the vicinity of L_{oo} = 170 cm, k = 0.65/year are on higher relation when compared to other. The gut length growth pattern related to year is given in (Fig. 48).

SECTION C : Tagging experiment on H. nobilis and A. mauritiana

The candidate tagged 20 H. nobilis and 50 A. mauritiana with small and numbered plastic tags. The tags were tied in December 1990 with nylon thread by piercing near the anal region. The length of the animals were taken at the time of tagging as a initial stage. Initially these animals were kept in aquarium tanks for observation by providing sediment collected from their respective habitat as food. It was noticed that the tagged animals were subjected to heavy shrinkage and stopped feeding for first 4 days.

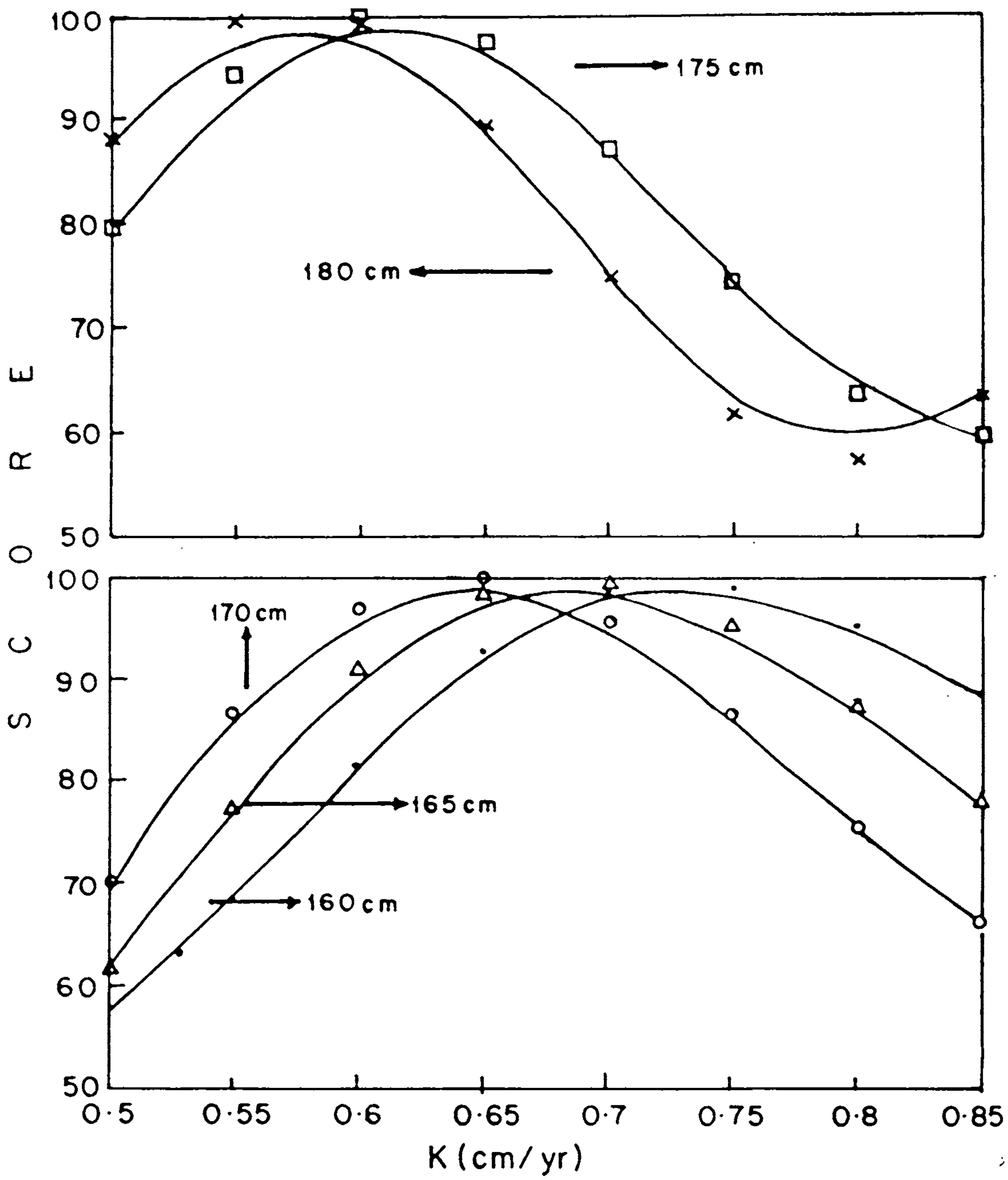


Fig.46. Gut length growth pattern K (cm/yr) of A.mauritiana during 1990 obtained by Score function value.

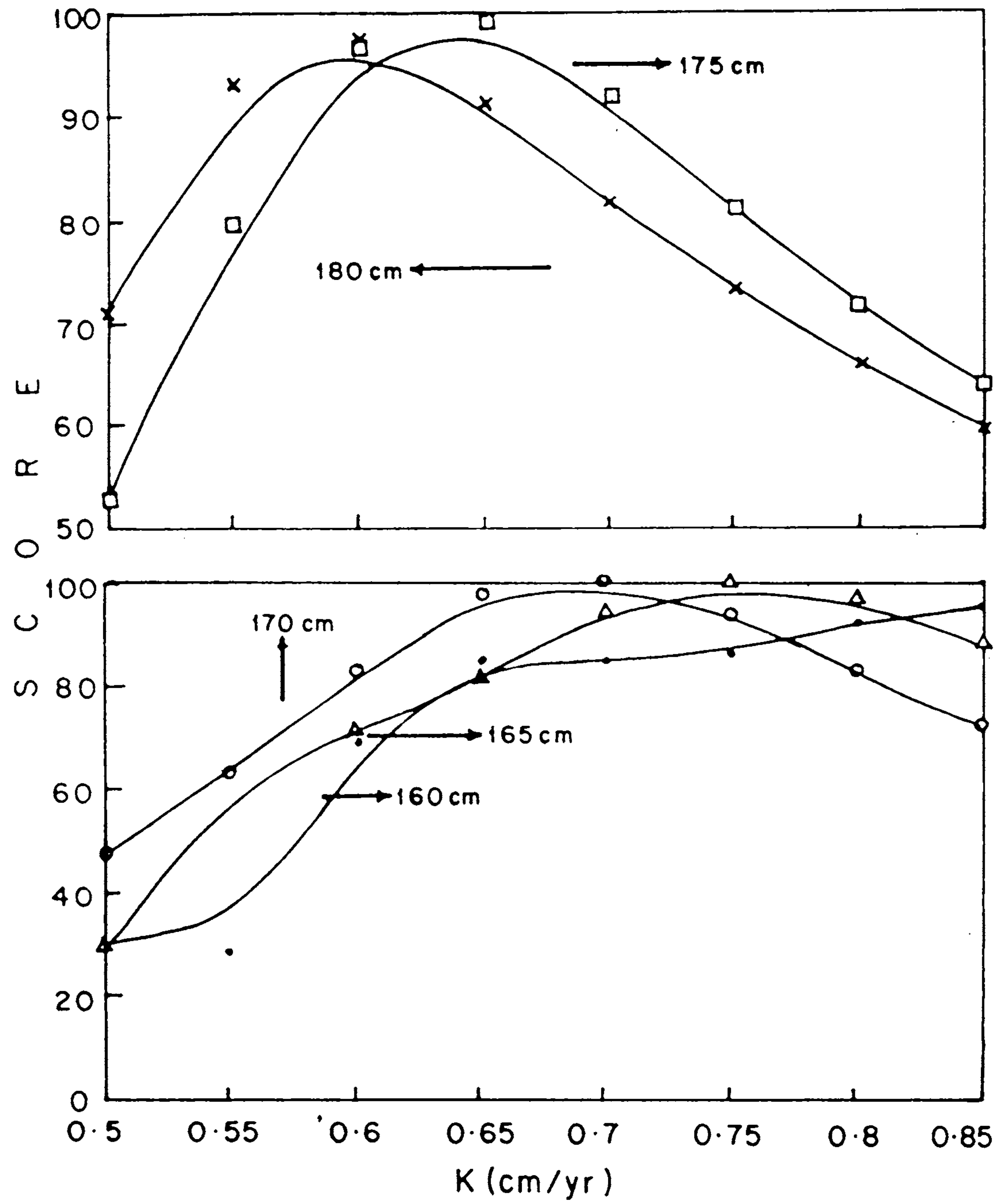


Fig. 47. Gut length growth pattern K (cm/yr) of <u>A.mauritiana</u> during 1991 obtained by score function value.

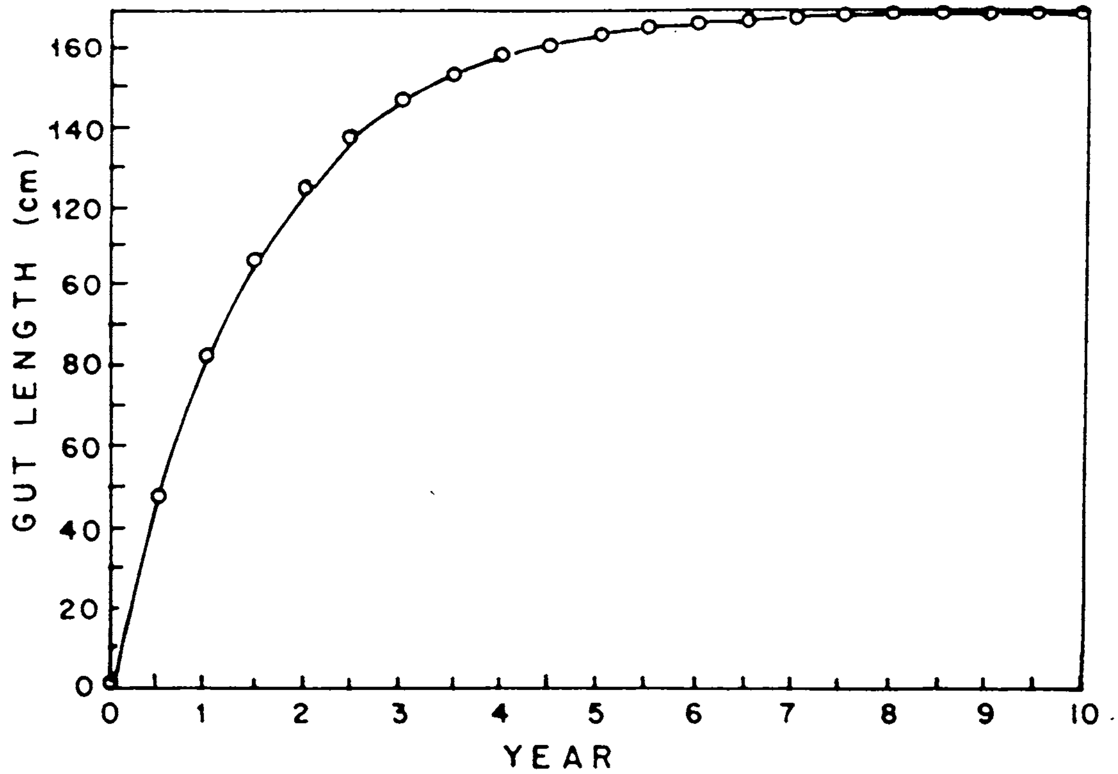


Fig.48. Gut growth of *A.mauritiana* in relation to year.

This was confirmed by the absence of faecal matters. Due to their non feeding these animals were transported carefully to their natural habitat i.e. lagoon and reef flat. After 10 days the entire lagoon and reef flat were searched for tagged holothurians and none of them were traced out till December 1991 throughout the entire collection period.

A second set of experiment in tagging was conducted after the above unsuccessful attempt. The animals were tagged on the spot and left immediately in their habitat. These animals were also could not be traced out.

SECTION D : Growth study on sea-cucumbers in aquarium tank

Holothuria nobilis

Four animals measuring 23.0 cm, 30.0 cm, 33.0 cm, 36.0 cm total length were stocked in an aquarium tank containing habitat water and sediment from natural environment i.e. from the lagoon. It was ascertained from the absence of faecal matter in the tank continously for first 4 days that the animals stopped feeding in the artificial environment. After 7 days all animals eviscerated internal organs and died. Hence the experiment was unsuccessful and terminated.

Actinopyga mauritiana

Ten individual measured between 10.0 cm and 20.0 cm were stocked separately in the aquarium tank by providing reef sediment for their food and small boulders for their attachment, which is an unique character of this species. All these animals were very active for the first 10 days consuming sediments and wandering in the aquarium tank. Afterwards they ceased feeding and evicerated all internal organs. So body shape shrinked badly and died.

DISCUSSION

The investigation on age and growth of *Holothuria nobilis* and *Actinopyga mauritiana* by three different methods such as (i) using progression mode of total length and gut length (ii) tagging (iii) observing individual in aquarium over a period of time were adapted. Among these methods, the tagging experiments and observation of animals in tanks were not successful. Conand (1983) reported that most of the tagged sea-cucumbers in Papua New Guinea, the external tag have been rejected by the integument or having necrosis. Shelley (1981) reported that the tagging experiment was unsuccessful in most of the holothurians in Great Barrier Reef. Hence after a month it was impossible to find out the tagged individual in reef area. These two authors have explained that the use of tags and keeping the animals in aquarium tank may interfere with the holothurian normal metabolism resulting in their gradual loss of weight and resulting death. Choe (1963) found that *Stichopus japonicus* kept in aquarium for growth study, ceased to feed in aquarium and the reason was not known. These all reports are well coincide with present study.

Use of the progression modal of total length and gut length showed some positive results for calculating approximate growth and age of *H. nobilis* and *A. mauritiana* in the present study. According to estimation by total length, the calculated growth rate for *H. nobilis* was 0.72 cm/month and 8.67 cm/year in 1990, 0.94 cm/month and 11.35 cm/year in 1991. For A. mauritiana, the growth was 0.7 cm/month and 8.4 cm/year in 1990, 1.0 cm/month and 12.0 cm/year in 1991. **In India, this is the first work on age and growth estimation applying "modal progression" method in holothurians** and no literature is available on this aspect for comparison. But Shelley (1985) estimated the growth of H. scabra from Papua New Guinea based on the progression modal of total length was 0.5 cm/month and 6.00 cm/year and for A. echinites the growth was 0.90 cm/month and 10.8 cm/year. Other reports are: Mitsukri (1903) noticed Stichopus japonicus increased by individual observation from the tanks from 4.0 mm to 25.0 mm in first year while Edwards (1909) noticed H. floridana increases from 0.33 mm to 4.0 mm in 75 days. Rutherford (1973) estimated the growth of Cucumaria pseudocurata based on monthly mean dry weight, which increased from 0.17 mg to 5.0 mg/year.

The results obtained by the candidate in the present investigations on growth rate per month and year for H. nobilis, the age of the animal at first maturity (24-25.9 cm) was calculated as 2.9 years old in 1990 and 2.2 years old in 1991. The age of the maximum size (38.0 cm) was 4.4 years old in 1990 and 3.4 years old in 1991. For A. mauritiana the calculated age of the minimum size (6.0 cm) animal was 0.7 years old in 1990 and 0.5 years in 1991. The age of maximum size (30.0 cm) animal was 3.6 years old in 1990 and 2.5 years old in 1991. Rutherford (1973) reported that Cucumaria pseudocurata reached sexual maturity in the third year and large specimen in fact probably 4 or 5 years old, since they do not continue to grow at the same rate as the first year individual which would be less that 2 years old.

The growth rate obtained based on gut length data also showed almost similar for H. nobilis and A. mauritiana as in the case of total length.

CHAPTER 4

CHAPTER IV : SEA-CUCUMBER FISHERY IN MINICOY ISLAND

INTRODUCTION

Sea-cucumber has long been recognised as an auspicious food item of ethnic Chinese, wherever they have settled in the world. For the last 100 years they get the processed Sea-cucumber mostly from Indo-Pacific regions where economically important holothurians are available. The fisherfolk living in these regions know how to collect and process it properly. The processed Sea-cucumber is known as Beche-de-mer which means burrowing Sea-slug. This dried sea-cucumber is said to have many nutritive values. It contains

Protein	43%
Fat	2%
Moisture	27%
Minerals	21%
insoluble ash	7%

Recent scientific information indicates that Beche-de-mer is having curative powers for human ailments like high blood pressure and muscular disorders (Roa, 1987). But it is surprising that among 1200 species found world wide only 10 species of Sea-cucumbers are reported to have commercial value. Among these 10 species, *H. nobilis*, *H. scabra* and *A. mauritiana* are the important (Krishnaswamy, 1991).

In general commercial grading of Beche-de-mer is mainly based on the properties of body wall such as shrinkage, odour, purity and taste after processing. Among these properties shrinkage is the most important factor for export purpose, since undersized animals are not fetching any price in the international market. For example, Beche-de-mer less than 7.5 cm of size is considered as lower grade (Sakthivel and Swamy, 1994; James, 1994). It is noted that the traditional method is still being used for processing the Sea-cucumbers, though fishery started about 100 years before.

In the present study *H. nobilis* and *A. mauritiana* were used for Beche-de-mer preparation and also to quantify the shrinkage during processing.

MATERIALS AND METHODS

Seventyfour *H. nobilis* measuring between 28.0 cm and 37.0 cm from the lagoon and hundred and eleven *A. mauritiana* measuring between 10.0 cm and 30.0 cm from reef flat were collected for Beche-de-mer preparation and processed by the method suggested by South Pacific Commission (1973) and Conand (1990). To find out shrinkage in their size and loss in weight, all these animals were individually tagged with aluminium foil with proper number as suggested by Baskar and James (1989). The measurements such as length and weight were taken in every step of processing and shrinkage were estimated for both the species.

Section A : Beche-de-mer preparation

Degutting

Animals were degutted by cutting the body lengthwise on the ventral side to remove their internal organs.

First Boiling

The degutted animals were boiled separately in 25 litre capacity aluminium vessal with clean sea water. Boiling time depended upon the size of the animals and the thickness of the body wall (2 hours to 4 hours). The boiling was continued till they achieve a leathery consistency. Coconut leaves, husks and drift woods were used as firewood.

Burrying

After first boiling, these animals were burried in a pit on seashore for 12 to 18 hours to remove the calcarious spicules and chalky epidermis.

Second boiling

After 10 to 18 hours, these animals were removed from the sand pit and cleaned properly for second boiling. This time animals were boiled in clean sea water for 1/2 to 1 hour.

Smoking

After second boiling, the boiled animals were smoked placing on a wire mesh in smoke chamber, which is made of bricks. The material used for smoking was coconut husk and some dried leaves. The time for smoking vary depending upon sizes.

Sun-drying

After smoking, the smoked sea-cucumbers were placed on asbestos sheet and kept under sun for 90 hours. Improperly dried sea-cucumber is said to be easily attacked by fungi during storage.

Packing

After ensured that the animals are properly dried, the final products were packed in Polythene bags with some rice flour, which absorbs moisture.

Section B: Reduction (shrinkage) while Beche-de-mer Preparation

To calculate shrinkage, during Beche-de-mer processing in every step - first boiling, second boiling, smoking and sundrying of H. nobilis and A. mauritiana, the length and weight measurements were taken carefully and it compared to the initial stage.

Table 84 shows the reduction of length and weight of H. nobilis during processing into Beche-de-mer. All size groups have showed considerable reduction in length and weight. The animals with mean length of 30.85 cm and mean weight of 1360.18 gm of this species showed remarkable difference during every processing steps. If considered this mean length and mean weight are 100% at initial stage, the reduction noticed was 79.68% in length and 60.76% in weight at first boiling, 71.38% in length and 40.24% in weight at second boiling, 68.27% in length and 37.64% in weight after smoking and 49.21% in length and 14.34% in weight after sun drying about 90 hours durations. It is found that this species lost 85.66% in total weight 55.79% in length on conversion to Beche-de-mer.

Table 85 gives the reduction of length and weight of A. mauritiana during processing into Beche-de-mer. These animals with an average length of 22.76 cm and an average weight of 511.66 gm undergone remarkable reduction during every step of processing. If considered these mean length and mean weight as 100% at initial

TABLE 84. Changes in length and weight during processing of the *H. nobilis*

Animal Size groups (cm)	No. of animals	Initial stage		Ist boiling		IInd boiling		Smoking		Drying (90 hours)	
		Length (cm)	Weight (gm)	Length (cm)	Weight (gm)	Length (cm)	Weight (gm)	Length (cm)	Weight (gm)	Length (cm)	Weight (gm)
23.0 - 25.9	10	24.80	800.00	18.50	650.00	16.20	300.20	16.00	280.00	10.00	120.00
26.0 - 28.9	14	27.85	1020.50	22.00	790.80	20.80	480.00	20.00	410.00	13.00	190.00
29.0 - 31.9	22	30.70	1450.20	26.00	810.60	22.00	600.80	21.30	580.00	13.00	200.00
32.0 - 34.9	20	33.40	1630.20	27.10	860.10	25.10	640.00	23.00	610.00	18.60	225.50
35.0 - 37.9	8	36.50	1900.00	29.30	1020.60	26.00	715.50	25.00	680.00	21.30	240.00
Total	74	153.25	6800.90	122.90	4132.10	110.10	2736.50	105.30	2560.00	75.90	975.50
Mean value of parameters		30.85	1360.18	24.58	826.42	22.02	547.30	21.06	512.00	15.18	195.10
Shrinkage in length and weight (%)		100.00	100.00	79.68	60.76	71.38	40.20	68.27	37.64	44.21	14.34
Weight loss (%)		100.00	100.00	20.32	39.24	28.62	59.80	31.32	62.36	55.79	85.66

TABLE 85. Changes in length and weight during processing of the *A. mauritiana*

Animal Size groups	No. of animals	Initial stage		Ist boiling		IInd boiling		Smoking		Drying (90 hours)	
		Length (cm)	Weight (gm)	Length (cm)	Weight (gm)	Length (cm)	Weight (gm)	Length (cm)	Weight (gm)	Length (cm)	Weight (gm)
10.0 - 13.9	22	13.80	100.00	8.50	30.0	7.00	25.00	6.20	20.00	5.00	5.00
14.0 - 17.9	28	17.50	210.00	9.50	50.0	8.50	35.00	8.00	32.00	6.00	10.00
18.0 - 21.9	20	20.25	390.00	11.38	43.00	9.90	46.00	9.00	40.00	7.00	20.00
22.0 - 25.9	20	24.50	520.00	12.00	120.00	10.50	65.00	10.00	60.00	8.05	25.00
26.0 - 29.9	18	29.70	850.00	16.00	190.00	14.00	145.00	13.00	138.00	11.00	50.00
30.0 - 33.9	8	30.80	1000.00	26.00	565.00	24.00	460.00	20.00	370.00	18.00	130.00
Total	116	136.55	3070.00	83.38	990.00	73.90	776.00	66.20	660.00	55.50	240.00
Mean value of parameters		22.76	511.66	13.90	166.33	12.32	129.33	11.03	110.00	9.42	35.43
Shrinkage in length and weight (%)		100.00	100.00	61.07	32.51	54.13	25.28	48.46	21.50	41.39	6.92
Weight loss (%)		100.00	100.00	38.93	67.49	45.87	74.72	51.54	78.50	58.61	93.08

stage, the shrinkage noticed were 61.07% in length and 32.51% in weight at first boiling, 54.13% in length and 25.28% in weight at second boiling, 48.46% in length and 21.80% in weight at smoking and 41.39% in length and 6.92% in weight after sun drying for about 90 hours. It is seen that this species lost 93.08% of total weight on conversion into Beche-de-mer.

Based on the shrinkage on these two species, the number of Beche-de-mer per kilogram in relation to size group is given in Table 86. It shows 9 pieces of dried *H. nobilis* is required at the size of 23.0 - 25.9 cm and 5 pieces enough at the size of 35.0 - 37.9 cm for 1 kilogram weight. In *A. mauritiana*, 200 pieces are required at the size of 10.0 - 13.9 cm and 8 pieces are enough at the size of 30.0 - 33.9 cm for 1 kilogram weight. Moreover in *A. mauritiana* the animal size 10.0 - 13.9 cm, 14.0 - 17.9 cm and 18.0 - 21.9 cm were not considered for Beche-de-mer. Hence these animals shrunk badly in length, less than 7.5 cm after sun drying. Which is not suitable for commercial grade.

Section C : Economics of Beche-de-mer preparation

'Based on the information collected from some of the old people from different Lakshadweep Islands namely, Minicoy, Kavarathi, Kalpeni, Kiltan and Chetlet, it is understood that the people are not knowing the value of the sea-cucumbers annd even they considered sea-cucumber as a sea-snake particularly *Synapta maculata*. But about 100 years back the Chinese those who have halted in some of the islands, educated the islanders about the importance and value of the sea-cucumbers. They have also taught the islanders to prepare the Beche-de-mer. However, none of the islanders came forward to establish an industry of Beche-de-mer and to take up as a profession.

TABLE 86. Number of processed pieces (animals) in one Kg. of *Beche-de-mer* at different size groups studied in *H. nobilis* and *A. mauritiana*

H. nobilis		*A. maruitiana*	
Animal size group(cm)	Number/Kg	Animal size group(cm)	Number/Kg
23.0 - 25.9	9	10.0 - 13.9	200
26.0 - 28.9	6	14.0 - 17.9	100
29.0 - 31.9	5	18.0 - 21.9	50
32.0 - 34.9	5	22.0 - 25.9	40
35.0 - 37.9	5	26.0 - 29.9	20
		30.0 - 33.9	8

One Mr. Kunhikoya in Kiltan Island, processed a few sea-cucumbers during 1930-1940 by using some crude methods. But he was neither able to follow correct processing procedure nor to identify the species of sea-cucumbers that he collected. Even now people are not interested in the collection and processing sea-cucumbers. Because people do not know the benefit of Behce-de-mer and their export value when compared to other fish product.

The candidate has calculated the economics of Beche-de-mer preparation to make the Lakshadweep people to understand the benefits from the Beche-de-mer processing.

The estimates and economics of Beche-de-mer preparation for 100 numbers of *H. nobilis* and *A. mauritiana* based on experimental preparations and current market value are given in Table 87 and 88. The expenditure incurred in the preparation of 100 *H. nobilis* and *A. mauritiana* separately worked out to Rs.750.00 and Rs.270.00. The expenditure includes hire charges, labour charges, cost of firewood, coconut shell and packing materials. In the case of *A. mauritiana* only man power was used for collecting the animals from reef flat, while boats were used for collecting *H. nobilis* from the lagoon area.

Holothuria nobilis has yielded 20 kg of Beche-de-mer from 100 animals where as *A. mauritiana* has given only 6 kg out of 100 animals processed. This vast difference is mainly due to the thick body wall and larger size of *H. nobilis*, while *A. mauritiana* comparatively smmaller with thin body wall. The profit realised for the above two species are Rs.2250.00 and Rs.330.00 at the rate of Rs.150.00 and Rs.100.00 per kg respectively.

Since, there is no commercial Beche-de-mer industry in Lakshadweep, the prevailing buyer rate in the Gulf of Mannar, India

TABLE 87. Economics of *Beche-de-mer* preparation and marketing of 100 numbers of *H. nobilis*

	Particulars/rates		Rs.
I.	Expenditure		
	Boat hire charges @ Rs.15/hour for an average of 10 hours, required to collect 100 No. of Sea-cucumber of *H. nobilis*		150
	Labour charges @ Rs.5/ hour/head for five persons for 10 hours, in an average for total preparation.		250
	Cost of fire wood @ Rs.5/ kg for an average of 50 kg required for boiling		250
	Cost of coconut shell @ Rs.2/kg for an average of 25 Kg required for smoking.		50
	Cost of packing materials		50
			750
II.	Profit		
	Yield	20 kg	
	Income @ Rs. 150/Kg		3000
	Profit	(3000-750)	2250 or 113/kg

TABLE 88. Economics of Beche-de-mer preparation and marketing of 100 numbers of *A. mauritiana*

	Particulars/rates		Rs.
I.	Expenditure		
	Labour charges @ Rs. 5/hour/head for two persons an average of 3 hours required to collect 100 No. of *A. mauritiana*.		30
	Labour charges @ Rs.5/ hour/head for two persons for 10 hours, in an average for total preparation.		100
	Cost of fire wood @ Rs.5/ kg for an average of 20 kg required for boiling		100
	Cost of coconut shell @ Rs.2/kg for an average of 10 Kg required for smoking.		20
	Cost of packing materials		20
			270
II.	Profit		
	Yield	6 kg	
	Income @ Rs. 100/Kg		600
	Profit	600.00 - 270.00	330 or 55/kg

as Rs.150.00 for first grade species and Rs.100.00 for other grades were used to calculate the income in the present study.

Though *H. nobilis* and *A. mauritiana* are available in reasonable quantities as evidenced from Chapter V : Quantitative abundance of sea-cucumbers in Minicoy Island, there is absolutely no *Beche-de-mer* industry in Lakshadweep due to the unaware of the processing method and the fishing for the sea-cucumbers and benefits from the *Beche-de-mer* export.

DISCUSSION

Though the sea-cucumber fishery is more than a century old in many parts of the world, still only the traditional processing method is followed, which includes cleaning, boiling, burrowing in the sand, smoking and sun-drying and found suitable (Hornell, 1917; South Pacific Commission, 1973; Durairaj, 1982; Trinidad Roa, 1987; James, 1989; Joseph and Shakeel, 1991). However, all these authors have mentioned that the above said processing steps may vary depending upon the species body wall. In the present study also only the traditional method was used for *Beche-de-mer* preparation of *H. nobilis* and *A. mauritiana*.

In international market, the price of *Beche-de-mer* is determined by the size of the product (Conand, 1990). Sachithananthan (1986) stated that not only the length, but also the number of the pieces per kg judges the price in Singapore market. Durairaj *et al.* (1984) graded the *Beche-de-mer* based on the length as :

$>$ 10.0 cm	-	first grade
$\sim$ 7.0 cm and 10.0 cm	-	second grade
$\sim$ 5.0 cm and 7.0 cm	-	third grade.

However, James (1987) and Sakthivel and Swamy (1994) have confirmed and mentioned that the length of processed sea-cucumbers below 7.5 cm is not suitable for export. In 1987, the Government of India by its Ministry of Agriculture constituted a committee of Experts with Dr. P.S.B.R. James, Director, CMFRI, as the Chairman to re-examine the ban on export of Beche-de-mer below 3" (7.5 cm), which was imposed by Government of India based on the recommendations of the Marine Products Export Development Authority, on 16.8.1982. Hence below 3" (7.5 cm) Beche-de-mer is lower grade in the international market and also to stop the over-exploitation of sea-cucumber in under size group in India. The committee recommended that the ban already imposed on the export is entirely justifiable from the existing knowledge on the holothurians and as such the ban should be continued. This ban is still in force in India.

From the present study it is clearly understood that the shrinkage in length and reduction in weight of *H. nobilis* and *A. mauritiana* indicates that live animal with above 23.0 cm and 500 - 800 gm weight gives nearly 8.5 cm to 10.0 cm after processing, which is suitable for export. Further it has been found from the present study that 20 kg and 6 kg of Beche-de-mer is obtained from 100 animals of *H. nobilis* and 100 animals of *A. mauritiana* respectively. This difference is mainly due to the thick body wall and larger size of *H. nobilis* compared to *A. mauritiana*, which is smaller with thin body wall. this finding clearly indicates that *H. nobilis* may be regarded as First Grade species and *A. mauritiana* the next category as mentioned by different investigators based on the international trade (Sachithananthan, 1986; Sakthivel and Swamy, 1994; Conand, 1990; Krishnasamy, 1991; Joseph and Shakeel, 1991).

From the above discussion and findings of the candidate, it suggested that *H. nobilis* with live body length of above 20.0 cm and weight of 600 gm may be collected and processed for Beche-de-mer and export. The processing of *A. mauritiana* not be economical for export, unless larger sized animals are fished and processed. Further, in the candidate's opinion, extension services such as Seminars, meetings, advertisements through various communication media are very much required in Lakshadweep to propagate the importance of sea-cucumbers, availability of commercially important species, fishing and processing method, list of local buyers and export value and on the benefit to the islanders along with other fish products to get foreign exchange and to improve their socio-economic condition.

CHAPTER 5

CHAPTER V : QUANTITATIVE AND SEASONAL ABUNDANCE OF SEA-CUCUMBERS FROM MINICOY ISLAND

INTRODUCTION

Among 1200 species of holothurians recorded from all over the world sofar, the highest diversing and great numbers were noticed in tropical shallow waters (Pawson, 1982). In the shallow water regime economically important holothurians belonging to genera *Holothuria*, *Actinopyga* and *Stichopus* are found to be more in Indo-Pacific. Most of the species of these genera are exploited for *Beche-de-mer* and as they are found suitable for processing with thick body wall. In recent years they became a major and conventional fishery in shallow water coral reef islands of Indo-Pacific and they are indiscriminately collected irrespective of their sizes. This over exploitation has lead to the depletion of natural population. Only recently attempts are on the way to culture of sea-cucumbers and ranch the young ones in embankments along the coastal area to augment the population. The indiscriminate fishing of sea-cucumbers is mainly due to lack of knowledge on the sizes of different species and their abundance and distribution.

The studies on the distribution, occurrence and abundance especially on economically important holothurians are prerequisite for fishery population dynamics (Conand, 1990). There are some reports available on these aspects from Pacific regions (Harriot, 1980; Shelley, 1981; Conand, 1990). Though more than 100 species were recorded in India and systematically reported (Bell, 1902; Koehler and Vany, 1908; James, 1969), only very few reports are available on Taxonomy, Zoogeography and the faunastic distribution (Daniel and Halder, 1974; Mukhopadhyay and Samanta, 1983; James, 1988). However, all these reports are mainly on the species availability from the mainland and rarely from the Union Territories of Andaman & Nicobar Islands and Lakshadweep.

There is absolutely no information on quantitative and seasonal abundance on any economically important species from India so far. A good population is still available for fishery from the shallow waters of Lakshadweep and Andaman & Nicobar Islands, where coral reefs are flourishing.

In Minicoy Island in Lakshadweep, there is a great diversity of various holothurians in different biotopes. But there is no quantitative and qualitative study on these animals so far. So the candidate felt that this type of study would enhance the knowledge available on sea-cucumber in the view of sea-cucumber fishery, Beche-de-mer industry and for culture activity, and he has taken up the present study on systematic survey and assessed quantitatively the available sea-cucumbers in the Minicoy Lagoon and reef flat separately and the results are presented and discussed elaborately in this chapter.

MATERIALS AND METHODS

Many investigators have adopted different methods to estimate the abundance of sea-cucumbers. Conand (1990) who used many sampling techniques for quantifying these peculiar animals, stated that the systematic sampling is difficult to assess the population as the holothurians are sedentary mega or macro-benthic organisms and live on hard substratum, under the stone, sea-grass and sea-weedbed. However, quadrate, transect and visual assessment were found suitable and reliable to some extent (Conand, 1990; Bakus, 1992). In the present study also quadrate method was found useful and adapted.

Description of sectors

The study area has been divided in to 12 sectors (6 in lagoon and 6 in reef flat) for the quantitative assessment of major sea-cucumbers (Fig. 4). The various details and description of the area *viz*. location, area in sq.km, bottom characteristics with associated flora and major sea-cucumbers are given in Table 89.

From all the 12 sectors, quantitative assessment was carried out once in three months during 1990 and 1991. A quardrate of 5 x 5 m size was used for sampling the holothurian density. In every quarter, in each sector 5 quardrate sampling were made and the animals were hand picked, identified and counted. The data were enumerated separately for the species available in the lagoon and in the reef flat separately, the results of these studies are enumerated in the following paragraph.

Section A : Sea-cucumbers in the lagoon

The important sea-cucumbers observed in different quarters in the Minicoy Lagoon from January 1990 to December 1991 were *Holothuria atra*, *Holothuria nobilis* and *Bohadschia marmorata* (Fig. 49). Their occurrence and quarterwise abundance in different sectors are dealt in detail below.

Species composition in the lagoon

The species composition in percentage showed that in 1990, *Holothuria atra* constituted 37.93% in Ist quarter (January - March), 36.91% in IInd quarter (April - June), 39.35% in IIIrd quarter (July - September) and 41.02% in IVth quarter (October - December). *H. nobilis* constituted 20.69%, 32.21%, 20.61% and 13.68% in I, II,

TABLE 89. The details of the 12 sectors of the Minicoy Lagoon and Roof flat areas

Sector	Location		Total approximate area in sq.km.	Bottom characteristics	Major sea-cucumbers
	Latitude	Longitude			
1	08°16'10" - 08°17'30"	73°00'40" - 73°02'00"	7.807	With dead corals, boulders With sea weeds *Padina* sp.	*H. atra* *H. nobilis*
2	08°17'50" - 08°18'90"	73°00'50" - 73°02'00"	2.974	Sandy with dead corals and sea weeds *Helimeda gracilis* and *Sargassum* sp.	*H. atra* *H. nobilis*
3	08°17'50" - 08°16'30"	73°02'00" - 73°03'00"	3.653	Sandy with sea grass	*H. marmorata* *H. nobilis*
4	08°17'50" - 08°19'50"	73°02'40" - 73°03'00"	4.101	Sandy with coral boulders	*H. marmorata* *H. atra*
5	08°16'50" - 08°18'60"	73°00'40" - 73°03'90"	2.271	Sandy with dead corals	*H. nobilis*
6	08°18'00" - 08°19'60"	73°00'00" - 73°04'50"	7.064	With dead coral (*Acropora* sp) fragments and sea weeds	*H. atra*
7	08°18'00" - 08°19'30"	73°04'00" - 73°04'80"	1.296	Coralline lime stone with sea weeds *Spiridea felamentasa*, *Gelliedella acerosa*	*H. cinerscenus* *A. mauritiana*

TABLE 89. The details of the 12 sectors of the Minicoy Lagoon and Roof flat areas (contd.)

Sector	Location: Latitude	Location: Longitude	Total approximate area in sq.km.	Bottom characteristics	Major sea-cucumbers
8	08°17'00" - 08°18'0"	73°03'90" - 73°04'20"	0.915	Coarse grained calcarious beach rock with sea weeds *Gelliedella acerosa*	*H. cinerscenus* *A. mauritiana*
9	08°15'80" - 08°17'00"	73°02'80" - 73°04'00"	1.524	Coral rubbles with sea weeds *Turbinaria* sp. and *Acanthopora* sp.	*A. mauritiana* *H. impatiens* *H. atra*
10	08°15'50" - 08°16'10"	73°01'20" - 73°02'80"	1.524	Sandy with seaweeds *Turbinaria* sp. and live coral heads.	*A. mauritiana*
11	08°16'20" - 08°16'80"	73°00'30" - 73°00'60"	0.808	Sandy bottom with coral rubbles and boulders. *Turbinaria* sp. are abundant in this sector.	*A. mauritiana* *H. leucospilota*
12	08°16'80" - 08°18'30"	73°00'40" - 73°00'70"	1.570	Sandy with rubble, boulders and dead coral heads.	*A. mauritiana* *H. leucospilota*

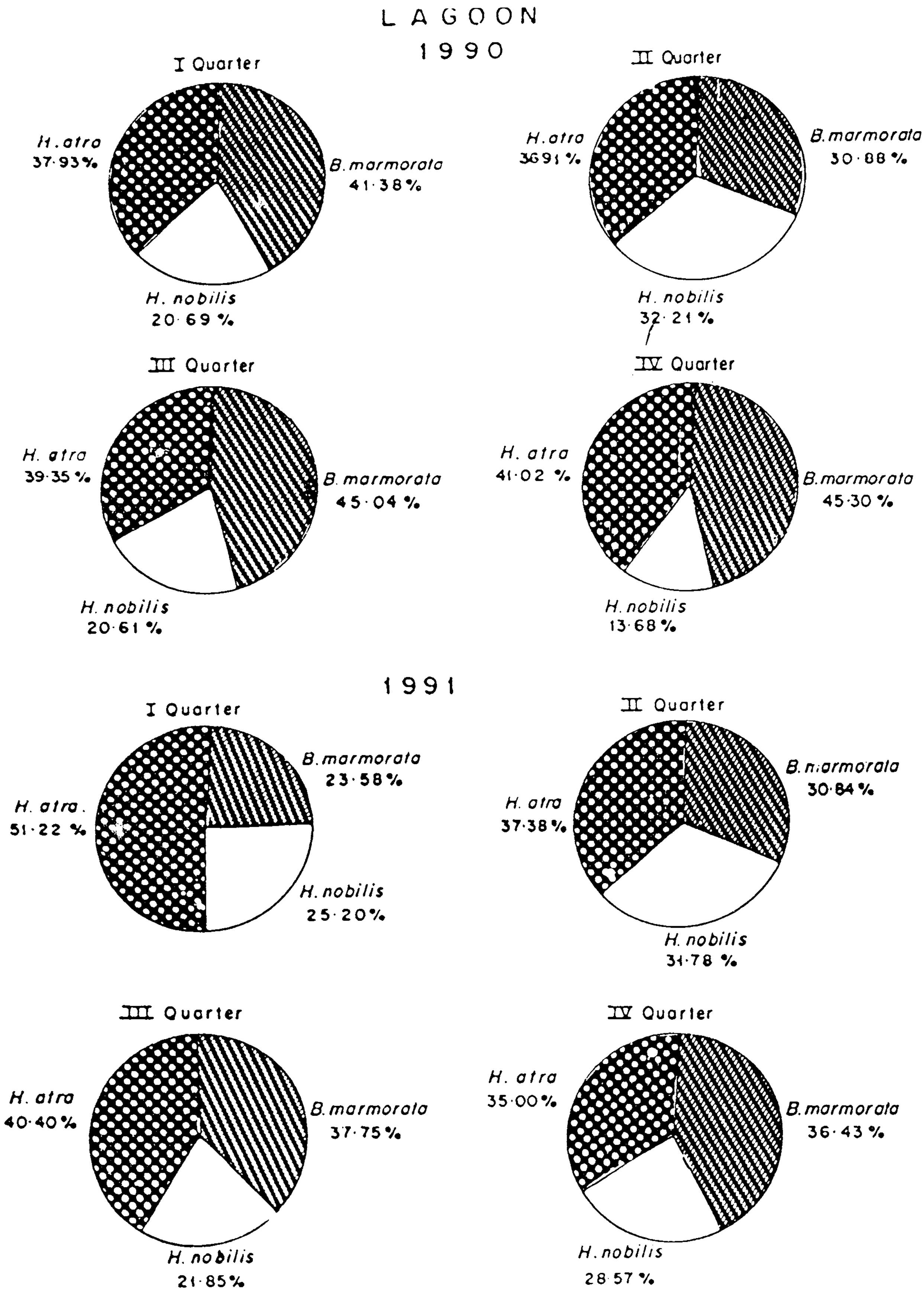


Fig. 49. Composition of sea-cucumbers during different quarters in 1990 and 1991 at Minicoy Lagoon.

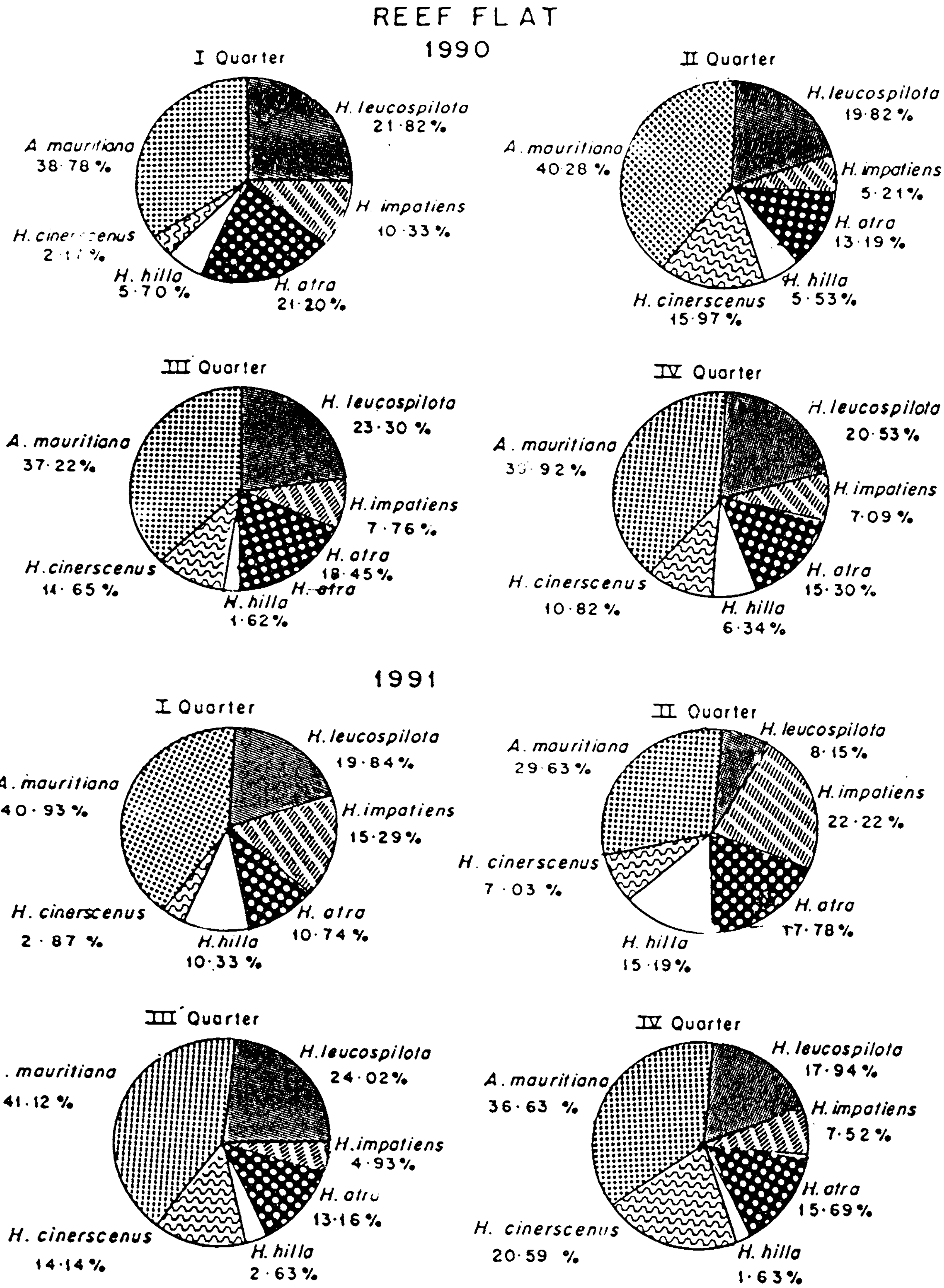


Fig. 50. Composition of sea-cucumbers during different quarters in 1990 and 1991 at Minicoy Reef Flat.

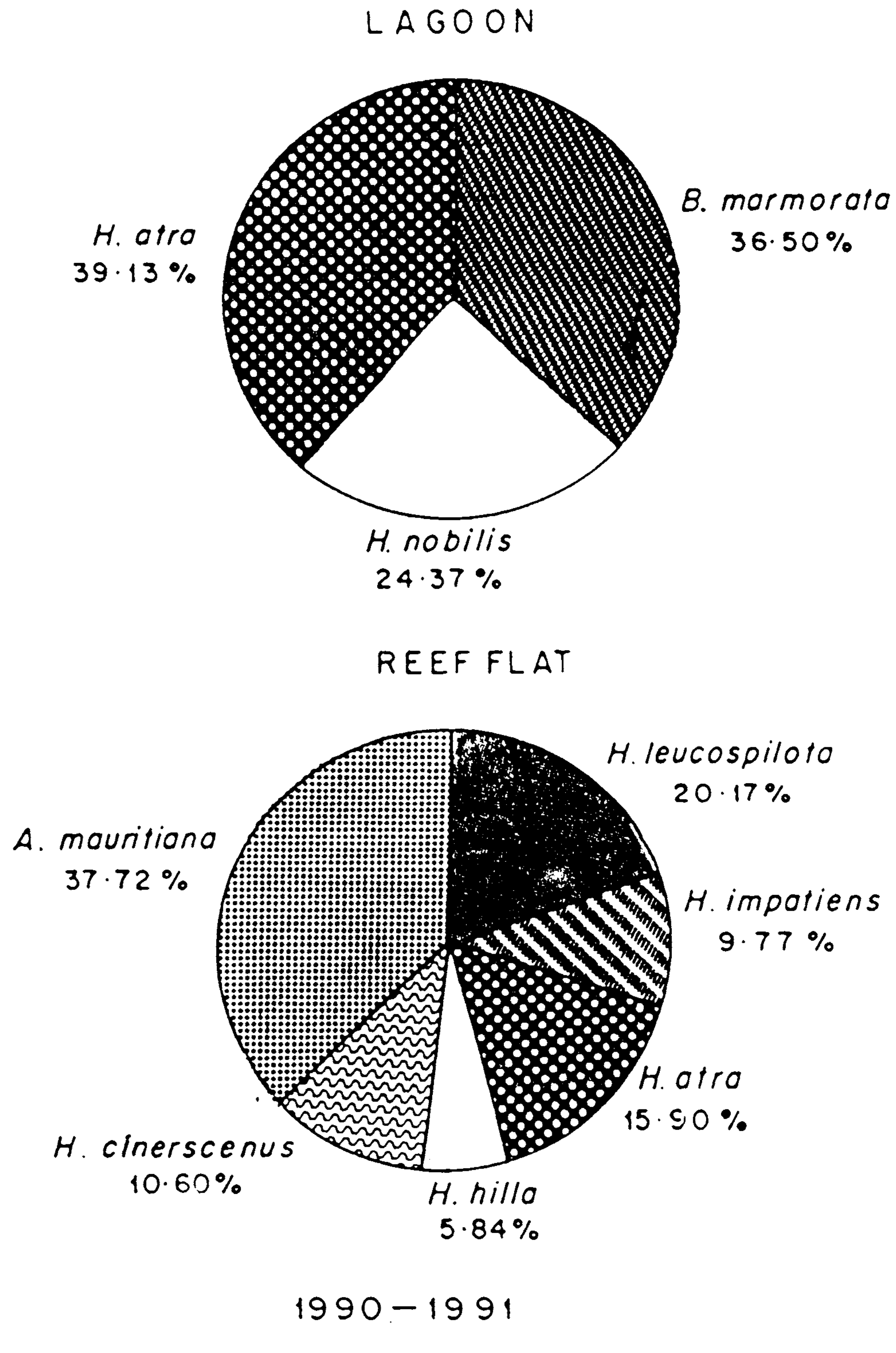


Fig. 51. An average abundance of different species of sea-cucumbers in Minicoy Lagoon and Reef Flat during 1990–1991.

III and IV quarters respectively. B. marmorata showed highest composition among the three species available at lagoon with 41.38%, 30.88%, 40.04% and 45.30% in I, II, III and IV quarters respectively.

In 1991, H. atra was 51.22%, 37.38%, 40.40% and 35.00% in Ist, IInd, IIIrd and IVth quarters. H. nobilis was with 25.20%, 31.78%, 21.85% and 28.57% and B. marmorata was with 23.58%, 30.84%, 37.75% and 36.43% in four quarters respectively.

Holothuria atra

Though Holothuria atra was common in the whole lagoon, the highest percentage composition (41.02%) was noticed in the IVth quarter (October - December) of 1990. The lowest composition was in the IIIrd quarter (July - September) with 39.35%. In the Ist and IInd quarters, the composition was 37.93% and 36.91% respectively. Contrary to 1990, this species was highest (51.22%) in Ist quarter (January - March) and lowest (35.00%) in IVth quarter (October - December). In the IInd and IIIrd quarters, they were 37.38% and 40.40% respectively. But the overall average for two years, H. atra population was 39.13% (Fig. 51).

The quarterwise abundance of H. atra in six different sectors in 1990 was from 2 to 12/100 m^2 in Ist, IIIrd and IVth quarters. In the IInd quarter the density was uniformly between 6 and 10/100m^2 (Fig. 52). In 1991, density was between 2 and 13/100 m^2 during all the four quarters (Fig. 53). The overall average density calculated for 2 years 56/100m^2 in Minicoy Lagoon.

Holothuria nobilis

Holothuria nobilis showed extremely dispersed distribution in the lagoon. In 1990, the highest percentage was recorded in

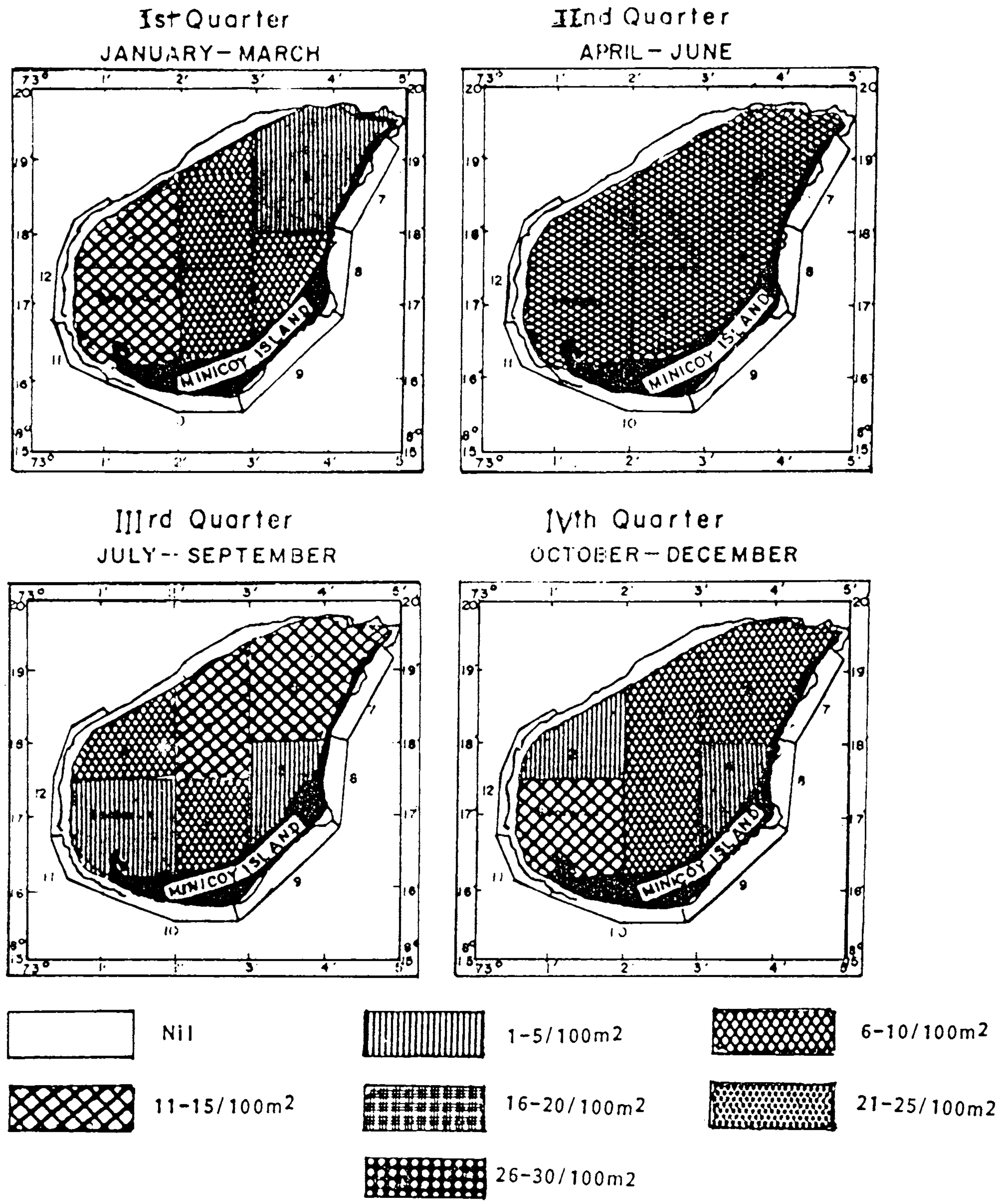


Fig. 52. Quarterwise abundance of H. atra in various sectors in Minicoy Lagoon in 1990

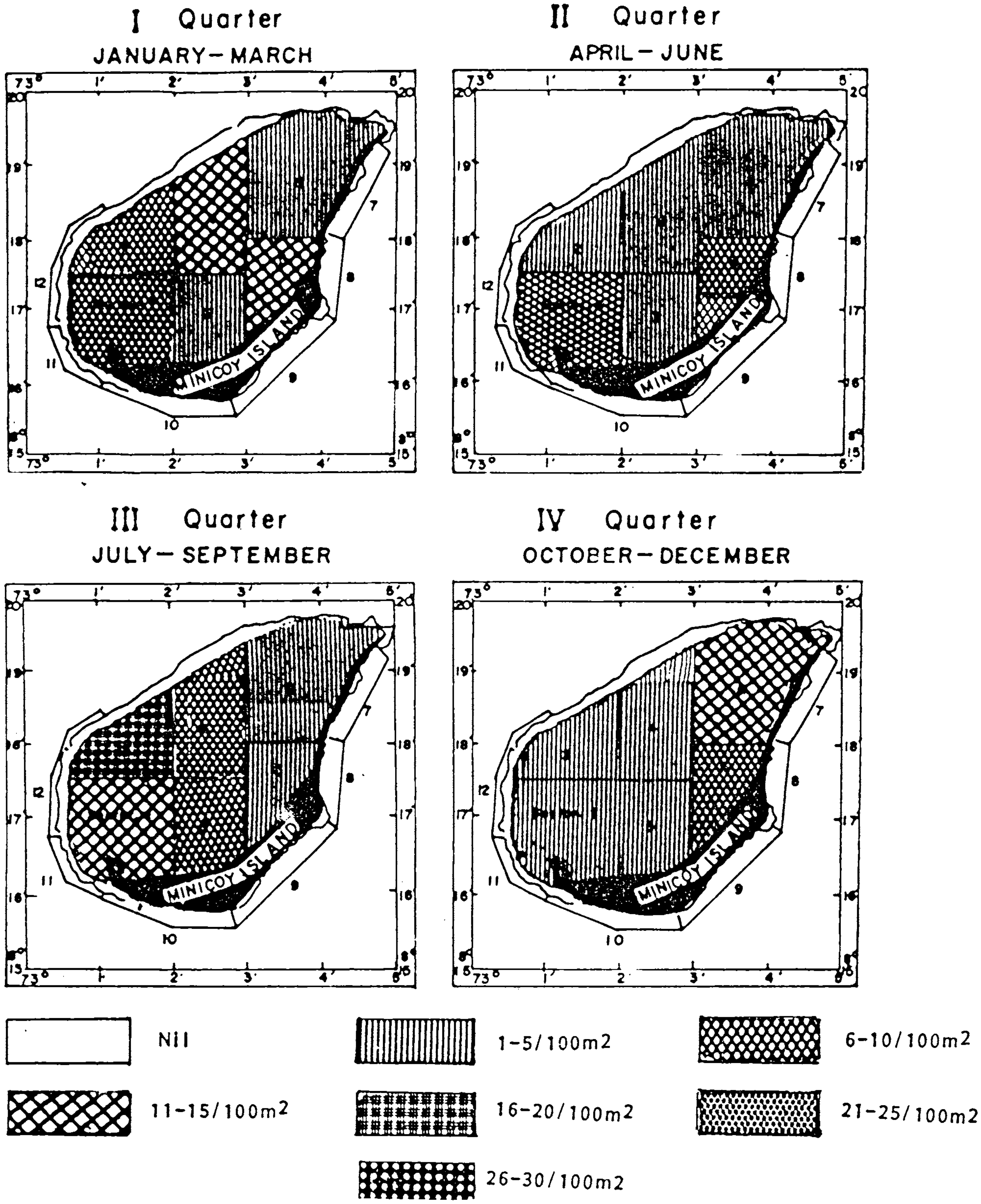


Fig. 53. Quarterwise abundance of H. atra in various sectors in Minicoy Lagoon in 1991

the IInd quarter with 32.21% and the lowest composition was in the IVth quarter with 13.6%. In Ist and IIIrd quarters the percentage compositions were 20.69% and 20.61% respectively. In 1991, the highest was (31.78%) in the IInd quarter and the lowest in the IIIrd quarter with 21.85%. In quarters Ist and IVth the composition was 25.20% and 28.57%. However, the two years average showed 24.37% among three species in the lagoon (Fig. 51).

The quarterwise abundance of H. nobilis in six different sectors and in quarters varied between 0/100 m^2 and 11/100 m^2 in 1990. The highest density (11/100 m^2) was noticed in sector 3 in IInd quarter and sector 5 of IIIrd quarter (Fig. 54). The same for 1991 was in sector 5 in the IIIrd quarter and the no animal was recorded in sector 2 and 4 during IIIrd quarter (Fig. 55).

Bohadschia marmorata

Bohadschia marmorata was the second abundant species next to H. atra in the lagoon. This species was found in groups in the lagoon where substratum was sandy. In 1990, the highest percentage composition (45.30%) was recorded in the IVth quarter, while lowest percentage (30.88%) in the IInd quarter. In the Ist and IIIrd quarter the compositions were 41.38% and 40.04% respectively. In 1991, the same was highest in the IIIrd quarter with 37.75% and the lowest was in the Ist quarter with 23.58%. In the IInd and IVth quarters, the percentage compositions were 30.84% and 36.43% respectively. The two years average showed 36.50% among three species in the lagoon.

The quarterwise abundance of B. marmorata in 1990 varied between 0/100 m and 20/100 m^2. The highest density of 18, 16 and 20/100 m^2 were recorded in sector 3 in the Ist, IIIrd and IVth quarters respectively. In the IIIrd quarter, in sector 5 and 6 no

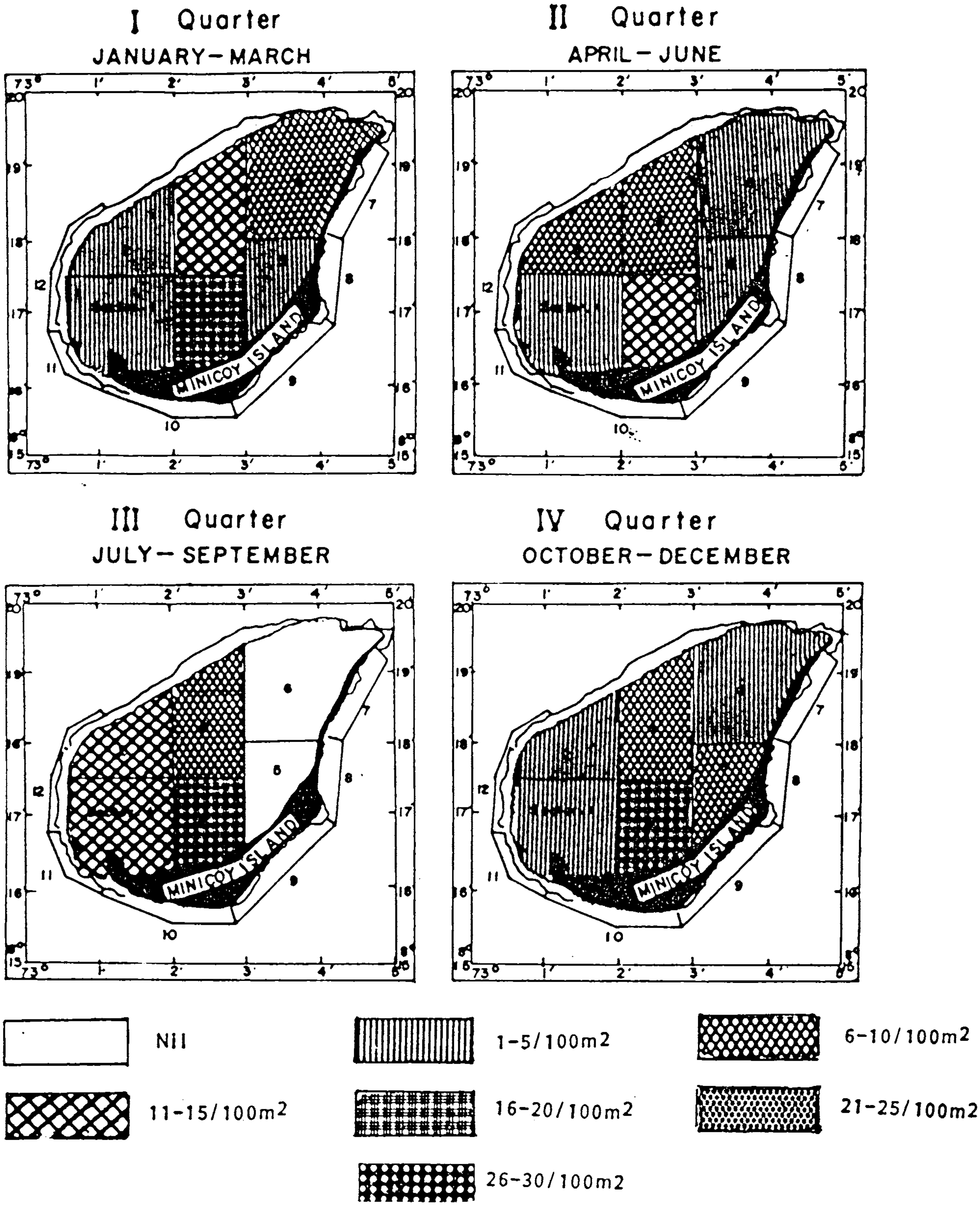


Fig. 54. Quarterwise abundance of B. marmorata in various sectors in Minicoy Lagoon during 1990.

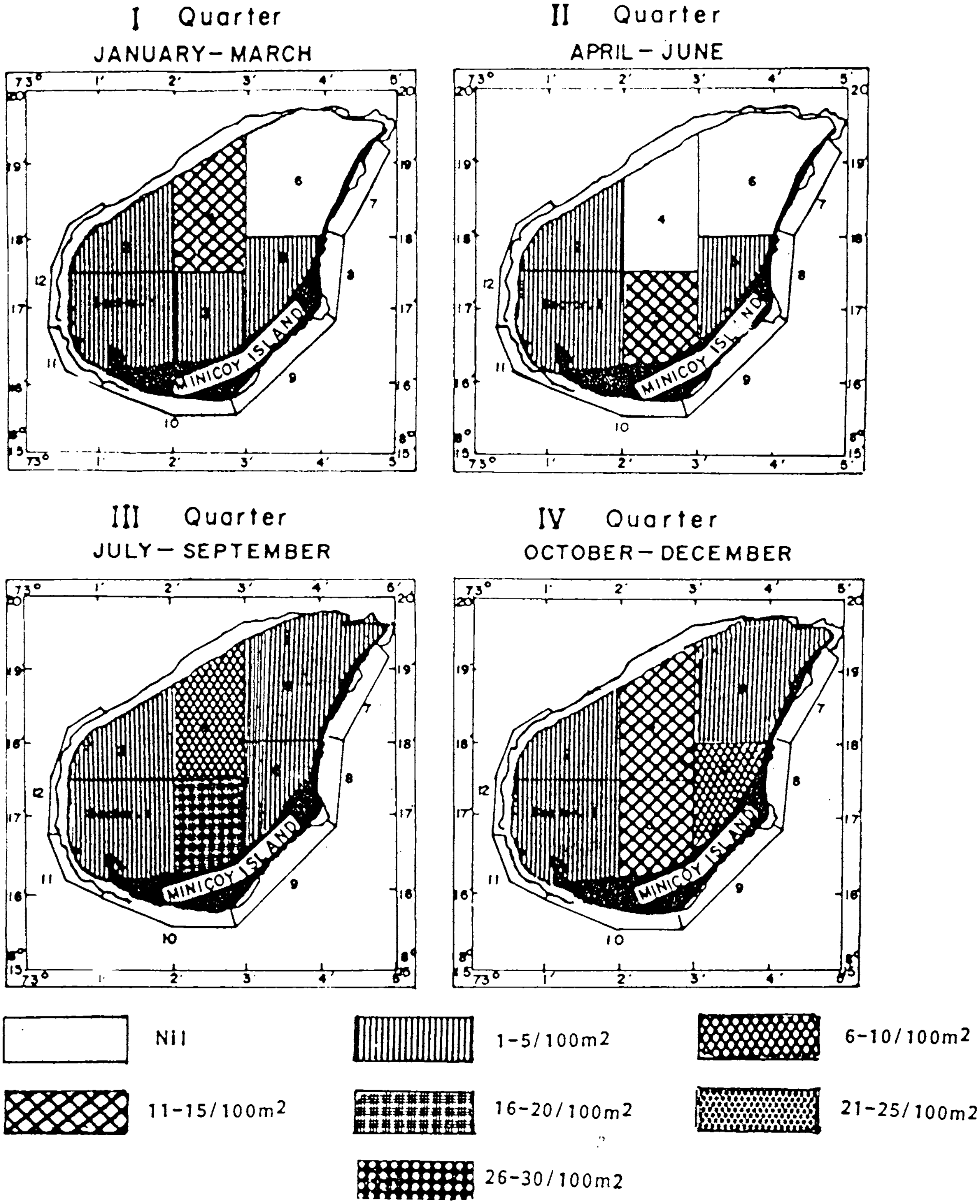


Fig. 55. Quarterwise abundance of B. marmorata in various sectors in Minicoy Lagoon.

animal was recorded in 1990 (Fig. 56). In 1991, the density varied from 0/100 m^2 to 20/100 m^2. The highest density of 20/100 m^2 was noticed in sector 3 in the IIIrd quarter. The lowest density of 0/100 m was noticed in sector 6 of Ist quarter and sector 4 and 6 of IInd quarter (Fig. 57). The over all density calculated was 52/100 m^2 in the Minicoy Lagoon.

Section B : Sea-cucumbers in the Reef Flat

The abundance of six species of sea-cucumbers viz. Actinopyga mauritiana, Holothuria cinerscenus, Holothuria hilla, Holothuria atra, Holothuria impatiens and Holothuria leucospilota during four quarters of 1990 and 1991 in the Minicoy Reef Flat were studied and presented here (Fig. 50).

Species composition in the Reef Flat

The percentage of species composition in Ist quarter (January-March), IInd quarter (April-June), IIIrd quarter (July-September) and IVth quarter (October-December) respectively during 1990 is as follows. A. mauritiana was with 38.78%, 40.28%, 37.22% and 39.92%; H. cinerscenus was with 2.17%, 15.97%, 11.65% and 10.82%; H. hilla was with 5.70%, 5.53%, 1.62% and 6.34%; H. impatiens was with 10.33%, 5.21%, 7.76% and 7.09%; H. atra was with 21.20%, 13.19%, 18.45% and 15.30%; H. leucospilota was with 21.82%, 19.82%, 23.30% and 20.53% in I, II, III and IV quarters respectively.

In 1991, A. mauritiana was 40.93%, 26.63%, 41.12% and 36.63% in I, II, III and IV quarters respectively. H. cinerascenus was with 2.87%, 7.03%, 14.14% and 20.59%; H. hilla was with 10.33%, 15.19%, 2.63% and 1.63%; H. atra was with 10.74%, 17.78%, 13.16% and 15.69%

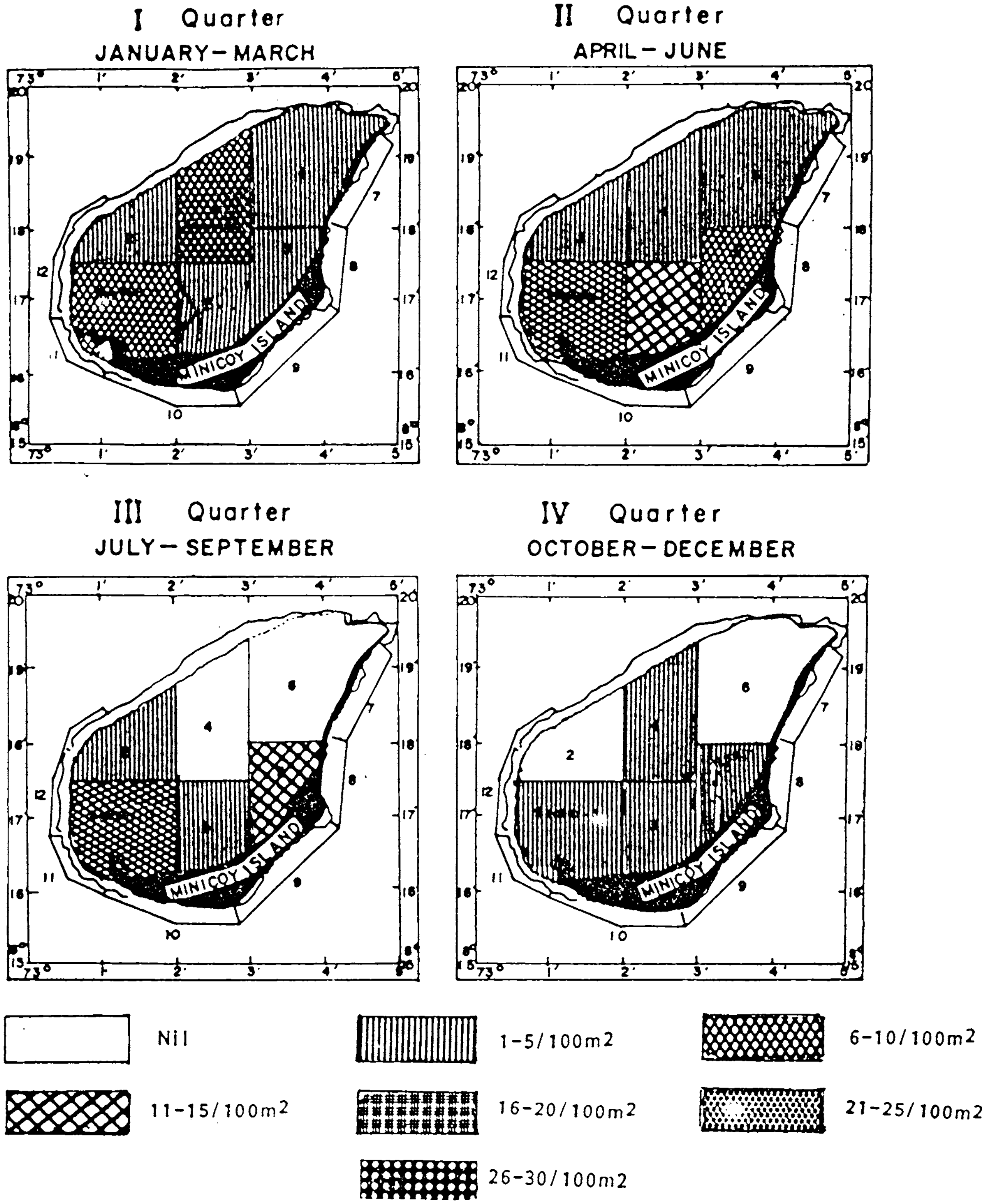


Fig. 56. Quarterwise abundance of H. nobilis in various sectors in Minicoy Lagoon during 1990.

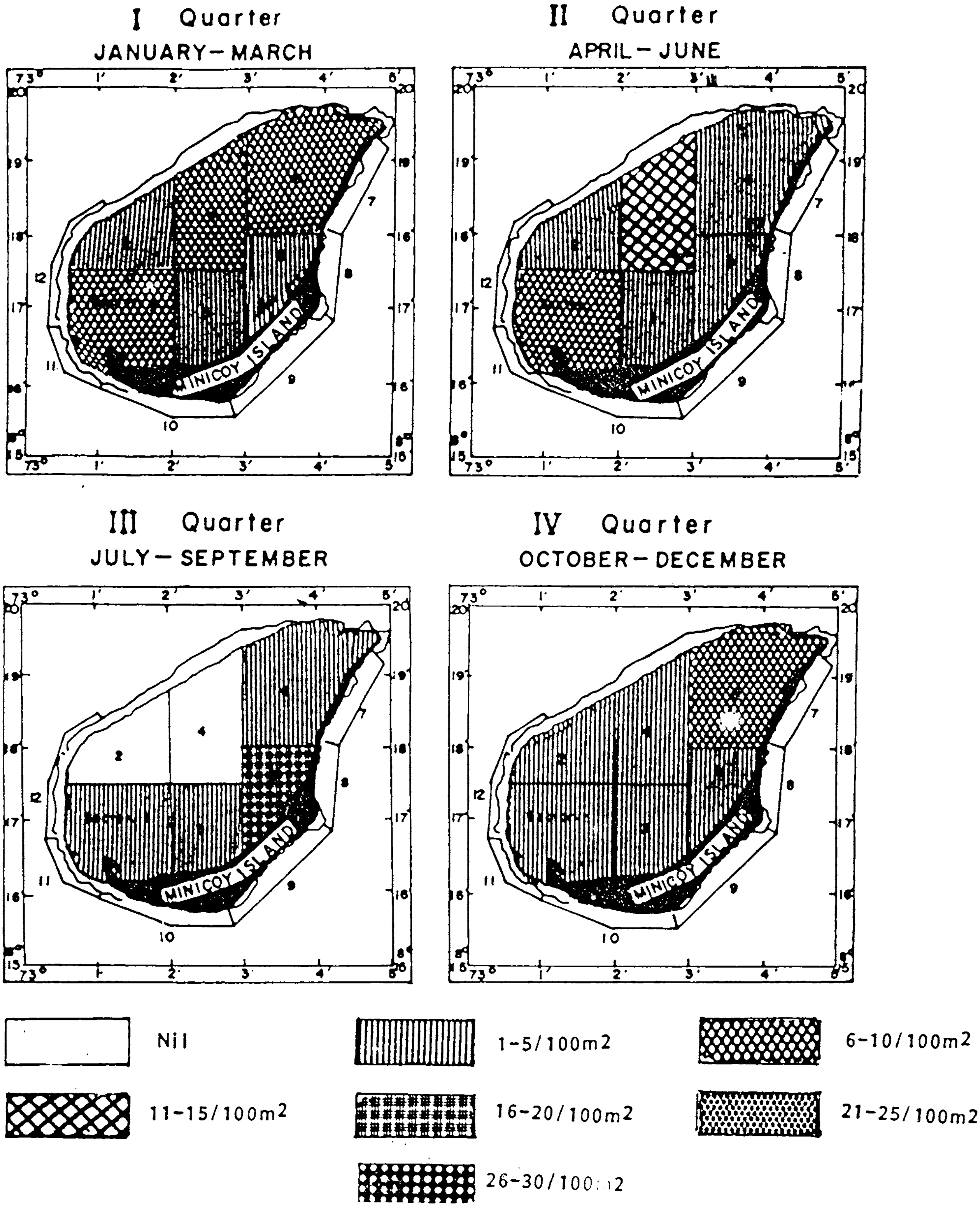


Fig. 57. Quarterwise abundance of H. nobilis in various sectors in Minicoy Lagoon during 1991.

H. impatiens was with 15.29%, 22.22%, 4.93%, 7.52% and H. leucospilota was with 19.84%, 8.15%, 24.02% and 17.94% in I, II, III and IV quarters respectively.

Actinopyga mauritiana

Actinopyga mauritiana was commonest in the reef flat. The highest percentage (40.28%) was noticed in the IInd quarter and lowest (37.22%) in the IIIrd quarter of 1990. In Ist and IVth quarters the percentage was 38.78% and 39.92% respectively. In 1991, this species was recorded highest (41.12%) in the IIIrd quarter and the lowest (29.63%) in the IInd quarter. In Ist and IVth quarters the percentage was 40.93% and 36.63% respectively. The two year average was 37.72% among six species in the reef flat (Fig. 51).

The quarterwise abundance of A. mauritiana in 1990, varied between 3/100 m^2 and 30/100 m^2. The highest density was noticed in sector 8 (30/100 m^2) of the Ist quarter, sector 12 (26/100 m^2) of the IIIrd quarter, sector 10 (26/100 m^2) of the IVth quarter (Fig. 58). In 1991, the abundance varied between 2/100 m^2 and 26/100 m^2. The highest density was noticed in sector 9 (26/100 m^2) during I, II and III quarters (Fig. 59). The two year average density calculated was 118/100 m^2 in Minicoy Reef Flat.

Holothuria cinerscenus

Holothuria cinerscenus was scarce in the reef flat. In 1990, the maximum percentage was recorded in the IInd quarter (15.97%) and the lowest in the Ist quarter (2.17%). In IIIrd and IVth quarters the percentage was 11.65% and 10.82% respectively. In 1991, the density was maximum (20.59%) in the IVth quarter and the lowest (2.87%) in the Ist quarter. In II and III quarters the percentage was 15.19% and 14.14% respectively. The two years average showed 10.60% among six species in the reef flat (Fig. 51).

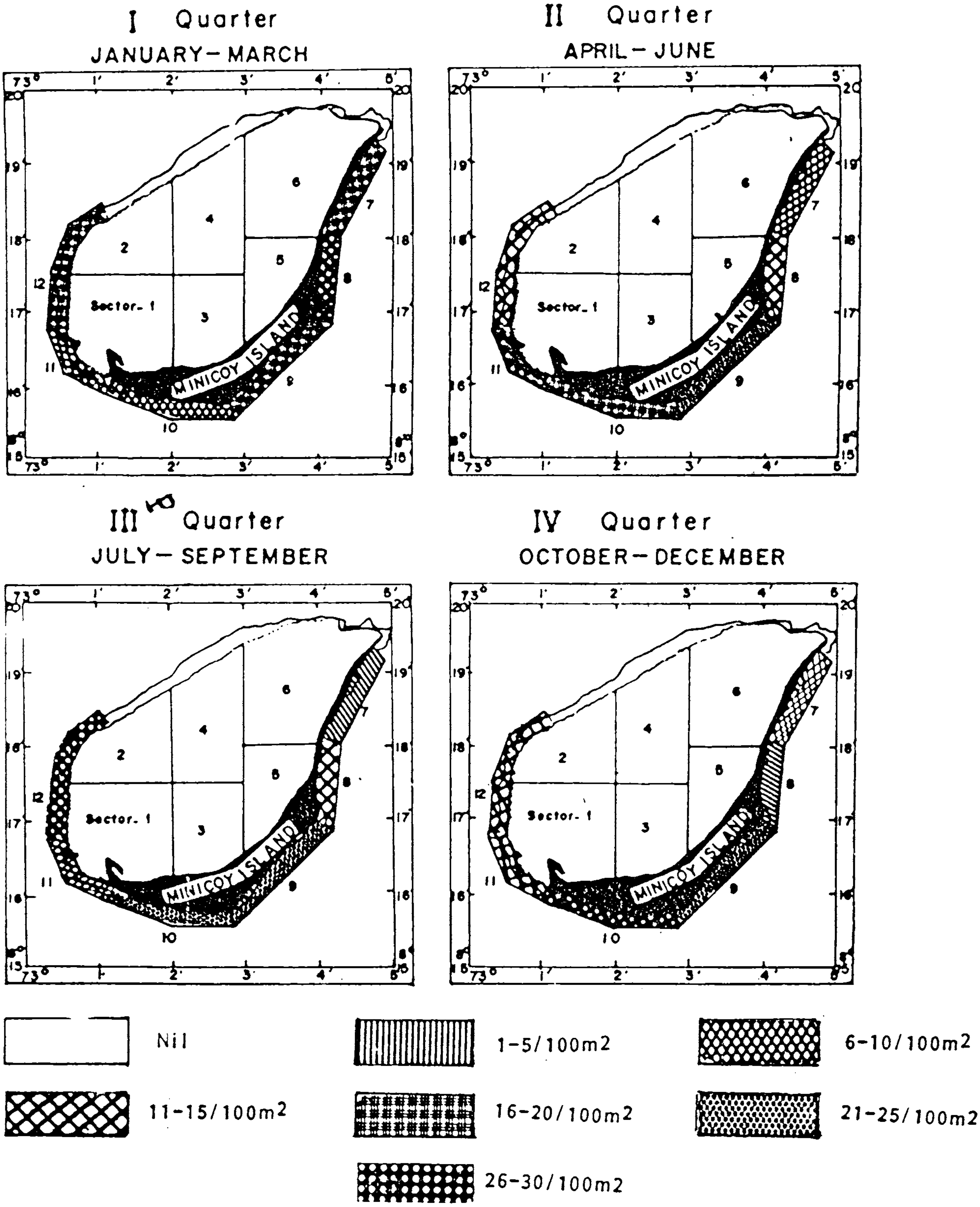


Fig. 58. Quarterwise abundance of A. mauritiana in various sectors in Minicoy Reef Flat during 1990.

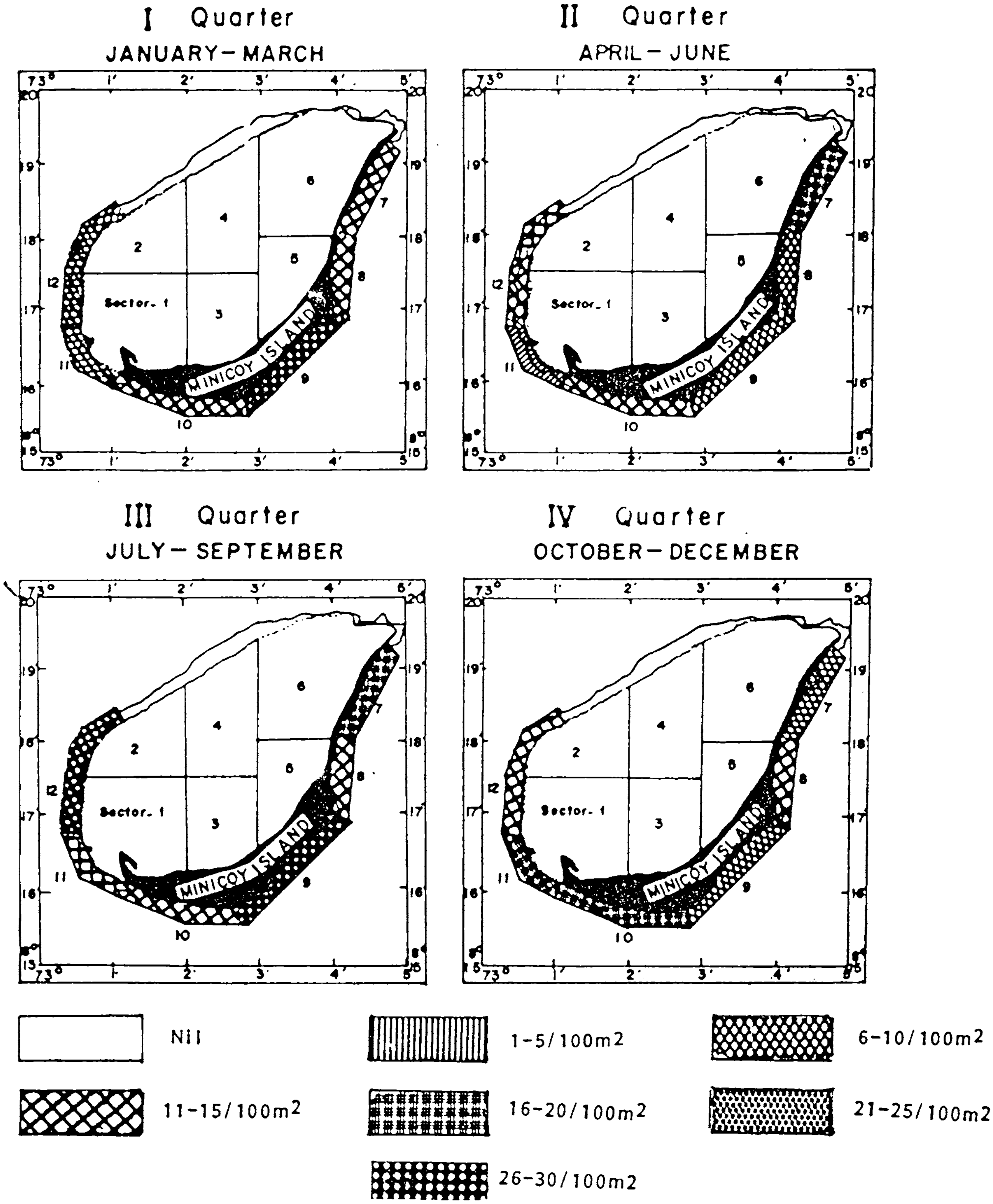


Fig. 59. Quarterwise abundance of A. mauritiana in various sectors in Minicoy Reef Flat during 1991.

The quarterwise abundance of <u>H. cinerscenus</u> varied from 0/100 m^2 to 23/100 m^2 in 1990 (Fig. 60). The highest density (23/100 m^2) was noticed in sector 7 in the Ist and IVth quarters. No animal was recorded in sectors 9 and 11 of I, II, III and IV quarters, sector 10 of the Ist and IVth quarters, and sector 12 of I, III and IVth quarter.

In 1991, this species abundance varied from 0/100 m^2 to 33/100 m^2 (Fig. 61). The highest (33/100 m^2) was found in the sector 7 in IVth quarter. No animal was found in the sector 9 in IInd and IIIrd quarters, in sector 10 of the Ist and IInd quarter, in sector 2 of the IIIrd and the IVth quarter and in sector 12 of Ist, IInd and IIIrd quarters. The overall average density calculated for 2 years was 15/100 m^2.

<u>Holothuria hilla</u>

<u>Holothuria hilla</u> was the least abundant species among the six species recorded in the reef flat. The characteristic of this species is that during day time it is found under coral stone and in night time they move freely in the reef flat. In 1990, the highest percentage (6.34%) was noticed in the IVth quarter and the lowest (1.62%) in the IIIrd quarter. In Ist and IInd quarters the percentage was 5.70% and 5.53% respectively. In 1991, this species was more in the IInd quarter with 15.19% and lowest in the IVth quarter with 1.63%. In Ist and IIIrd quarters the percentage was 10.33% and 2.63% respectively. The two years average was only 5.84% (Fig. 51).

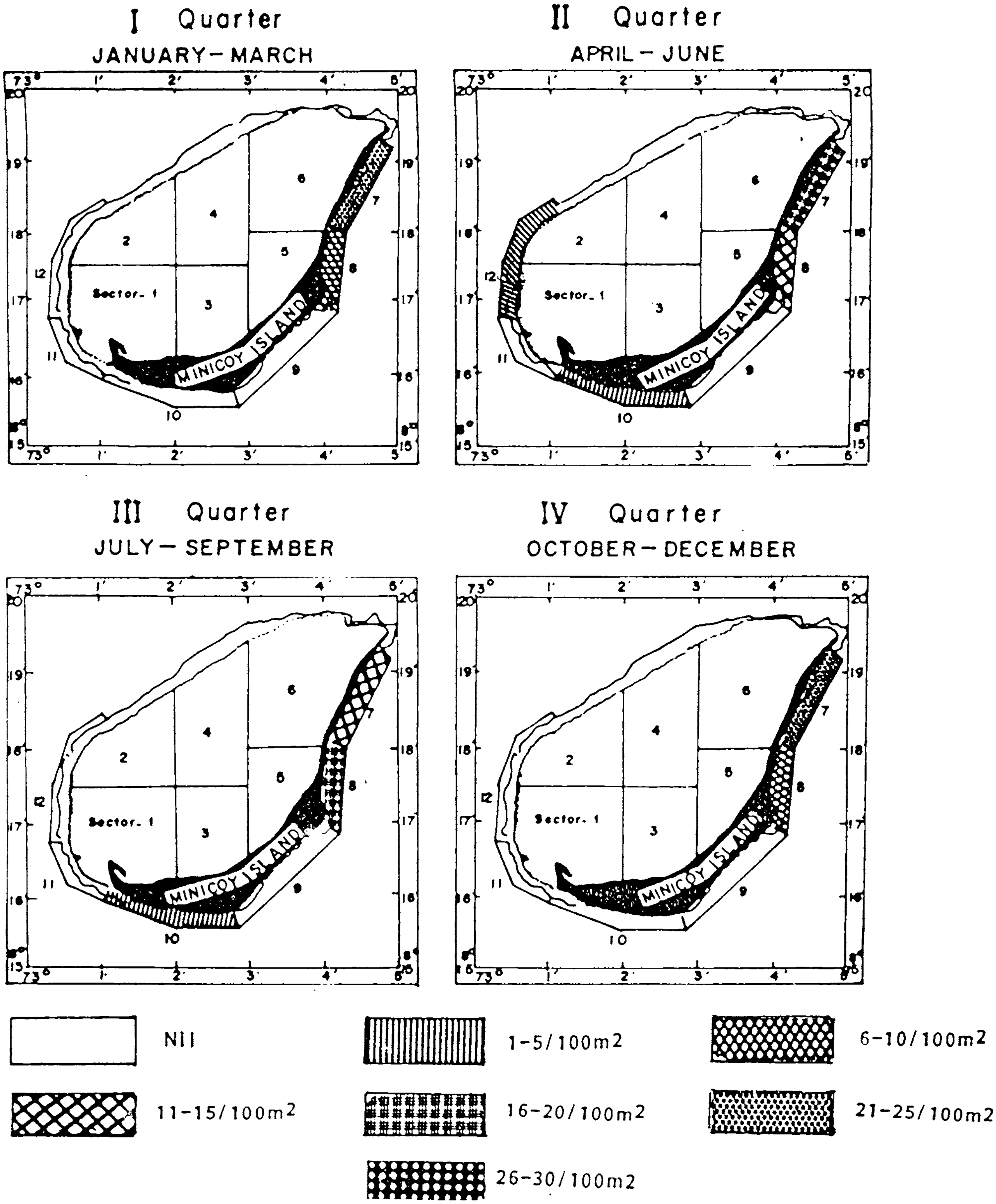


Fig. 60. Quarterwise abundance of H. Cinerscenus in various sectors in Minicoy Reef Flat during 1990.

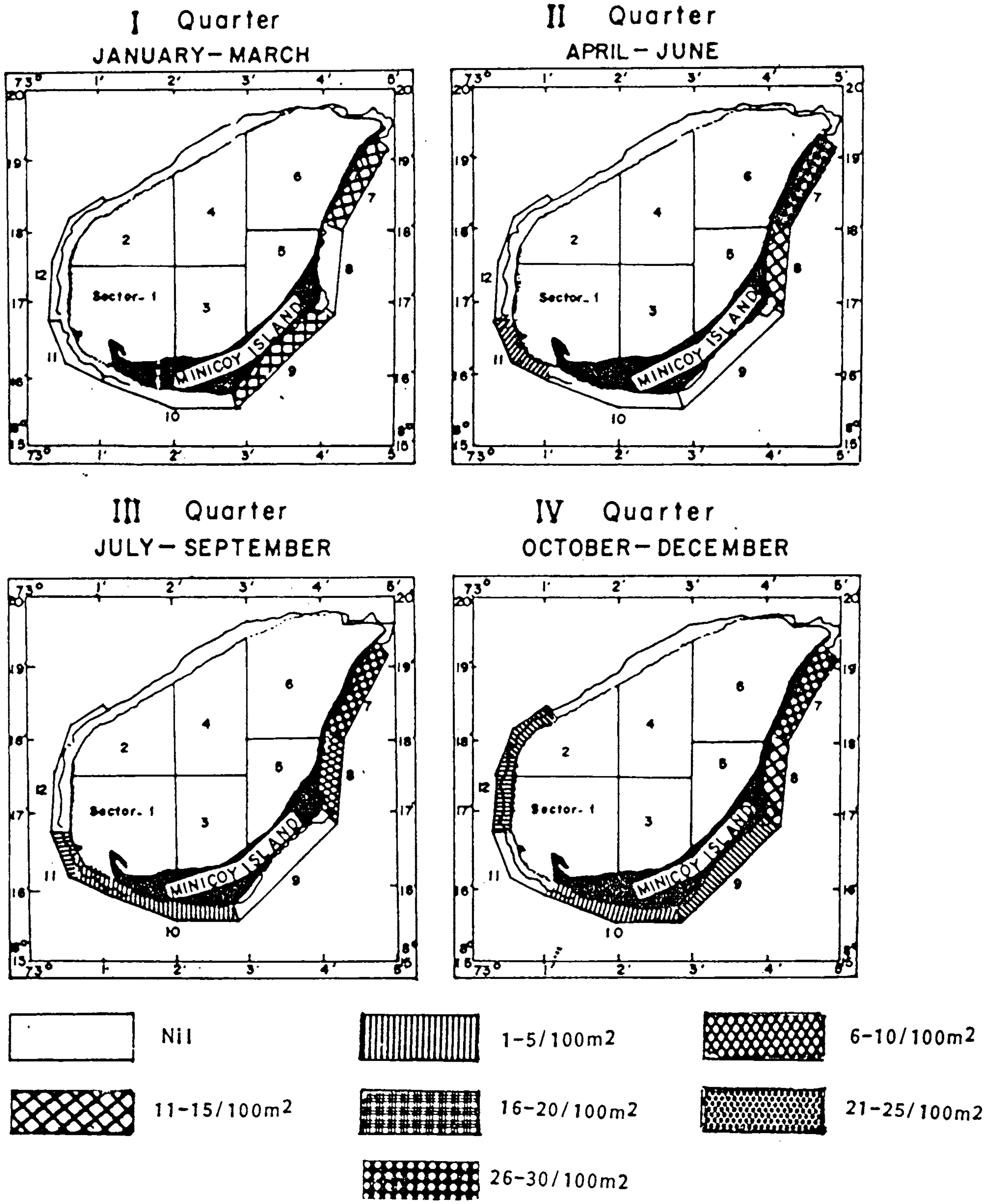


Fig. 61. Quarterwise abundance of H. Cinerscenus in various sectors in Minicoy Reef Flat during 1991.

The quarterwise abundance of *H. hilla* in 1990, varied from 0/100 m^2. The highest density (8/100 m^2) was found in sector 8 in the IInd quarter. No animal was found in sector 8 in IIIrd quarter, in sector 9 in IInd quarter and in sector 10, 11 and 12 in IInd and IIIrd quarters (Fig. 62). In 1991, the abundance varied between 0/100 m^2 and 4/100 m^2. The highest density (4/100 m^2) was found in sector 7 in the IInd quarter and in sector 12 of the Ist quarter. No animal was found in sector 7 and 11 in IIIrd quarter, in sector 8 and 12 of IInd and IIIrd quarters, in sector 9 and 10 of Ist quarter (Fig. 63). The overall average density calculated for 2 years was 14/100 m^2.

Holothuria atra

Holothuria atra was the third dominant species in the reef flat. But compared to the lagoon, their composition and abundance were very low in the reef flat. In 1990, this species was the highest (21.20%) in the Ist quarter and the lowest (13.19%) in the IInd quarter. In IIIrd and IVthe quarters the percentage was 18.45% and 15.30% respectively. In 1991, the highest percentage was noticed in the IInd quarter (17.78%) and the lowest in the Ist quarter (10.74%). In IIIrd and IVth quarters the percentage was 13.16% and 15.69% respectively. The over all average percentage calculated for 2 years was 15.90% (Fig. 51).

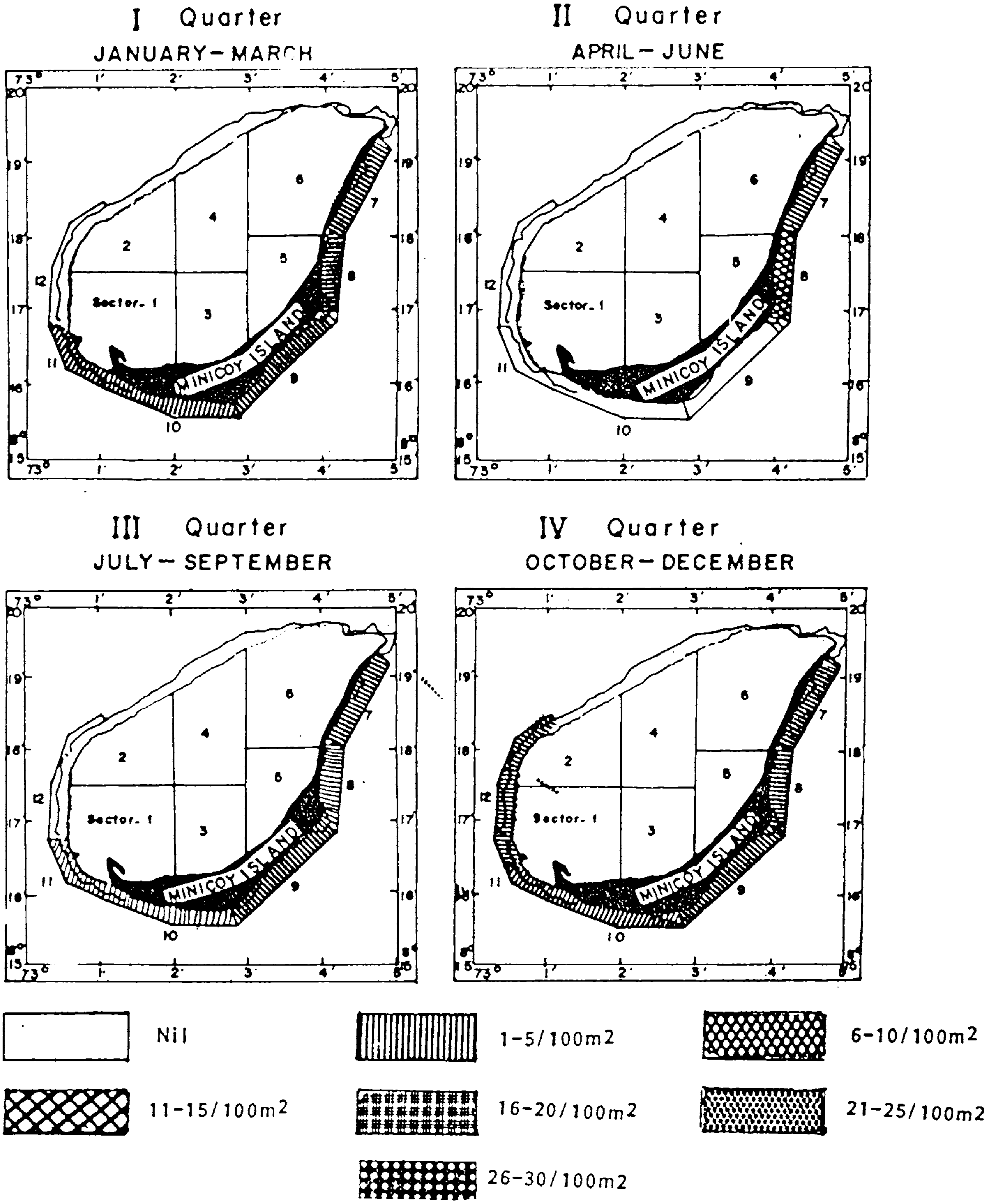


Fig. 62. Quarterwise abundance of H. hilla in various sectors in Minicoy Reef Flat during 1990.

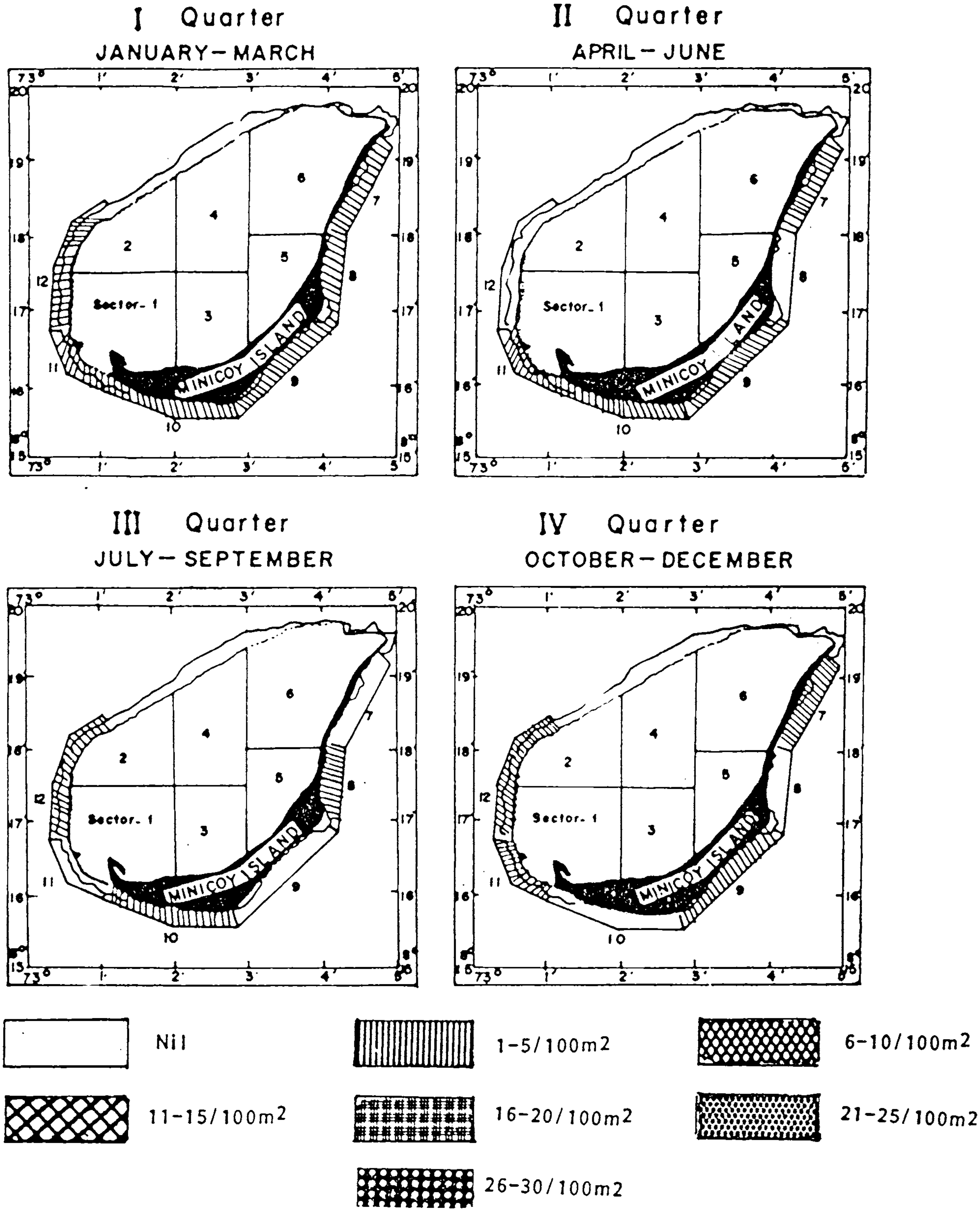


Fig. 63. Quarterwise abundance of H. hilla in various sectors in Minicoy Reef Flat during 1991.

The quarterwise abundance of H. atra in six different sectors in four quarters varied between 0/100 m^2 and 19/100 m^2 in 1990 (Fig. 64). The highest density (19/100 m^2) was found in sector 8 in Ist quarter, while no animal was found in sector 7 of Ist and IInd quarters and in sector of Ist quarter. In 1991, the abundance varied between 0/100 m^2 and 12/100 m^2. The highest density of 12/100 m^2 was recorded in sector 9 in IVth quarter (Fig. 65). No animal was recorded in sector 8 in the Ist quarter.

Holothuria impatiens

Holothuria impatiens was also one of the least abundant species in reef flat. This species inhabits mostly in the reef edge where live corals are available. In 1990, the highest percentage (10. 33%) was noticed in the Ist quarter and loweest (5.21%) in the IInd quarter. In the IIIrd and IVthe quarters the composition was 7.76% and 7.09% respectively. In 1991, this species was in the highest percentage (22.22%) in IInd quarter and the lowest in the IIIrd quarter (4.93%). In the IInd and IVth quarters the composition was 15.29% and 7.52% respectively. The two years average of this species composition was nearly 9.77% among six species recorded in the reef flat (Fig. 51).

The quarterwise abundance of H. impatiens in six different sectors varied between 0/100 m^2 and 22/100 m^2 in 1990. The highest density (22/100 m^2) was found in sector 9 of the Ist quarter and no animal was found in sector 8 of IIIrd quarter, in sector 10, 11 and 12 of IInd quarter (Fig. 66). In 1991, the same was varied from 0/100 m^2 to 14/100 m^2. The highest density (14/100 m^2) was found in sector 9 in the IIIrd quarter and no animal was found in sector 7 in the Ist and IInd quarters, in sector 10, 11 in the Ist and IIIrd quarters and in the sector 12 of IIIrd quarter (Fig. 67).

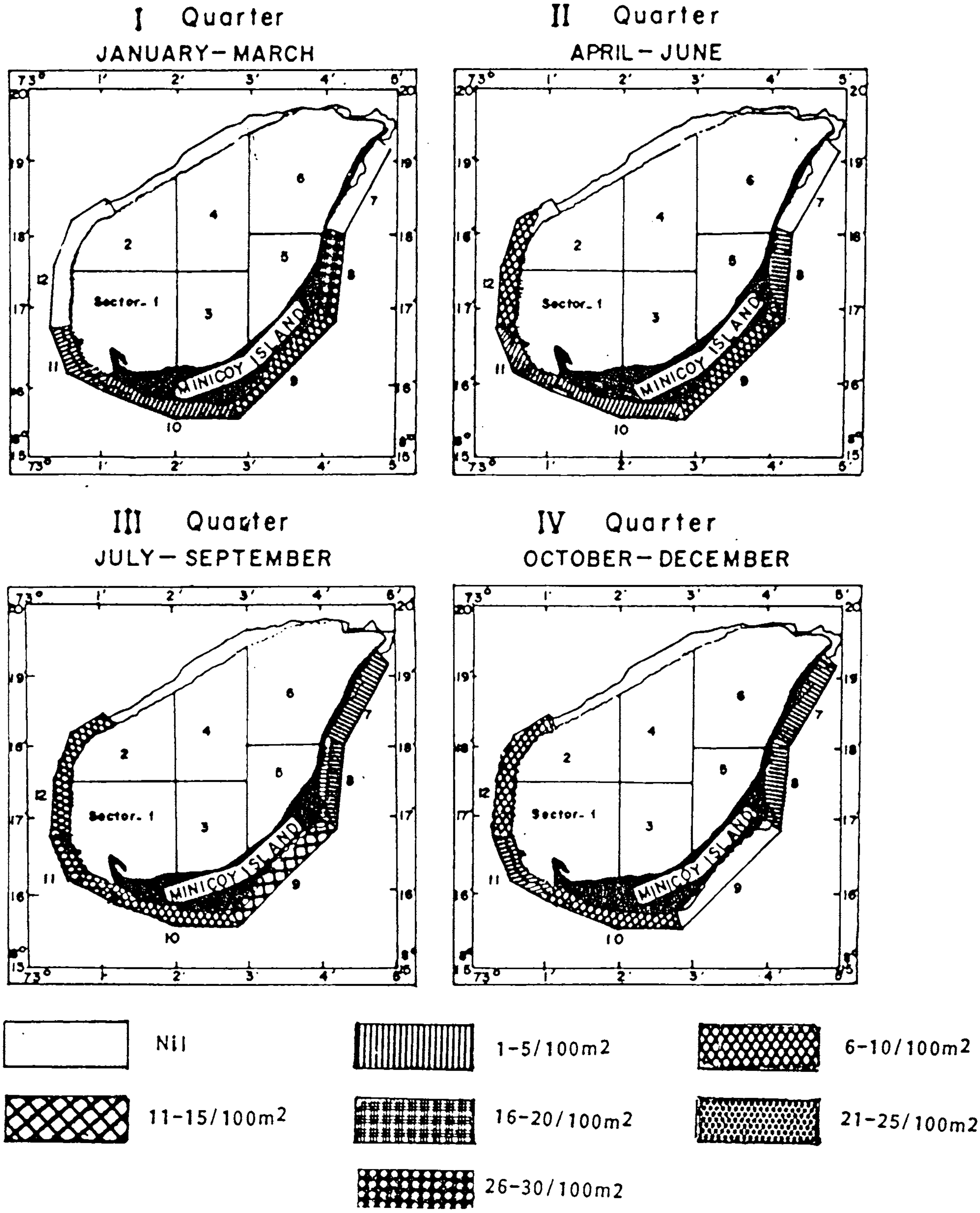


Fig. 64. Quarterwise abundance of H. atra in various sectors in Minicoy Reef Flat during 1990.

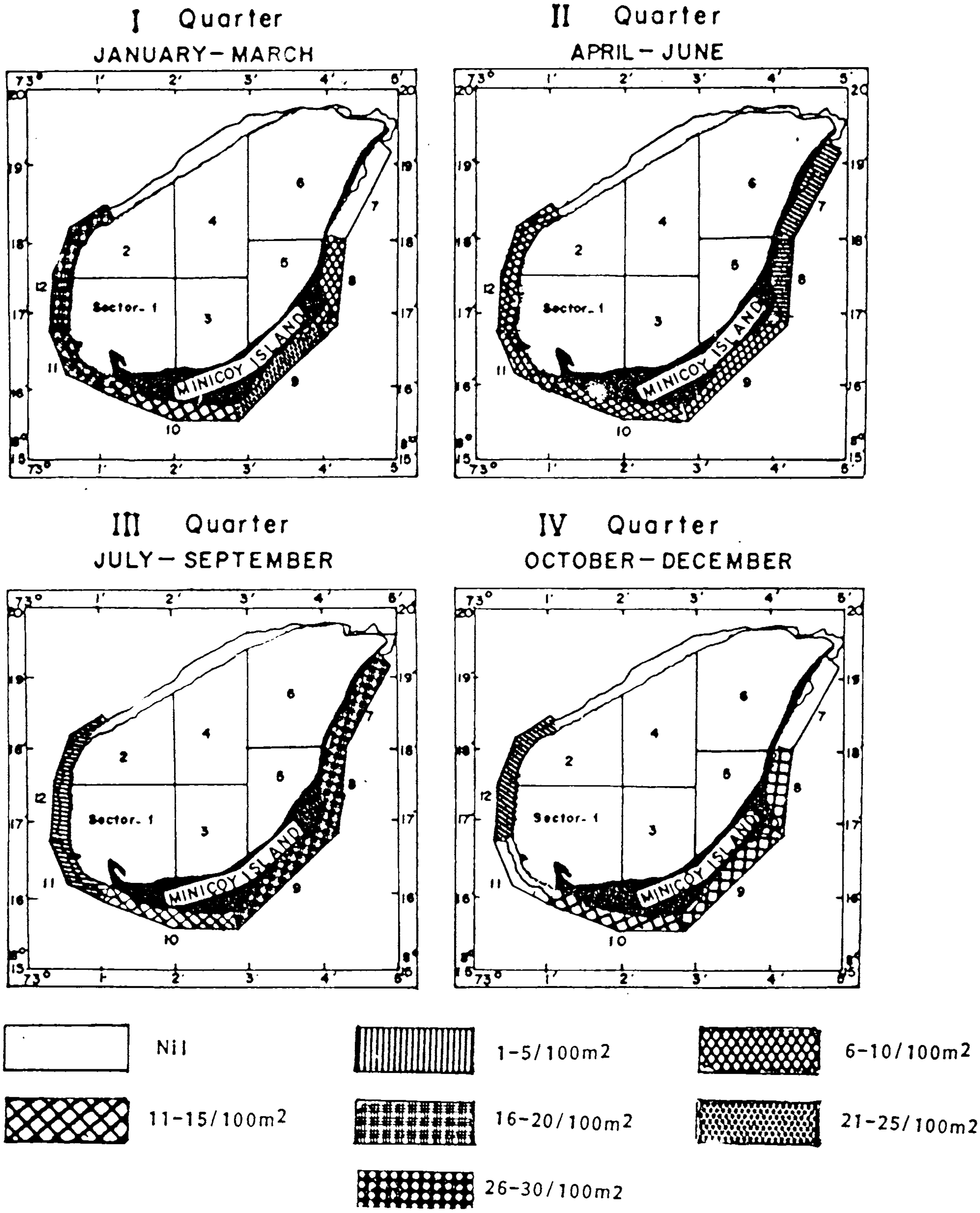


Fig. 65. Quarterwise abundance of H. atra in various sectors in Minicoy Reef Flat during 1991.

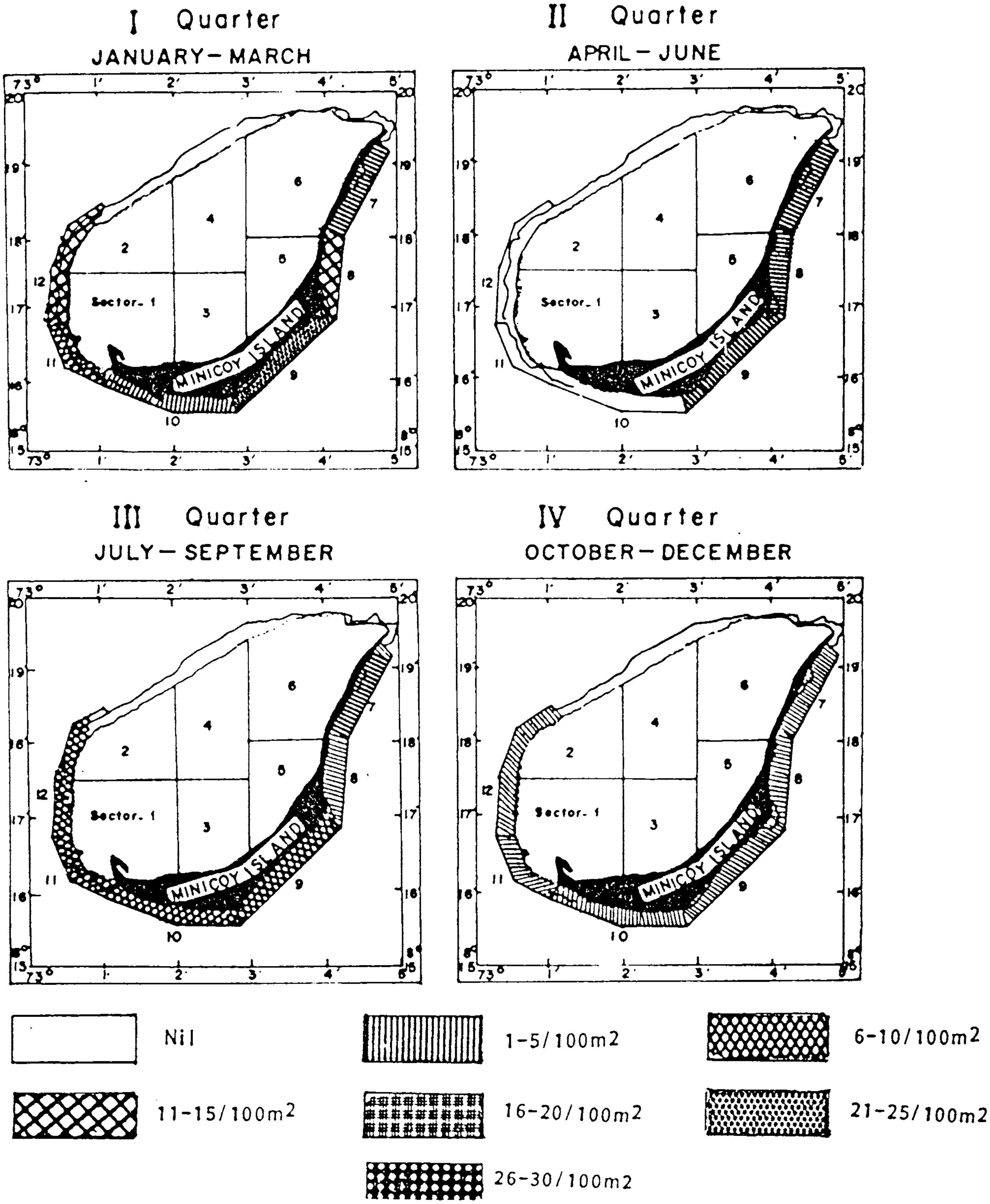


Fig. 66. Quarterwise abundance of H. impatiens in various sectors in Minicoy Reef Flat during 1990.

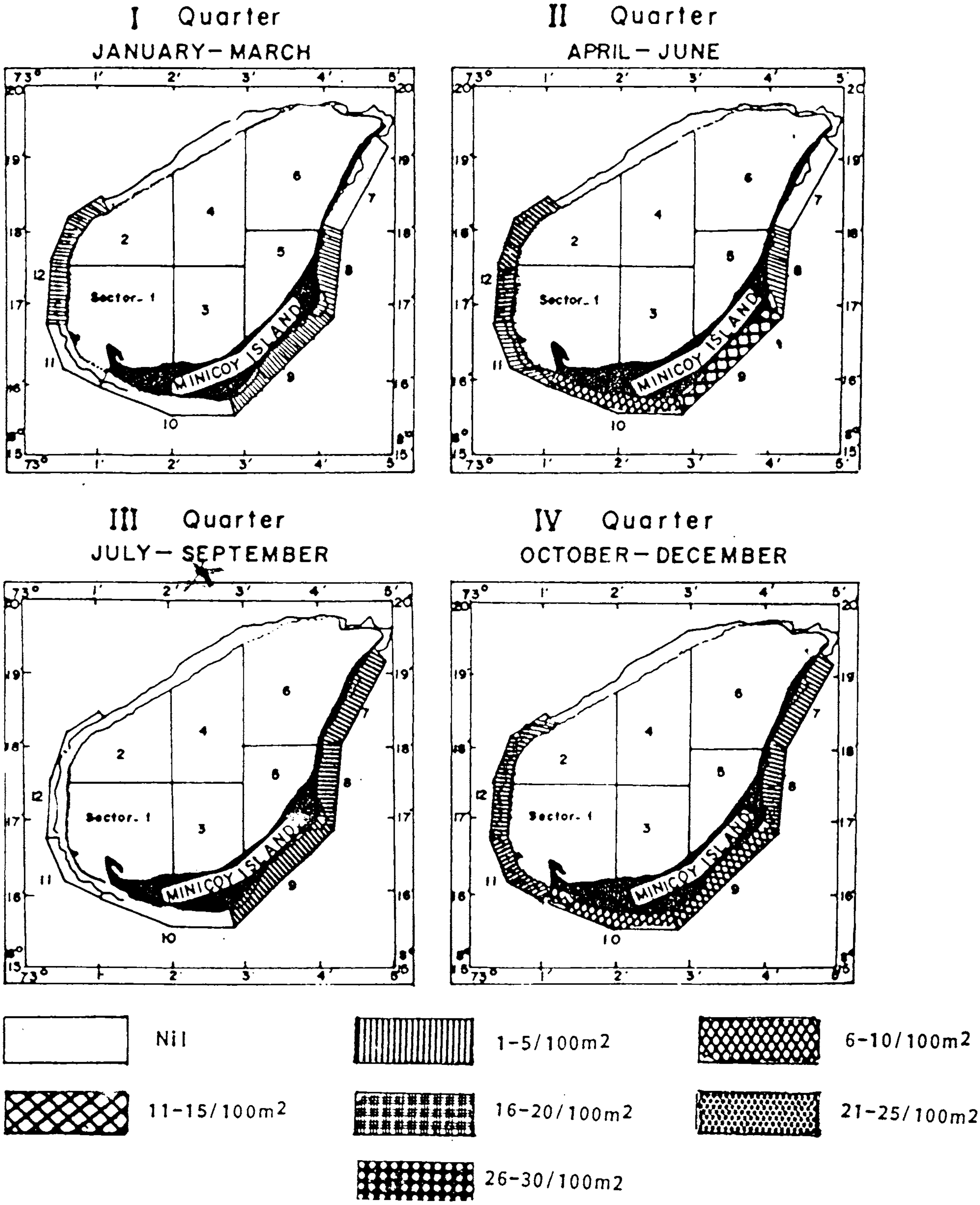


Fig. 67. Quarterwise abundance of H. impatiens in various sectors in Minicoy Reef Flat during 1991

Holothuria leucospilota

Holothuria leucospilota was the second highest in abundance and next to A. mauritiana in reef flat. In 1990, this species composition was the highest (23.30) in the IIIrd quarter and lowest (19.82%) in the IInd quarter. In the Ist and IVth quarters the composition was 21.82% and 20.53% respectively. In 1991, the same was highest (24.02%) in the IIIrd quarter and the lowest (8.15%) in the IInd quarter. In the Ist and IInd quarters, the composition was 19.84% & 17.94% respectively. The two years average of this species composition was 20.17% (Fig. 51).

The quarterwise abundance of H. leucospilota in 1990, varied between 0/100 m^2 and 21/100 m^2. The highest density of 21/100m^2 was recorded in sector 9 in the Ist quarter and no animal was recorded in sector 7 during Ist to IIIrd quarter (Fig. 68).

In 1991, the density varied between 0/100 m^2 and 19/100 m^2. The highest density of 19/100 m^2 was found in sector 9 in the IVth quarter and no animal was found in sector 7 in the II, III and IVth quarters, and in the sector 9 during IInd quarter.

DISCUSSION

Sea-cucumber is gaining importance as one of the secondary resources from the marine environment, along with the seaweeds, molluscs and corals, while the finfishes and crustaceans particularly the prawns are consideredd as major living resources from the sea. The recent advancement in India as well as elsewhere in the world is the large scale culture of sea-cucumbers by ranching the hatchery developed/reared juveniles and young ones. This, to some extent

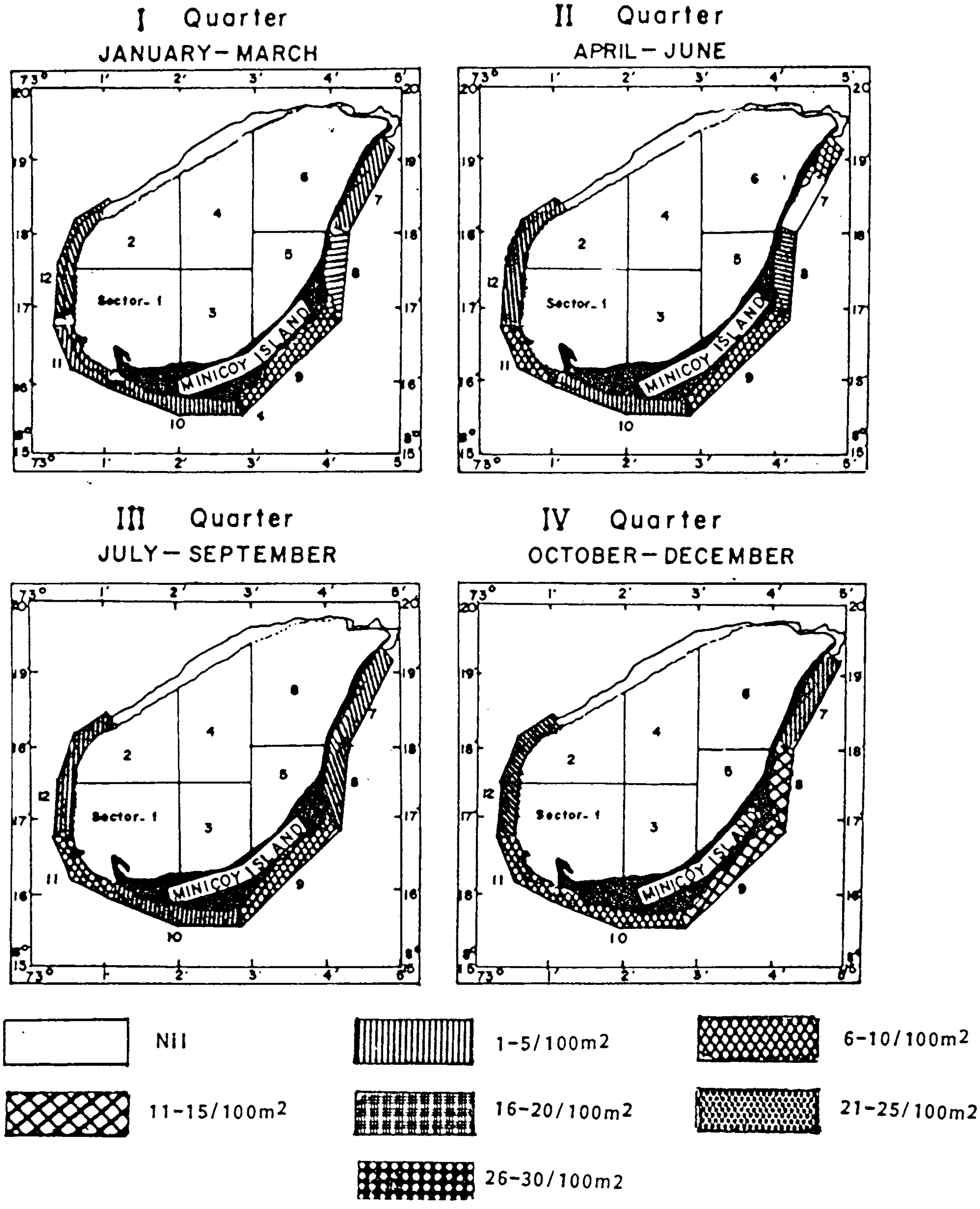


Fig. 68. Quarterwise abundance of H. leucospilota in various sectors in Minicoy Reef Flat during 1990.

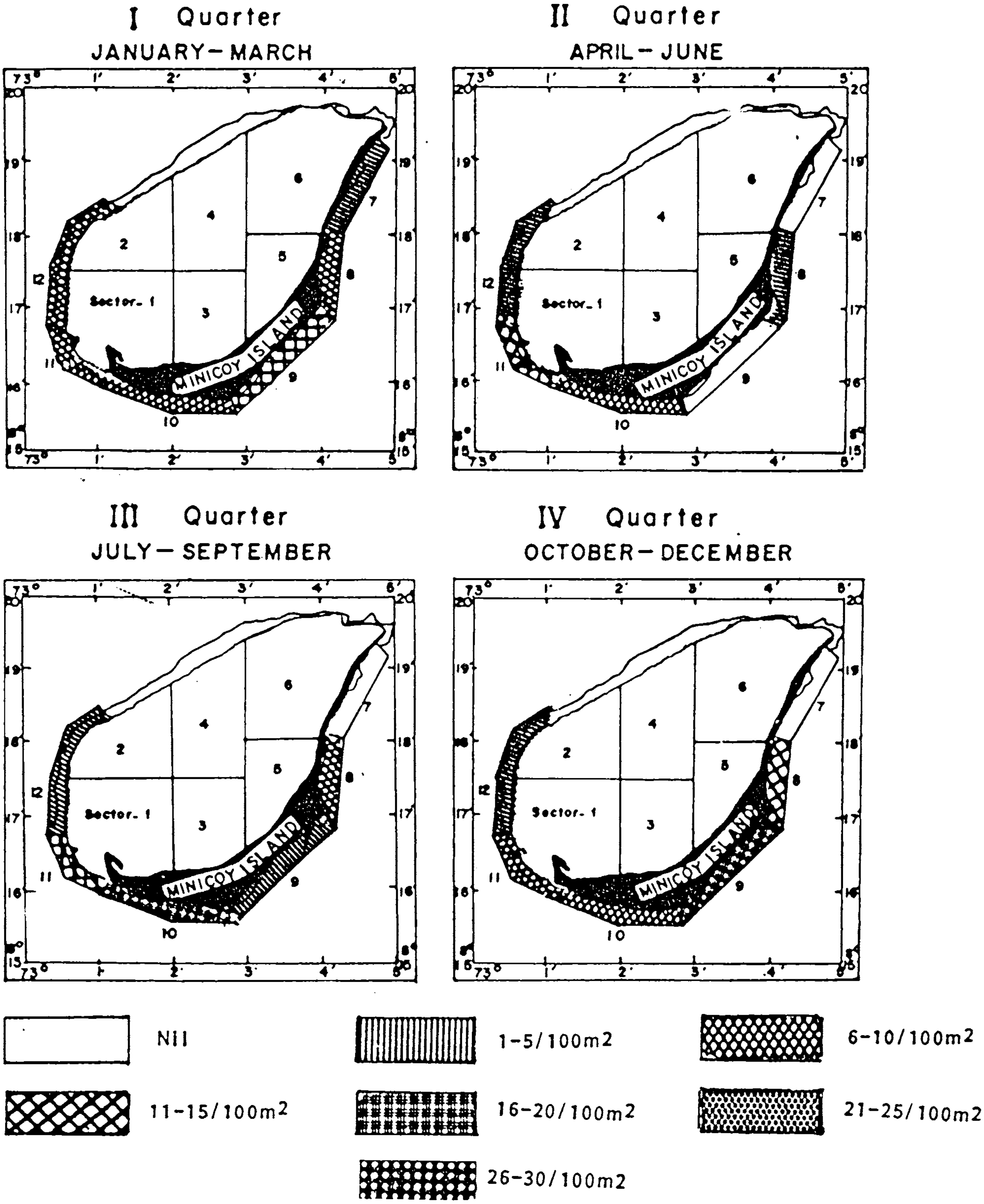


Fig. 69. Quarterwise abundance of H. leucospilota in various sectors in Minicoy Reef Flat during 1991.

may meet the Beche-de-mer requirements of the world, particularly the requirements of the Asian countries and more specifically the Chinese. Though some studies have been carried out on the occurrence of sea-cucumbers, their taxonomical account, their ecology and to a smaller extent on the hatchery technology, production of seeds of sea-cucumbers, no work has been so far initiated to quantitatvely estimate the abundance and their seasonal fluctuations in Indian waters. At the same time, considerable amount of works have been carried out on the quantitative estimation of zooplanktons such as foraminiferans (Coswamy, 1979), siphonophores (Rengarajan, 1983), Copepodes (Pillay, 1976; Thomson, 1980), Ostrocodes (James, 1975), Euphansids (Mathew, 1982) from Indian waters particularly from the south west coast of India.

A reasonable amount of work on quantitative estimation of sea-cucumbers have been investigated from the different regions of the world by different workers as given below.

Species	Density	Locality	Reference
Holothuria atra	7/25 m^2	Gaua Is., New Hebrides	Baker, 1929
H. atra	5/m^2	Inhaca Is., Mozambique	Macnae and Kalk, 1962
H. atra	0.44/m^2	Palau Is.	Yamanouti, 1939
H. atra	1/10 m^2	Enewetok Atoll Marshall Is.	Bakus, 1968
H. atra	5-35/m^2	Aniyaanii Is.	Bakus, 1968
H. atra	56/100 m^2	Minicoy Is.	Present study

To fill up the cap from Indian water and to understand the abundance of commercially important and abundantly available species of sea-cucumbers from Minicoy Island both from the lagoon and the reef flat area, it has been investigated by the candidate and interesting results obtained are discussed in the following paragraphs.

"The earth worm of the sea" the holothurians are mainly deposit feeders and they are considered as a "reworkers" of sediments in coral reef Islands (Bonham and Held, 1963; Bakus, 1973; Webb et al., 1977). However, larger numbers of holothurians are occurring in sheltered shallow water habitat particularly in the tropics. The present study area in Minicoy Island in the Indian Ocean is having the holothurian fauna similar to that of Indo-Pacific region (James, 1989).

Lagoon species

Holothuria atra

The three species from the lagoon are H. atra, H. nobilis and B. marmorata of which H. atra was dominant constituting 39.13% with a density of $56/100\ m^2$. This finding well coincides with the observations of Hammond et al. (1985) who have obtained 41% with a density of $0.25/m^2$ to $0.50/m^2$ from the central section of the Great Barrier Reef. Conand (1990) reported that H. atra represents 33% in the lagoon of the New Caledonia. The other reports on the abundance and density of H. atra have already been shown.

The slight variations in the findings of the different authors with that of the candidate may mainly be due to a variety of estimation methods adopted.

Crozier (1915) reported and found regeneration of either end of the body in about 10% of H. surinamensis. Asexual reproduction by fission is not uncommon in holothurians as observed by many workers Frizzell and Exline (1958), Ebert (1978) and by the candidate.

Contradictory to the above, the candidate also found only 4 animals not having any sex organs out of 64 H. atra were dissected and sexes differentiated. It is further observed by the candidate that the animal was found in different size groups in the population in the study area. Ebert (1978) stated "It is possible that large individuals are not found in certain areas, because transverse fission takes place at small and medium sizes. Certain environmental features could promote asexual reproduction and in such location only small to medium size animals would be found". Bonham and Held (1963) reported that the lack of apparent age class or frequency mode is due to fission in this animal from Rongelap Atoll, Marshall Island. These statements may optly be applied to the present observation by the candidate from the Minicoy Island where different size groups of H. atra were found in the population.

The non-selectivity of feed by H. atra from the study area by the candidate is also similar to the observations by Massin and Douman (1986). This is further evidenced by the uniform distribution of this species in all the sectors in the Minicoy Lagoon, which has varied substratum and the availability of all type of feed in the gut content of H. atra which was discussed in earlier chapter in this Thesis.

Bohadschia marmorata

Next to H. atra, B. marmorata is the second abundant species with 36.05% and density of 52/100 m^2. An another species Bohadschia argus was found to be 19% in the total population with density 50/hectare as reported by Conand (1990) from New Caledonia.

This species was found mainly from the very coarse sandy habitat where water current and wave action were less. This view is confirmed from the observation of 16 to 20/100 m^2 from sector III, which is known for its sandy bottom with boulders. This is further evidenced by the burrowing habitat of the animal which was also reported by Hammond et al. (1985) from the central sector of the Great Barrier Reef, Australia.

Holothuria nobilis

It was observed that H. nobilis was constituting 24.37% in population with a density of 33/100 m^2 from the study area, which is very much comparable to that from the New Caledonia (Conand, 1990). Harriot (1985) observed from Australia that H. nobilis was found 20/hectare from outer reef slope. The candidate has observed a scattered distribution for H. nobilis from Minicoy Lagoon with a higher abundance in section III and V. These two sectors are closer to the land with little wave action and water current, which forms an ideal habitat for H. nobilis. However, Townsley and Townsley (1973) found that H. nobilis was in higher numbers in the seaward reef of Fanning Island and identified this as a reef species. But Conand (1990) from New Caledonia, Gentle (1979) from Suva Reef and Massin and Doumen (1986) from Papua New Guinea have described H. nobilis as lagoon species. This species was collected by SCUBA diving from 8 m depth from the slope area and 5 m depth from the lagoon area from the New Caledonia by Conand (1981, 1990). It is observed here that H. nobilis was much influenced by monsoon and no population was found from the II quarter of 1990 and 1991 from sector 4 and 6. It is observed here that H. nobilis was much influenced by monsoon and no population was found in the sector 4 and 6 of IIIrd quarter and in the sector 2 and 6 of IVth quarter during 1990. In 1991, no animal was found at sectors 2 and 4 in IIIrd quarter, where the wave action was found more due to heavy monsoon rain fall.

Reef species

Actinopyga mauritiana, Holothuria cinerscenus, Holothuria hilla, Holothuria impatiens, Holothuria atra and Holothuria leucospilota are common in the reef flat of Minicoy Island.

Actinopyga mauritiana

Actinopyga mauritiana was the most dominant with 37.72% and high density of 118/100 m^2. This species also widespread in the tropical Indo-Pacific region (Clark and Rowe, 1971) and the maximum density was recorded by Rowe and Doty (1977) in Guam as 1.2 to 1.5/m^2 . This is almost similar to the present observation. But Lawrence (1980) reported highest density of 12/m^2 on a wind ward reef flat of Enewetok atoll. This variation may be due to area covered and method adopted for the survey.

The distribution and abundance in different sector shows that A. mauritiana is mainly habitat specific. These animals were found to be attached with help of well developed tube feet in the reef flat which is known for strong wave action throughout the day, but never recorded in the lagoon or outer edge of the reef slope. Mostly small animals were noticed in seaweed bed (Turbinaria sp.), while bigger animals were found under the coral boulder. This observation well coincides with that of Hammond et al. (1985) who reported that among the nine species recorded in reef flat of Central section of Great Barrier reef, A. mauritiana was dominant and lives under high energy condition. Massin and Doumen (1986) have not found much of this species on the reef flat of Laing Island, but appeared principally on the reef edge among living corals. These findings by these two authors are highly contradictory with present observation when A. mauritiana was not found in live coral area and this is a significant observation.

A relatively uniform density was recorded in all sectors 7 to 12 during 1990 and 1991 leading to a conclusion that certain biological phenomena like asexual reproduction in A. mauritiana may be one of the reasons for this type of uniform distribution. Moreover in the present study all animals dissected showed no trace of sex organs. Hence it may be well presumed that this species maintains its population by means of asexual transverse fission which is common in this species.

Holothuria leucospilota

Holothuria leucospilota is the second dominant species (20.17%) with a density of 26/100 m^2. This value well coincides with the finding of Bakus (1968) 2.5 to 5/100 m^2 in Eniwetok atoll, Marshall Island. Bonham and Held (1963) estimated 1.6×10^5 for the entire reef area.

It is interesting to note that the distribution in different sectors and abundance of this species in reef flat were always related to large pools where coarse sand particles and coral boulders were noticed. It is observed that the coarse sand particles with sediments provide food to these animals, while boulders are providing shelter to hide, as they are showing cryptic way of life. This is well proved that in sectors 9 and 10 the density was higher due to more tidal pools and boulders. This similar type of distribution and cryptic way of life of this species as reported by various authors throughout the Indo-Pacific region (Baker, 1929; Bonham and Held, 1963; Rowe and Doty, 1977; Sloan 1979; Sloan et al., 1979; Lawrence, 1980).

Holothuria atra

Holothuria atra was the third abundant species (15.90%) with a density of 52/100 m^2 in Minicoy reef flat. Yamanouti (1939) estimated the abundance of *H. atra* as $0.44/m^2$ in Palu Island, which is nearest value to the present observation. It is seen that *H. atra* was higher in sector 9 and 10 where coral rubbles and seaweeds are more providing ideal condition for their living compared to other sectors. Asexual reproduction and selectivity of food by this species also have some role in their abundance as discussed earlier in the lagoon.

Holothuria cinerscenus

Holothuria cinerscenus is the fourth abundant (10.60%) with a mean density of $15/100\ m^2$. No literature is available on the quantitative abundance on this species of from any part of the world for comparison. It is rather, difficult to assess this species quantitatively because of its burrowing and hiding nature. This species is generally found burrowed vertically in the fine sand among the reef boulders available in the habitat. This may be the reason why no work has been carried out on the quantitative abundance and makes its quantitative estimation difficult. This view is further strengthened from the present result that in sector 7 and 8 is uniform in all the quarters compared to the rest of the sectors. Its smaller counts in abundant made difficult to compare between seasons.

Holothuria impatiens

The percentage occurrence of *Holothuria impatiens* was 9.77% with mean density of $8/100\ m^2$ in Minicoy Reef Flat. Hammond *et al.* (1985) reported that *H. impatiens* occurs only infrequently and at lower abundance (0.3 to $0.4/100\ m^2$) when compared to other species. In sector 9 the density was higher irrespective of season when compared to other sectors. This indicates that coral rubble with seaweed *Turbinaria* sp. forms an ideal habitat for this species.

H. impatiens is very less in their abundance in various sectors during 1990 and 1991, there is no remarkable variation in their density related to various season.

Holothuria hilla

Holothuria hilla occurred only 5.84% with a mean density of 14/100 m . In central section of Great Barrier Reef, *H. hilla* showed a density of 0.08/m (Hammond *et al.*, 1985) which is very closer to the present observation. This species was highest in number in the sector 8 of the present investigation which is characterised by the presence of coarse, grained, calcareous and rock with sea weed *Gilliedella acerosa*. This observation is comparable to that by Hammond *et al*. (1985) who reported "*H. hilla* which is diurnally cryptic showed its weakest association with pavement and its strongest association with rubble, which would provide day time cover".

From the above results and discussion it can be firmly concluded that the occurrence, abundance and seasonal fluctuation of different species of holothurians depend on different factors and not by a single factors. For example (i) *H. atra* reproduces asexually to maintain its population and by selective feeding, (ii) *B. marmorata* is a burrower on sandy bottom, (iii) *H. nobilis* is poor sedentary animal found in the areas of poor wave action, (iv) *A. mauritiana* is sedentary form found mostly in the areas with stronger wave action. This animal was well developed pedicels for attachment and reproduces asexually.

In addition to the above findings, the present investigation has also clearly indicated the areas and seasons of abundance of some of the sea-cucumbers, particularly the commercially important ones from the Minicoy Island. It can be taken this investigation as a preliminary one and further investigation would be preferred to have a conclusive results over a period of time. This will definitely help to identify the different islands in the Lakshadweep group which are productive for sea-cucumber fishery and to establish Beche-de-mer industry. There are possibilities for culture of sea-cucumbers in the protected embankments in some of the islands and coral reef flats, if the sea-cucumber seeds are produced and ranched.

CHAPTER 6

CHAPTER VI : ECOLOGY OF *HOLOTHURIA NOBILIS* AND *ACTINOPYGA MAURITIANA*

INTRODUCTION

There is always an intimate interaction between the Physico-chemical properties of the living media and the organisms living in it. The notable ecological works on sea-cucumbers are those by Pearse (1908), Hyman (1955) and Ursin (1960) and review on "ecology of holothurians" by Pawson (1966). Very recently Conand (1993) studied the ecology of the tropical Indo-Pacific Aspidochirotes holothurian *Stichopus variegatus* and attempted to study their abundance in relation to sediment properties. No literature is available from India on the ecology of sea-cucumber. This lacunae was felt very much and the candidate collected all hydrological, sedimentalogical and biological data during the two years (1990-1991) investigation from Minicoy Island, the data processed statistically and significant and interesting results are given in the following paragraph.

Parameter studied

The habitat topography, physico-chemical parameters of the habitat such as water temperature, salinity, dissolved oxygen, sedimentalogical parameters such as sand grain size, organic carbon content, were studied in relation to the occurrence and abundance of *H. nobilis* and *A. mauritiana*. The data were statistically analysed by correlation matrix method, to know whether there is significant relation or not.

Section A : Ecology of H. nobilis

Temperature

In Minicoy Lagoon during 1990, the temperature was ranging between 25.5°C and 32.5°C. The maximum was found (32.5°C) in October at stations 1, 2, 3 and 9 and minimum in July (25.5°C) at station 1 to 3. In 1991, the maximum was (33.0°C) in December at stations 5 to 9 and minimum was 26.6°C at stations 1 and 2 in July. The computed mean temperature for the two year period was 31.70 ± 1.1251 (Table 90).

The data analysed for seasonal variation in temperature (Table 92) showed that among the 4 seasons the highest temperature was during northeast monsoon period (December-February) with 32.5°C at station 6. The lowest temperature was found in southwest monsoon period (May-August) with 28.08°C in station 1. The analyses of data by two-way ANOVA (Table 93) proved that there is significant variation between stations ($F = 4.93$) and between seasons ($F = 210.3686$) at 5% level.

Temperature correlated with H. nobilis abundance (Table 91) showed a negative relationship at station 2 ($r=-0.26530$, $P < 0.05$) and station 6 ($r = -0.26014$, $P < 0.05$). No significant relationships in rest of the stations war found.

Salinity

The range of salinity recorded during 1990 was between 32.0 ppt to 36.29 ppt. The maximum (36.29 ppt) was found in November at station 1, 2 and 5, while the minimum (32.0 ppt) was in July at stations 3 and 6. In 1991, the salinity ranged from

32.95 ppt to 36.61 ppt. The maximum (36.61 ppt) was recorded in December at station 3 and 4 and the minimum (32.95 ppt) was recorded in July at station 7. The computed mean salinity for the two year period was 34.51 ± 1.0536 (Table 90).

The data analysed for seasonal variation in salinity (Table 94) showed that among 4 seasons the highest salinity was recorded during northeast monsoon period (December to Fabruary) at station 2 with 35.50 ppt. The lowest salinity was (34.29 ppt) at station 6 during southwest monsoon period. The analysis of data by two-way ANOVA (Table 95) proved that there is no significant variation between stations (F = 0.4078), but showed significant variation over seasons (F = 9.45) at 5% level.

In the present study salinity indicated a positive relationship with H. nobilis abundance at station 9 ($r = 0.25517$, $P < 0.05$) and there is no significant relationship in rest of the stations (Table 91).

Dissolved oxygen

In 1990, the recorded DO range was between 4.29 ml/l and 7.04 ml/l. The highest 7.04 ml/l was noticed in October at station 8 and lowest was in February at station 2 with 4.29 ml/l. In 1991, the DO was recorded between 4.8 ml/l and 6.93 ml/l. The maximum value (6.93 ml/l) was noticed in March at station 1 and 9 and the lowest (4.8 ml/l) in June at stations 1 to 3. The computed data for 1990-1991 showed a mean of 5.98 ± 0.6813 (Table 90) in Minicoy Lagoon.

The seasonal variation of DO indicated (Table 96) the highest was recorded during southwest post-monsoon period (September to November) with 6.09 ml/l at station 8 and minimum was during

TABLE 90. Physico-chemical and sedimentological parameters of *H. nobilis* habitat collected during 1990-1991 in Minicoy Lagoon.

Parameters	No. of observation	Minimum	Maximum	Mean & SD
Temperature	24 months	$25.5^{o}C$	$33.0^{o}C$	31.70 ± 1.1251
Salinity	24 months	320 ppt	36.61ppt	34.51 ± 1.0536
Do	24 months	4.29 ml/1	7.04 ml/1	5.98 ± .6813
Bottom fauna	24 months	43 number/ 100 gm wet sediment	133 number/ 100 gm wet sediment	70.62 ± 22.8932
Depth	24 months	2m	6m	5.28 ± .5851
Granular sediment	24 months	16.18%	28.98%	19.20 ± 3.3026
Very coarse sediment	24 months	6.00%	21.80%	13.00 ± 5.1708
Very fine sediment	24 months	25.60%	49.56%	34.20 ± 11.5018
Organic carbon	24 months	0.28%	0.48%	0.37 ± 0.0551

TABLE 91. Correlation between abundance of <u>Holothoria Nobilis</u> and other ecological, biological and sedimentalogical parameters

Stations	Water temperature	Salinity	DO	Fauna	Depth	Granular	Very coarse	Very fine	Organic carbon
1	-.11382	-.18355	.91892	-.22211		.13723	-.02347	.08329	-.02749
2		-.16373	.16695	-.13364	.09205	.12625	.14188	-.09045	-.19903
3	-.10033	-.07394	-.13896	-.01986	.15822	-.11709	-.15113	.08007	
4	-.01158	-.07602	-.03785	-.10780	.05435	-.09970		-.09077	.11630
5	.19435	-.06051	.06016	-.05073	.19835	.03653	.09555	-.01292	-.12514
6		.01046	-.12750	-.01723	-.06746	-.02194	.19167	-.01673	-.04035
7	-.23899	.11941	-.13944		.10058	.22848	-.04325		-.14528
8	.06404	.04902	-.06116	-.12620	-.22824	.04081	.13506	-.02969	-.05399
9	-.03516		.09494		-.06344		.00844	-.10862	.00392

TABLE 92. Seasonal variation in water temperature at Minocy Lagoon during 1990-1991.

STA-TIONS	North East Monsoon Period		Transion Period		South West Monsoon Period		South West Post Monsoon Period	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	31.54	1.0919	30.16	1.6681	27.08	1.4832	29.43	2.1381
2	31.86	.9328	30.99	.9077	27.47	1.1540	29.78	3.2616
3	31.74	.9408	31.31	1.1630	27.76	1.4241	30.39	1.4920
4	31.62	.9057	30.34	1.2693	27.58	1.2491	29.88	2.3680
5	32.30	.5854	31.00	1.1649	27.69	1.2635	30.15	2.1300
6	32.25	.6768	31.66	2.3415	28.14	1.5662	30.31	1.4615
7	31.94	1.0689	29.94	2.0077	27.90	1.6272	29.60	1.9162
8	31.76	.9943	30.39	1.9096	28.40	1.8611	30.14	1.911
9	31.98	1.0913	32.06	2.2468	28.87	1.9740	30.34	1.2398

TABLE 93. Level of Significant variation in water temperature between stations and seasons in Minicoy Lagoon, by analysis of ANOVA II.

SOURCE	DF	SS	MS	F
STATION	8	4.917969	.6147461	4.937255**
PERIOD	3	78.58008	26.19336	210.3686 ***
ERROR	24	2.988281	.1245117	

TABLE 94. Seasonal variation in Salinity at Minocy Lagoon during 1990–1991.

STA-TIONS	North East Monsoon Period		Transion Period		South West Monsoon Period		South West Post Monsoon Period	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	35.29	1.0412	35.30	.9075	34.69	1.4509	34.89	.9075
2	35.55	.6527	35.50	.4823	34.29	1.0814	34.32	2.5382
3	35.16	.7474	35.10	1.0757	34.75	1.9439	35.44	.9691
4	35.32	.9293	34.54	1.0104	34.40	1.60800	35.39	1.1756
5	35.49	.88357	35.12	1.0919	34.40	1.1001	35.54	1.0095
6.	35.44	1.0531	34.95	.8094	34.24	1.0565	35.48	.9721
7	35.05	1.3403	34.92	1.1932	34.83	1.2596	35.18	1.5502
8	35.41	.9053	35.09	.8876	34.69	1.2426	35.49	1.0842
9	34.97	1.0565	35.38	.8887	34.91	.7708	35.56	.9452

TABLE 95. Level of Significant variation in Salinity between stations and seasons in Minicoy Lagoon, by analysis of ANOVA II.

SOURCE	DF	SS	MS	F
STATION	8	.3398438	4.248047E-02	.4078125
PERIOD	3	2.953125	.984375	9.45 **
ERROR	24	2.5	.1041667	

TABLE 96. Seasonal variation in dissolved oxygen at Minocy Lagoon during 1990-1991.

STATIONS	North East Monsoon Period		Transion Period		South West Monsoon Period		South West Post Monsoon Period	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	5.48	.6769	6.01	.6182	4.89	.4870	5.78	.7085
2	5.70	.4595	5.79	.6480	5.07	.4576	5.83	.4653
3	5.57	.7381	5.81	.3976	5.29	.5564	6.00	.6235
4	5.84	.3826	5.93	.6332	4.96	.6439	6.02	.9349
5	5.77	.3844	5.74	.3829	5.23	.5484	6.02	.7070
6	5.78	.2748	5.58	.6125	5.80	.5500	5.82	.7257
7	5.54	.6276	5.48	.6312	5.17	.4986	5.81	.7482
8	5.68	.4953	5.36	.3877	5.36	.4217	6.09	.6774
9	5.70	.4058	5.71	.3999	5.35	.4794	5.91	.7038

TABLE 97. Level of Significant variation in dissolved oxygen between stations and seasons in Minicoy Lagoon, by analysis of ANOVA II.

SOURCE	DF	SS	MS	F
STATION	8	10.318129	1.289764	.9392612
PERIOD	3	.5059815	.1686605	.1228257
ERROR	24	32.95606	1.373169	

southwest monsoon period (May to August) with 4.89 ml/l at station 1. The analyses of data by two-way ANOVA (Table 97) proved that no significant relationship between stations (F = 0.9392) and between seasons (F = 0.1228) existed.

No significant relationship, either positively or negatively shown between DO and H. nobilis abundance at any stations (1 to 9) studied at Minicoy (Table 91).

Bottom fauna

The bottom fauna/100 gm of wet lagoon sediment showed the range between 43 and 133 in 1990. The maximum was noticed in March at station 8 and minimum number 43 was in June at station 2 and 3 in November at station 4 and 6.

In 1991, the range was between 47 and 102 numbers/100 gm wet lagoon sediment. The maximum number 102 was noticed in April at station 6, while the lesser number was in July at station 9. The computed data for 1990-1991 showed the mean number of 70.62 ± 22.89 (Table 90).

The data analysed for seasonal variation in faunal numbers at 9 stations for 4 seasons (Table 98), showed the highest numbers during southwest post-monsoon period in station 6 with 81.5 numbers. The lowest numbers during northeast monsoon period in station 5 with 60. The two-way ANOVA (Table 99) showed that there was significant variation between stations (F = 4.9919) and between seasons (F = 4.7248) at 5% level.

The correlation between fauna and H. nobilis abundance showed positive relationship at station 7 ($r = 0.44960$, $P < 0.05$) and station 9

($r = 0.25386$, P   0.05) and no significant relationship was found in rest of the stations (Table 91).

Water depth

In 1990, the maximum depth among 9 stations recorded was in July at station 3 and 5 with 5 m and minimum depth was in January at station 1 and 4 with 2 m. In July 1991, station 5 showed 6 m depth and in March at station 1 the depth was 2 m. The computed data of depth for 1990-1991 showed the mean of 5.28 ± 0.5851 (Table 90).

The seasonal variation in depth showed that maximum was recorded in southwest monsoon period (May to August) in station 9 with 5.22 m and minimum depth was in station 1 with 2.47 m (Table 100). The two-way ANOVA (Table 101) indicated significant variation in depth between stations ($F = 156.5878$) and not between seasons ($F = 2.6710$).

The correlation between water depth and *H. nobilis* abundance showed negative relationship at station 1 ($r = 0.3122$; $P < 0.05$) and in rest of the stations no significant relationship was found (Table 91).

Sediment grain size

The various grain size distribution of the lagoon sediment indicated the range between 14.00% and 26.40% during 1990. The highest was recorded in July at station 8 and 9, while the lowest was recorded in July at station 4 and 5. The grain size ranged between 14.00% and 30.40% in 1991. The highest was recorded in October at station 1 and the lowest was in July at station 7, 8 and 9.

TABLE 98. Seasonal variation in bottom fauna/100gm wet sediment at Minicoy Lagoon during 1990–1991.

STA-TIONS	North East Monsoon Period		Transion Period		South West Monsoon Period		South West Post Monsoon Period	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	64.00	18.2673	70.75	20.1476	69.56	18.2024	71.50	20.2507
2	70.28	16.1789	68.88	15.7519	70.06	16.3522	77.50	18.5692
3	71.93	19.1852	70.88	19.8885	70.06	20.8948	76.92	18.7639
4	67.71	13.9638	68.00	20.5287	68.44	11.8994	72.17	23.4321
5	60.00	14.3205	60.88	9.6575	63.50	26.8303	73.75	24.0798
6	74.14	23.8935	77.75	23.3712	71.13	23.8240	81.50	20.9784
7	58.50	16.9785	74.13	21.8987	72.56	22.4468	70.25	26.4682
8	60.00	20.0115	64.50	18.5087	59.38	17.6403	65.00	17.2152
9	67.29	28.8001	73.63	15.6016	66.43	18.2901	71.00	17.6738

TABLE 99. Level of Significant variation in bottom fauna between stations and seasons in Minicoy Lagoon, by analysis of ANOVA II.

SOURCE	DF	SS	MS	F
STATION	8	699.4219	87.42774	4.991971**
PERIOD	3	248.25	82.75	4.72488**
ERROR	24	420.3282	17.51367	

TABLE 100. Seasonal variation in water depth at Minicoy Lagoon during 1990–1991.

STA-TIONS	North East Monsoon Period		Transion Period		South West Monsoon Period		South West Post Monsoon Period	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	2.86	.7187	2.63	.3535	2.47	.3859	2.75	.5000
2	2.93	.3315	3.00	.2673	3.09	.3750	2.91	.3589
3	3.14	.3631	3.00	.2673	3.03	.4270	2.96	.3343
4	3.11	.7384	3.13	.3535	3.12	.5627	2.96	.5418
5	3.21	.5789	3.00	.3779	3.25	.5164	2.92	.3588
6	3.71	.5789	3.31	.5303	3.72	.4069	3.54	.5418
7	4.79	.5447	4.25	.3780	4.84	.9437	4.33	.4923
8	4.61	.4875	4.75	.4629	4.88	.6455	4.58	.5967
9	5.05	.6022	5.50	.5629	5.22	.5468	5.20	.3988

TABLE 101. Level of Significant variation in water temperature between stations and seasons in Minicoy Lagoon, by analysis of ANOVA II.

SOURCE	DF	SS	MS	F
STATION	8	28.86322	3.607903	156 5878**
PERIOD	3	.1846314	6.154378E-02	2.671082
ERROR	24	.5529785	2.304077-E	

The pooled data for 1990-1991 gives minimum of 16.18% and maximum of 28.98% with the mean of 19.20 ± 3.3026 (Table 90).

The seasonal variation in sand grain size indicated (Table 102) highest percentage during the southwest post-monsoon period (September to November) in station 2 (24.18%). The lowest percentage was found during transition period (March and April) in station 7 (16.83%). The two-way ANOVA (Table 103) showed a significant relationship in the percentage of grains between stations (F = 3.0377) and not between seasons (F = 1.2265) at Minicoy Lagoon.

The correlation between grain size and H. nobilis abundance showed a positive relationship at stationn 9 (r = 0.24825) and in rest of the stations no relationship was found (Table 91).

Very coarse sediment

In 1990, the percentage of very coarse sediment ranged between 6.0% in December at station 8 and 9 and 21.8% in February at station 9. In 1991, the highest (18.00%) was recorded in December at station 2 and 7 and in September at station 6. The lowest (10.48%) was recorded in station 1 and 5. The pooled data for 1990-1991 showed the mean percentage of 13.00 ± 5.1708 (Table 90).

The seasonal variation in this sediment showed the highest percentage during southwest monsoon period (May to August) and in station 9 (14.43%). The lowest was in station 7 (11.54%) in the same season (Table 104). The two-way ANOVA (Table 105) indicated no significant variation between stations (F = 1.3099) and significant variation between seasons (F = 4.9055).

The correlation between very coarse sediment and abundance

TABLE 102. Seasonal variation in granular sediment at Minicoy Lagoon during 1990-1991.

STATIONS	North East Monsoon Period		Transion Period		South West Monsoon Period		South West Post Monsoon Period	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	19.33	2.9243	17.64	3.4415	18.72	2.8200	20.4	5.5766
2	21.28	3.7442	22.40	4.4899	21.08	3.4618	24.13	3.3869
3	20.99	3.0948	19.85	1.7880	31.09	4.9114	23.07	4.8880
4	19.94	3.2490	20.20	5.3238	18.56	3.2994	20.45	4.6555
5	21.19	2.8145	21.50	5.0404	20.28	3.9120	22.33	4.1528
6	22.80	4.2679	20.95	3.2980	21.26	3.3722	22.27	6.2208
7	19.24	3.4592	16.83	3.3881	19.09	4.1445	20.60	6.1128
8	21.81	3.3626	20.75	4.9704	18.61	3.8021	20.20	5.1210
9	23.40	3.3750	21.45	2.9311	23.77	3.7199	23.93	4.0629

TABLE 103. Level of Significant variation in granular sediment between stations and seasons in Minicoy Lagoon, by analysis of ANOVA II.

SOURCE	DF	SS	MS	F
STATION	8	96.84278	12.10535	3.037739*
PERIOD	3	14.66309	4.887696	1.226528
ERROR	24	95.63965	3.984985	

TABLE 104. Seasonal variation in very coarse sediment at Minicoy Lagoon during 1990-1991.

STATIONS	North East Monsoon Period		Transion Period		South West Monsoon Period		South West Post Monsoon Period	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	13.06	1.9976	9.85	3.7503	11.875	2.4946	12.80	3.2807
2	13.64	4.7072	10.00	2.6533	14.338	2.9165	15.03	2.0069
3	12.29	3.8586	11.85	4.9911	12.62	3.2509	13.22	2.8572
4	12.97	3.3197	10.50	3.4723	10.60	8.3701	14.23	3.1563
5	13.24	3.0530	12.00	4.5406	12.29	2.5622	14.19	3.4600
6	12.54	3.3781	13.00	2.8282	12.68	3.2435	14.28	3.5722
7	12.20	3.0811	11.45	2.4278	11.54	2.7119	13.13	2.9373
8	11.76	4.1647	11.30	3.2758	12.10	2.4862	13.23	2.0285
9	13.08	3.7208	12.45	3.7059	14.43	3.1036	14.91	2.4627

TABLE 105. Level of Significant variation in very coarse sediment between stations and seasons in Minicoy Lagoon, by analysis of ANOVA II.

SOURCE	DF	SS	MS	F
STATION	8	24.5459	3.068237	1.30999
PERIOD	3	34.46924	11.48975	4.905571**
ERROR	24	56.2124	2.342183	

of H. nobilis showed a positive relationship at station 4 (r = 0.35332, P 0.05) and no relationship was found in rest of the stations (Table 91).

Very fine sediment

In Minicoy Lagoon, the very fine sediment distribution showed the range from 20.0% to 49.6% during 1990. The highest was recorded in January at station 4 and 6 and the lowest was in June at station 4 and July at station 5. In 1991, the same was seen ranging from 24.4% to 48.0%. The highest was recorded in July at station 4, 8 and 9 and the lowest of 24.4% was in September at station 7. The pooled data forr 1990-1991 showed the mean of 34.20 ± 11.5018 (Table 90).

The seasonal variation in very fine sediment indicated highest percentage in transition period (March and April) in station 7 with 44.35%. The lowest percentage was in southwest post monsoon period (September to November) in station 9 with 25.23% (Table 106). The two-way ANOVA (Table 107) analysis showed a significant variation in the percentage between stations (F = 21.5054) and between seasons (F = 12.9725).

The correlation between very fine sediment and H. nobilis abundance indicated positive relationship at station 7 (r = 0.35404, $P < 0.05$) and no significant relationship in other stations (Table 91).

Organic carbon

The organic carbon content in the lagoon sediment showed the range between 0.23% and 0.45% in 1990. The highest organic carbon was recorded in August at station 3 and in December at station 9 with 0.45% and the lowest in May at station 4 and July at stations with 0.23%. In 1991 the same was showed the range

TABLE 106. Seasonal variation in very fine sediment at Minicoy Lagoon during 1990-1991.

STA-TIONS	North East Monsoon Period		Transion Period		South West Monsoon Period		South West Post Monsoon Period	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	38.54	11.2100	43.48	9.8311	41.74	8.9995	39.59	11.6744
2	34.15	11.0262	35.16	7.7667	33.49	7.5222	27.6	7.0241
3	33.21	15.8050	33.21	8.0442	35.89	8.8844	31.66	8.8458
4	40.61	10.3969	39.96	8.9506	41.57	6.8719	30.58	8.8795
5	36.34	10.9158	38.61	10.6027	36.86	10.6043	32.47	9.1099
6	30.31	13.3766	31.20	8.6374	34.10	9.5133	30.59	14.6626
7	42.32	6.6805	44.35	6.8800	42.09	5.3719	38.27	13.5860
8	34.20	11.5298	41.20	8.54166	40.31	8.1992	35.25	10.3219
9	25.90	12.874	31.50	7.8172	26.58	8.8066	25.23	7.6169

TABLE 107. Level of Significant variation in very fine sediment between stations and seasons in Minicoy Lagoon, by analysis of ANOVA II.

SOURCE	DF	SS	MS	F
STATION	8	707.0196	88.37744	21.50545**
PERIOD	3	159.9336	53.3112	12.97255**
ERROR	24	98.62891	4.109538	

from 0.25% to 0.41%. The highest was recorded in December at station 1 and in November at station 4 while the lowest was in April at station 1 and July at station 5. The pooled data 1990-1991 given the mean of 0.37 ± 0.058 (Table 90).

The seasonal variation in the percentage of organic carbon showed the highest value during transition period (March and April) in station 6 with 0.47% and the lowest in southwest monsoon period (May to August) in station 8 with 0.24% (Table 108). The data analysed by two-way ANOVA (Table 109) indicated significant variation between stations ($F = 21.3306$) and not between seasons ($F = 2.4774$).

The correlation between the presence of organic carbon in the sediment and _H. nobilis_ abundance showed a significant relationship in station 3 ($r = 0.25707$, $P < 0.05$) and no relationship in rest of the stations (Table 91).

DISCUSSION

In Minicoy Island, the coral reef represents the atoll type, which is ring shaped reefs surrounding a sub-circular lagoon. This lagoon is shallow with depth ranging from 2.0 to 6.0 m and the clarity of water allows light to reach the bottom in full intensity during sunny days.

The present study shows a minimum temperature of 25.5°C and maximum of 33.0°C with a mean of 31.70 ± 1.1251 at Minicoy Lagoon. Girijavallabhan _et al_. (1989) reported the range of temperature in Minicoy Island during their indicative survey was 30.0 to 35.0°C. The difference between candidate's and Girijavallabhan's observations may be due to short time involved

TABLE 108. Seasonal variation in organic carbon (%) at Minicoy Lagoon during 1990-1991.

STA-TIONS	North East Monsoon Period		Transion Period		South West Monsoon Period		South West Post Monsoon Period	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.27	0.1201	0.35	0.0955	0.32	0.0671	0.34	0.0525
2	0.34	0.0901	0.31	0.0850	0.32	0.0944	0.31	0.0177
3	0.38	0.0435	0.41	0.1069	0.38	0.0829	0.36	0.0463
4	0.36	0.9487	0.39	0.1009	0.33	0.0762	0.35	0.0403
5	0.29	0.0559	0.33	0.0876	0.30	0.0830	0.33	0.0410
6	0.45	0.0844	0.47	0.0866	0.41	0.0655	0.39	0.0781
7	0.46	0.0506	0.46	0.0726	0.43	0.0723	0.40	0.0864
8	0.29	0.0419	0.27	0.0549	0.24	0.0380	0.31	0.0302
9	0.43	0.0528	0.45	0.0423	0.43	0.06850	0.38	0.0433

TABLE 109. Level of Significant variation in organic carbon (%) between stations and seasons in Minicoy Lagoon, by analysis of ANOVA II.

SOURCE	DF	SS	MS	F
STATION	8	.1051369	1.314211E-02	21.33067**
PERIOD	3	4.579067E-03	1.526356E-03	2.477394
ERROR	24	1.478672E-02	6.161134E-04	

in their observation, in which brief temporal variation might have occurred depending on the low and high tide. Dobinsky (1989) suggested that, to obtain a picture of seasonal changes in water mass structure in coral reef, it requires observations over 12 to 18 months at least of temperature and salinity and to be thorough on nutrients.

Seasonal variation in temperature showed in the present study that there is significant variation between seasons and stations. The variation between season is highly possible, because the lower value of temperature during July to September is due to the effect of monsoon rain fall. At the same time higher temperature during transition period is due to summer and lowest low tide occur in these period, when the sea water entry into the lagoon from the sea is reduced, water exchange is very limited and the removal water in the lagoon and mixing is reduced. These allow water to warm up from normal to maximum on sunny days. Sankaranarayanan (1973) and Goswami (1973, 1979) reported the same reason, when they found seasonal variation in temperature at Kavaratti Atoll in Lakshadweep.

The temperature correlated to H. nobilis indicates negative relationship in station 2 and 6 among 9 stations studied. Bakus (1973) reported that Holothuria sp. are tolerable higher temperature and did not effect the population due to massive skin and he found Holothuria difficialis tolerated natural ambient temperature of the 28° - 31°C under experimental conditions, the animal become immobile at 36°C, yet the tentacles are capable of moving at 40°C. They recovered from 1 10 minute sea water immersion at 38° - 40°C. H. atra can live in pools where the water temperature ranges from 31.1°C to 39.4°C (Bonham and Held, 1963). However, this temperature helps H. nobilis for their maturation and spawning at Minicoy Island as observed by the candidate (CHAPTER III, Part 2 - Reproductive biology of H. nobilis).

Salinity

Like temperature, salinity also ranges from 32.00 ppt to 36.61 ppt with mean of 34.51 ± 1.0536. Girijavallabhan *et al*. (1989) reported the minimum of 31.93 ppt and maximum of 35.41 ppt, which is almost nearer to the present observation. Eventhough variation in different months were noted between stations, none of them were found to be statistically significant over a long period of time. But salinity dropped during southwest monsoon period may be related to heavy rain fall occurred at Minicoy Island. Suresh (1992) reported that the slight drop in salinity during the peak monsoon month may also be due to the rain, which slightly dilute the surface water. Andrews (1983 a) reported that the seasonal variation in salinity is depending on three most significant determinators such as rainfall, evaporation and advection in the Great Barrier Reef Lagoon, Australia. Further higher salinity noticed during Northeast monsoon period and Transition period may be the effect of higher temperature on salinity. Girijavallabhan *et al*. (1989) assumed that higher salinity value could be attributed to heavy evaporation due to high atmospheric temperature and heat within the lagoons.

The correlation between salinity and *H. nobilis* abundance indicates positive relationship at station 9 only among 9 stations studied. So it is difficult to draw any conclusion that the salinity may have effect on this population. Bakus (1973) reported that "it is not known whether coral reef holothurians, many of which may live under relatively constant environmental conditions, are physiologically stenotopic". However, Thorson (1946) reported that the salinity variation may not have any effect on adult animals of echinoderm, but affect the larvae, because of sensitive to low salinity and life history stages may limit the distribution of echinoderms along salinity gradients. Stickle and Diehi (1987) reported that "with one exception, there appears to be a good correlation between the adult distributional patterns along salinity gradients and premetamorphic tolerance".

Dissolved oxygen

The present study exhibit the lowest DO 4.29 ml/l and highest 7.04 ml/l with a mean of 5.98 ± 0.6813 during 1990 and 1991. Girijavallabhan et al. (1989) reported maximum dissolved oxygen value 6.2 ml/l and minimum 3.39 ml/l, which is almost nearer to the present observation. The seasonal variation shows that some decreasing value during southwest monsoon period. But these variation are not significantly different between seasons and stations as seen from ANOVA result. Suresh (1992) reported that there is no seasonal fluctuation in dissolved oxygen in Kavaratti Atoll of Lakshdweep during the period 1988 to 1989 which well coincide with present observation. Dele Salle (1985) reports that concentration of dissolved oxygen shows values which vary very little (5.4 to 7.0 mg/l) and remain closer or higher than the value of water's saturation in function with the temperature and the salinity. Such value indicate a confined environment where photosynthetic organisms play a major role in the oxygenation of the water in Mataiva Atoll, Thomohu Archipelago.

The relation between DO and *H. nobilis* abundance did not show any relationship in any station in the present study. This indicate that their abundance neither increases nor decreases as this parameters varies moderately between stations and during different months.

Lagoon sediment

The porosity of lagoon sediment helps to shelter many microfauna and flora other than macro invertebrates and vertebrates.

These organisms are mainly involving in biogeochemical nutrient cycles in coral reef ecosystem (D'Elia and Webb 1990). In Minicoy Lagoon, polychaetes, nematodes, molluscs, foraminiferans, juvenile crustaceans, tubiculous polychaetes and sea-weeds like Helemeda sp. are contributing major part of the lagoon sediment. In the present study these bottom fauna showed minimum numbers of 43 and maximum of 133 with mean numbers of 70.62 ± 22.89. Further the ANOVA analysis shows that there is significant variation in numbers between seasons and stations also. This may be attributed to environmental factors (Physical and Chemical) that influences on sediments, which would affect the shelter of these organisms in Minicoy Lagoon. Hence the sampling stations (1 to 9) depth is 2 to 6 meter and the strong water current and wave action during hightide and monsoon period naturally interfere and adversely affect the population hiding in the porous nature of sediment. Gilbert and Voss (1960) reported that in Bahamas, there is a sharp and steady decline in the bottom fauna present as one passes from east to west over the banks. This is probably due to hydrographic conditions. Macnae and Kalk (1963) reported, the distribution of sediment organisms across the flats of Inhala Island is controlled by the level of the water table, rather than by variation in particle size.

The correlation between bottom fauna and *H. nobilis* abundance shows positive relationship at station 7 and 9. This may be that because *H. nobilis* consumes all the micro-organisms along with sediments as food, which would increase more *H. nobilis* population when number of bottom fauna increases in the sediment.

Water depth

In Minicoy Island the lagoon depth showed minimum of 2 m, maximum of 6 m with mean of 5.28 ± 0.5851. This depth was maximum during southwest monsoon period. This may be due to heavy flow of open seawater to the lagoon due to heavy rainfall, wind and wave action. But statistically this variation is insignificant. The variation found between stations is agreeable, because station 7, 8, 9 are more deep due to dredging of sediment for boat channel at Minicoy Island.

The correlation between water depth and H. nobilis abundance shows negative relationship at station 1 only. In other stations no significant relationship was found. Conand (1990) reported that H. nobilis in New Caledonia was more in the depth of 10 m, while in less than 10 m depth, the abundance was scattered. This almost coincides with present study that, Minicoy lagoon is normally 2 to 6 m in depth, so the population is not sharing any significant relationship.

Sediment size

In Minicoy, the lagoon sediment is purely white in colour due to calcium carbonate and terrigenous nature. The silt and clay particles are virtually absent in the lagoon sediment. The grain size ranges generally from medium sand upto boulder grade. But sediments are commonly well sorted while boulders are single deposition and composition of coral Acropora sp. It seems alga Helimada sp. and benthic community account for the bulk of sediment organisms in the lagoon. In the present study the sediment sand is classified as granular, very coarse, very fine by grain size analyses. Among these the contribution of granular size sediment is 5 to 20%, very coarse is 10 to 30%, very fine sediment is 10 to 50%. This is almost similar to other coral reef ecosystem in the world (Dubinsky, 1990). Macnae and Kalk (1962) reports the mixure of particles ranging from coarse (8 to 30%) medium (22.75%) and fine (10-46%) in Inhaca Island, Mozambique. Dabsalle (1985) reported in Mativa Atoll, the sediment in the lagoon, corresponds to fine or very fine sand.

The result of monthly grain size analysis shows that the percentage composition of all size is varying slightly between station to station and within station during 1990-1991. This coincides with conclusion of Dubinsky (1990) that the variation in different provinces in same lagoon is the presence of patchy reef which would also contribute various size particles to the sediments due to wave action or some hydrological parameters. The ANOVA analysis shows that no significant difference between seasons and stations except very fine sediment, which showed significant variation. This may perhaps be due to mechanical degradation of larger particles into very fine sand by strong wave action or water current.

The correlation between granular, very coarse, very fine sediment and H. nobilis abundance indicates positive relationship in certain stations out of 9 stations studied. Further the candidate observed that H. nobilis consumes all types of sediment particles as available in the sediment. So it can be assumed that not only particle size of sediment have effect on their abundance, but other parameters such as suitable substrate, availability food material or water movement also in Minicoy Island as Townsly and Townsly (1973) found in Fannig Island for Holothuria sp. population.

Organic carbon

The Organic carbon content in the lagoon sediment showed maximum of 0.45% and minimum of 0.23% with a mean of 0.37 ± 0.058 during 1990 - 1991. This is almost similar in all the coral reef ecosystem of the world. Hence lagoon sediments are formed of mostly calcium carbonate materials and less amount of organic debris (Dubinsky, 1990). Moriarty (1982) reported 0.40% to 0.50% of organic carbon in Great Barrier Reef, Australia which is almost equal to present observation. The seasonal variation in organic carbon percentage shows the highest value during transition period and lowest value during southwest monsoon period. But these variation is statistically not significant. But variation found between stations are possible, because the topography, fauna, flora, nature vary between each stations, which may contribute organic carbon to the particular station more. Gorden (1966) reported that the availability of organic matter in different places at Barnstable Harbour is due to the availability of micro-organism, seaweeds and other animals in the particular area.

The relationship between percentage organic carbon and H. nobilis abundance did not show significant relationship in all the stations studied (1 to 12) in Minicoy Island. But it can be explained that this organic carbon is important for holothurians, as they assimilate this carbon from the substratum for their energy.

Section B : Ecology of A. mauritiana

Temperature

In 1990, the temperature range was between 25.5°C and 32.5°C. The highest was recorded in December at stations 10, 11 and 12 and lowest was in June at station 10. The range for 1991 was from 27.8°C to 32.7°C. The highest was recorded in January as station 10 and the lowest was in May at station 10. The pooled data for 1990 - 1991 gave the mean value 31.50 ± 2.2505 (Table 110).

Seasonal variation of reef temperature showed that maximum temperature was recorded in the northeast monsoon period at station 10 (32.0°C) and minimum temperature during southwest monsoon period at station 12 (26.5°C) (Table 110). The two-way ANOVA (Table 113)

Table 110. Physico - Chemical and sedimentological parameters of *A.mauritiana* habitat collected during 1990 - 1991 in Minicoy Reef Flat

Parameters	No.of Observation	Minimum	Maximum	Mean & SD
Temperature	24 months	25.50^{o}C	32.7^{o}C	31.50 $\pm$ 2.2505
Salinity	24 months	36.60ppt	32.40ppt	35.16 $\pm$ 1.016
Do	"	4.61 ml/1	7.52 ml/1	6.19 $\pm$ 0.8088
Bottom Fauna	"	34 number/ 100gm wet sediment	100 number/ 100gm wt sediment	61.44 $\pm$ 17.6033
Depth	"	0.5m	2.5m	2.1 $\pm$ 0.2314
Granular Sediment	"	10%	26%	17.65 $\pm$ 4.8503
Very Coarse Sediment	"	7%	22%	18.55 $\pm$ 4.1518
Very fine Sediment	"	21%	46.2%	32.38 $\pm$ 11.50
Organic Carbon	"	0.40%	0.52%	0.46 $\pm$ 4.09

showed that there was no significant variation between stations (F = 2.3316). But showed highly significant variation between seasons (F = 162.4802).

The correlation between temperature and _A_. _mauritiana_ abundance did not show any significant relationship during the present study (Table 111).

Salinity

In 1990, the salinity range was between 32.55 ppt and 36.60 ppt. The highest was recorded in January at station 10, while lowest was in May in station 11. The salinity was ranging between 32.40 ppt and 36.49 ppt in 1991. The highest was recorded in October at station 12 and lowest was in June at station 12. The two year mean salinity value was 35.16 ± 1.016 (Table 110).

Seasonal variation in salinity showed that highest was recorded during southwest post monsoon period at station 10 with 35.5 ppt and lowest was also in southwest monsoon period in all stations (10 to 12) with 32.5 ppt respectively (Table 112). The two-way ANOVA showed (Table 113) no significant variation between stations (F = 0.5543) and highly significant variation between seasons (F = 34.23913).

The correlation between salinity and _A_. _mauritiana_ abundance did not show any relationship in stations 10 to 12 during the present study (Table 111).

Dissolved oxygen

The DO concentration in reef flat of Minicoy Island showed the range between 5.12 and 7.52 ml/l during 1990. The highest was recorded in January at station 10 and the lowest was in June at station 10 and 12. The same was ranging between 4.61 and 7.11 ml/l during 1991. The highest was recorded in December at station 10 and lowest was in June at station 10. The pooled data for 1990-1991 gave the mean DO content as 6.19 ± 0.8088 (Table 110).

The seasonal variation in DO showed that highest (6.52 ml/l) was recorded in Transition period at station 10 and lowest (4.20 ml/l) in southwest monsoon period at station 12 (Table 112). The two-way ANOVA (Table 113) showed no significant variation between stations (F = 0.7298) and highly significant variation between seasons (F = 9.4698).

The correlation between DO and A. mauritiana showed positive relationship at station 11 (r = 0.28097, P < 0.05) and no relationship was found in rest of the stations (Table 111).

Bottom fauna

The bottom fauna/100 gm of wet reef sediment showed the range between 40 and 100 minimum. The maximum number was noticed in February as station 10 and 11 and minimum number was in April at station 12. In 1991, the same was ranging from 34 to 92 number. The maximum number 92 was noticed in December at 10 and minimum 34 was in June at station 11. The mean from the pooled data for 1990-1991 was 61.44 ± 17.6033 (Table 110).

The seasonal variation in bottom fauna showed that maximum numbers (92) was found in Transition period at station 12, while minimum number (30) was found in station 11 during southwest monsoon period (Table 112). The two-way ANOVA indicated no significant variation in numbers/100 gm sediment between stations (F = 0.29658), but showed little significant variation between seasons (F = 2.5452) (Table 113).

TABLE 111. Correlation between abundance of *Actinopyga mauritiana* and other ecological biological and sedimentalogical parameters.

Stations	Water temperature	Salinity	DO	Fauna	Depth	Granular	Very coarse	Very fine	Organic carbon
10	.14011	.22943	.13859	.09233	.04996	-.01025	.09370	.16788	
11	.03363	.00697		.06247	-.03630	-.04623	-.00033	.02093	.21980
12	-.18622	.07042	-0.3243	.08399	-.13037	-.24742	-.18217	.24131	-.04780

TABLE 112. Seasonal variation in environmental, sedimentological and biological parameters of Minicoy Reef flat during 1990-1991

Station	Parameters	North East monsoon period Mean	SD	Transition period Mean	SD	South West monsoon period Mean	SD	South West Post monsoon period Mean	SD
10	Temperature	31.15	± 1.87	29.87	± 2.0182	27.47	± 1.1704	30.10	± 1.9879
	Salinity	34.15	± 1.87	35.47	± 1.869	34.28	± 1.74[illegible]	38.63	± .5469
	D O	6.62	± .7769	6.15	± .7776	5.85	± .8567	6.18	± .6340
	Bottom fauna	62.28	± 15.6275	60.50	± 22.5588	63.68	± 16.1192	64.58	± 20.1379
	Depth			1.00	± 0	1.37	± .4654	1.04	± .1443
	Granular sediment	14.79	± 3.0788	15.36	± 3.7542	16.80	± 4.0518	16.69	± 4.5729
	Very Course	15.52	± 5.6942	14.25	± 4.7132	38.83	± 8.9332	15.08	± 4.4406
	Very fine sediment	33.87	± 10.8316	28.51	± 5.6569	32.83	± 12.6219	32.69	± 14.1050
	Organic carbon	.50	± 7.3921	.46	± 4.0969	.45	± 5.4650	.49	± 2.2612
11	Temperature	32.6	± 1.9247	27.78	± 1.4824	30.03	± 2.0975	29.81	± 1.8745
	Salinity	35.65	± 6564	34.45	± 1.2621	35.37	± 1.776	35.41	± .3845
	D O	6.51	± .6284	5.99	± .4619	5.99	± .4299	5.83	± .6517
	Bottom fauna	58.71	± 14.9585	59.87	± 26.0227	55.25	± 9.9821	69.33	± 22.5563
	Depth	1.75	± .4702	1.75	± .4472	1.25	± .3779	1.5833	± .4174
	Granular	19.49	± 3.2777	15.76	± 2.2532	17.43	± 6.4666	22.83	± 4.2604
	Very Course	15.42	± 4.8787	13.40	± 5.8458	15.5	± 5.4772	19.29	± 2.5801
	Very Fine sediment	26.86	± 5.8612	28.04	± 10.6194	22.43	± 8.8617	17.54	± 6.2257
	Organic Carbon	.48	± 3.0534	.44	± 3.3838	.495	± 2.2038	.48	± 2.9949
12	Temperature	32.75	± .8847	30.13	± 1.9624	28.3	± 1.1724	29.88	± 1.9168
	Salinity	35.55	± .4957	35.36	± .9553	34.57	± 1.1840	35.89	± .4315
	D O	6.33	± .4154	6.19	± .6108	5.88	± .6187	6.12	± .4895
	Bottom fauna	54.5	± 19.1341	52.37	± 12.2700	71.87	± 23.7371	61.66	± 14.8160
	Depth	2.21	± .2567	2.12	± .2314	2.21	± .2561	2.16	± .2461
	Granular sediment	16.07	± 5.2426	15.87	± 3.5330	14.86	± 2.7271	18.50	± 5.7098
	Very Course	12.39	± 4.1510	16.75	± 5.8979	11.21	± 3.5729	14.89	± 4.4716
	Very fine sediment	32.29	± 11.5439	20.5	± 9.6214	37.18	± 4.9694	23.93	± 8.0706
	Organic Carbon	.50	± 4.9840	.48	± 6.6426	.46	± 5.5015	.4733	± 3.2286

TABLE 113. Level of significance variations in environmental sedimentalogical and biological parameters between seasons and stations during 1990–1991

PARAMETERS	SOURCE	DF	SS	MS	F
Temper-ature	STATION	2	.3066406	.1533203	2.331683
	PERIOD	3	32.05176	10.68392	162.4802**
	ERROR	6	.3945313	6.575521E-02	
Salinity	STATION	2	3.320313E-02	1.660156E-02	.5543478
	PERIOD	3	3.076172	1.025931	34.23913**
	ERROR	6	.1796875	2.994792E-02	
Do	STATION	2	.0295105	1.475525E-02	.7298113
	PERIOD	3	.5743713	.1914571	9.469686**
	ERROR	6	.1213074	.0202179	
Bottom fauna	STATION	2	15.24609	7.623047	.2965806
	PERIOD	3	196.2617	65.42057	2.545238**
	ERROR	6	154.2188	25.70313	
Depth	STATION	2	2.329292	1.164646	63.52581**
	PERIOD	3	.161499	5.383301E-02	2.93633
	ERROR	6	.1100006	1.833344E-02	
Granular sediment	STATION	2	8.623291	4.311646	1.583854
	PERIOD	3	28.68823	9.562744	3.51281
	ERROR	6	16.3335	2.722249	
Very coarse sediment	STATION	2	10.23022	5.115113	2.144071
	PERIOD	3	31.4917	10.49723	4.400062
	ERROR	6	14.31421	2.385702	
Very fine sediment	STATION	2	136.1553	68.07764	5.63075*
	PERIOD	3	167.4102	55.80339	4.615538
	ERROR	6	72.542	12.09033	
Organic carbon(%)	STATION	2	5.960465E-06	2.980232E-06	1.821715E-02
	PERIOD	3	2.812624E-03	9.375413E-04	5.730872*
	ERROR	6	9.815693E-04	1.635949E-04	

The correlation between bottom fauna and A. *mauritiana* abundance did not show any relationship in all the three stations studied (Table 111).

Water depth

In 1990, the depth varied between 0.5 m and 2.5 m. The maximum depth was recorded during June and July as station 12 and the minimum depth was in January and February at station 11. In 1991, the same was between 0.5 m to 3.0 m with maximum in July and August at station 11 and 12 and the minimum in December at station 11. The pooled data for 1990-1991 showed the mean of 2.1 ± 0.2314 (Table 110).

The seasonal variation in depth (Table 112) showed a maximum (2.22 m) at station 12 during southeast monsoon period, while the minimum was (1.0 m) at station 11 during northeast monsoon period. The two-way ANOVA (Table 113) indicated significant variation between stations (F = 63.525) and not between seasons (2.9363).

The correlation between depth and A. *mauritiana* abundance, did not show any significant relationship in all the three stations (10 to 12) studied at Minicoy Reef Flat (Table 111).

Sediment grain size

The percentage of granular sediment in the reef flat varied from 11% to 26% during 1990. The maximum percentage was recorded in January at station 12 and minimum was in November at station 10 and 11. In 1991, the same was from 10% to 24%. The maximum was recorded in October at station 12 and minimum (10%) was in May for station 10 and 11. The pooled data for 1990-1991 showed the mean percentage of 17.65 ± 4.8503 (Table 110).

Seasonal variation in the granular sediment (Table 112) showed the maximum (17%) during southwest post-monsoon period at station 12. The minimum (14%) was recorded during southwest monsoon period at station 10. The two-way ANOVA analysis (Table 113) showed no significant variation between stations (F = 1.5838) and seasons (F = 3.5128).

The correlation between granular sediment and the abundance of A. mauritiana did not show any relationship between the stations 10 to 12 studied (Table 111).

Very coarse sediment

The percentage of coarse sediment in the reef flat varied between 7% and 22% during 1990. The maximum was found in January at station 11 and in March at station 12. The minimum (7%) was found in June at station 12. In 1991, the range varied between 7% to 21%. The maximum was found in October at all the three stations, while the minimum was in May at station 12 (Table 110).

Seasonal variation in this sediment showed a (Table 112) maximum (19.29%) in station 10 during southwest post-monsoon period. The minimum of 11.29% was in station 12 during southwest monsoon period. The two-way ANOVA analysis (Table 113) showed no significant relation between stations (F = 2.1440) and seasons (F = 4.4000).

The correlation between very coarse sediment and A. mauritiana abundance did not show any significant relationship in all the three stations (11 to 12) studied from Minicoy Reef Flat (Table 111).

Very fine sediment

The percentage of very fine sediment varied between 23.0% and 46.2% in 1990. The maximum of 46.20% was found in July at station 12 and the minimum of 23.0% was in October at station 12. In 1991, the same was seen ranging between 21.0% in October at station 11 and 43.8% at station 12. The pooled data for 1990-1991 gave the mean percentage of 32.38 ± 11.50 (Table 110).

The seasonal variation in the percentage of very fine sediment showed the highest value (35.19%) in station 12 during southeast monsoon period and lowest value (17.59%) in station 11 during southeast post-monsoon period (Table 112). The two-way ANOVA (Table 113) showed a highly significant variation between stations (F = 5.6307) and less between seasons (F = 4.6155) at 5% level and 1% level.

The correlation between very fine sand and the abundance of A. mauritiana in stations 10, 11 and 12 did not show significant relationship (Table 111).

Organic carbon

In 1990, The organic carbon varied from 0.41% to 0.52% in Minicoy Reef Flat in 1990 and between 0.40% and 0.54% in 1991. The high organic carbon content was recorded in April 1990 at station 11 and less (0.41%) in August 1990 at station 14. In 1991, more organic carbon (0.54%) was recorded in August at station 11 and less (0.40%) in July at station 10. The pooled data for 1990-1991, showed the mean of 0.46 ± 4.09 (Table 110).

The seasonal variation in organic carbon of the reef flat sediment showed more (0.50%) during northeast monsoon period at station 12. The less percentage was (0.44%) in southwest monsoon period at station 11 (Table 112). The two-way ANOVA (Table 113) showed no significant variation between stations (F = 1.8217) and significant variation between seasons (F = 5.7308).

The relationship between organic carbon of the reef sediment and A. mauritiana abundance showed a positive significant relationship (F = 0.26732) at station 10 and no such a relationship in rest of the stations (Table 111).

DISCUSSION

Temperature

The coral reef flat of Minicoy Island is 3.5 km long and submerged near western region. This reef flat is exposed to strong sunlight during low tide normally more than 3 hours per day. In rainy season this reef flat is always submerged even at low tide, due to strong wave formation by monsoon wind and would hit the reef margin the whole day. The temperature was recorded in December and January to March. This is due to strong radiation during the summer months and more time of exposure for water pools. The low temperature was recorded from May to July and this is attributed to heavy rainfall during Southwest monsoon. This is also proved by ANOVA analysis that there is no significant difference between stations, but it was significant between seasons. The water temperature correlated with A. mauritiana showed negative in all the stations studied. But temperature influences the reproduction when it is high in A. mauritiana.

Salinity

Like temperature, salinity also showed significant variation between seasons, but not between the stations. The salinity range recorded during this study period is between 32.40 to 36.60 ppt. There is much dilution due to heavy Southwest monsoon resulting low salinity in the reef flat. This is also firmly proved by correlation co-efficient, which is positive and highly significant between temperature and salinity. The correlation between salinity and A. mauritiana abundance showed positive relationship only in station 10. So it is difficult to conclude how the salinity may influence the population of this species. But from the present study it is observed that high salinity coupled with higher temperature induce the fission in this species.

Dissolved oxygen

The dissolved oxygen range was between 4.61 to 7.52 ml/l during 1990 and 1991, which was always on the higher side in all stations (10, 11 & 12) in January and February in 1990 and December and February in 1991, when water temperature was high due to summer season. It may be attributed to the reason that, in reef flat of Minicoy Island and the slope projecting towards the sea and lagoon covered with density of corals Acropora sp. and Sea-weeds Helimada and Turbiraria sp. These coral and sea-weeds are responsible for the liberation of oxygen during prolonged photosynthesis in summer with good sunlight and higher temperature. Gardiner (1898) reported that the coral reefs liberate oxygen in the presence of sunlight and noted that oxygen production only occur in pigmented corals (coral containing Zooxanthallae). The low oxygen content in June July may be also due to low temperature effect and poor sunlight for photosynthetic active of these corals and sea weeds during monsoon months.

Bottom fauna

The number of bottom fauna/100 gm reef sediment of Minicoy showed irregularity between stations in respective to month and year. The seasonwise analyses showed no remarkable variation in their numbers. But the ANOVA analysis showed significant variation in their numbers between seasons, but not between stations. The little variation between stations may be related to topography of the stations, which would serve as a shelter for the bottom fauna. The variation between season is highly possible, because the heavy wind and wave action during monsoon hit the reef rim and collapse the coral boulders, sediment nature and algal interaction. This adversely affect the bottom fauna abundance.

Sediment

The reef flat of Minicoy Island is covered with full of coralline boulders, different sand particles, algae *Helimada* sp. and reef algae *Turbinaria* sp. The reef flat showed almost similar to Minicoy Lagoon sediment pattern like granular, very coarse and very fine sediment. However, the very fine sediment is dominating in their percentage when compared to other grain sizes. This mechanical break down of larger particles and bounders may be due to continuous wave action prevailing in the reef flat. This normally contribute more fine sediments to the substratum. ANOVA analysis also gives the clear results that variation between seasons and stations are not significant except for very fine sediments. Among the various size of sediment, very fine sediment showed positive relationship with *A. mauritiana* at station 12. This station is very near to boat channel where wave action is more and hit the coralline rocks. This station may be ideal for *A. mauritiana*, hence very fine sediment particles are more to feed as they are selective feeder.

Organic carbon

The organic carbon ranged from 0.50 to 0.60%. ANOVA analysis indicated a significant variation between stations and seasons in carbon. The variation between stations may be attributed to the animals and algal flora inhabitat in these (10 to 12) stations. The excretion of fauna and algal debris would contribute some amount of organic carbon to the reef sediments. In summer season carbon percentage is more, because of the long exposure of reef flat due to low tide to enhance the mixing of excretory matter and dead algae with sediment and increase organic carbon content. In monsoon period due to heavy rain and wave action this organic carbon found to be disturbed and dispersed to the various sectors. The correlation between organic carbon and abundance of A. mauritiana showed positive relationship at station 10 and 11. This indicates that A. mauritiana obsorbs organic carbon for the energy from the sediment particles. In the present study (Chapter III : food and fedding biology of A. mauritiana) it is noticed that this species assimilates nearly 30% of organic carbon from the substratum.

SUMMARY

SUMMARY

1. This Thesis contains a detailed account of the results of the investigations on the "Studies on sea cucumbers of Minicoy, Lakshadweep" from the Arabian Sea, carried out from January 1990 to December 1991. The results are presented and discussed in six chapters, preceded by an "Introduction", "Review of literature" and "Materials and Methods".

2. A brief account on the importance of sea-cucumbers, its general morphology, present status of sea-cucumbers and their fishery in India and the major objectives of the present study are given in the "Introduction".

3. "Review of Literature" has covered and reviewed almost all available published reports and informations on sea-cucumbers on global basis, with special emphasis on Indian region and particularly in Minicoy Island.

4. The Minicoy Island topography particularly the lagoon and reef flat area, discretion of sampling stations, survey on sea-cucumbers in space and time, analysis of samples both in the field and laboratory, statistical analysis of data, etc. and the period of study are given under "Materials and Methods".

A brief summary of the investigations and results are given below by chapterwise in the following paragraph.

5. The Chapter I deals with the taxonomy and anatomy of the sixteen species of sea-cucumbers from the Minicoy Island with synonyms, type locality, number of materials examined,

morphological and anatomical description with illustrations, geographical distribution and remarks wherever necessary.

6. The Chapter II presents the morphometry and biometry of *H. nobilis* and *A. mauritiana*. *H. nobilis* shows a minimum length of 20.0 cm with 500.0 gm and maximum of 39.0 cm with 2000.0 gm. The same for *A. mauritiana* is 6.0 cm with 18.0 gm and 30.0 cm with 1000.0 gm respectively. The size frequency distribution of morphometric characters showed "one size class in one locality" for both the species. The biometric relationship of *H. nobilis* and *A. mauritiana* indicates allometric growth pattern between body length and body weights such as total weight, drained weight and gutted weight.

7. The Chapter III deals with the biology of *Holothuria nobilis* and *A. mauritiana*. This Chapter is divided into 3 parts namely Part 1 : food and feeding, Part 2 : reproductive biology and Part 3 : age and growth for both the species and each is dealt separately.

Part 1 : Food and feeding has given the following important results and significant findings :

i. The food intaking is by mechanical process in *H. nobilis*, while the same is by chemical process due to adhesive secretion of nodules in *A. mauritiana*.

ii. The gut morphology shows that *H. nobilis* and *A. mauritiana* are surface sediment feeders. The gut length and total body length show a very fair positive relationship, since 'b' value is 3. There is no feeding ceasation at any time in these two species.

iii. Micro-fauna and flora are the main food items found in the gut, but these two species are not digesting any of the food items, instead they absorb the organic carbon from the sediment.

iv. *H. nobilis* is not a selective feeder and *A. mauritiana* is a selective particle feeder.

v. The organic carbon and assimilation efficiency is more in the foregut region than in other regions of the gut in both the species.

vi. *H. nobilis* assimilates nearly 40% of organic carbon, while *A. mauritiana* assimilates nearly 30%.

vii. The average digestion time in *H. nobilis* is 12 hours and it consumes 17.5 gm of dry sediment per day and 18.33 kg per year. The above for *A. mauritiana* are 14 hours, 6.8 gm of dry sediment per day and 2.28 kg per year respectively.

The Part 2 : Reproductive biology of *H. nobilis* and *A. mauritiana* has given that :

viii. *H. nobilis* reproduces by sexual means with 6 reproductive stages and one reproductive cycle in an year. 100% matured animals are found in July and August. The spawning takes place in September. The oocytes at the time of spawning are measured between 180 um to 190 um.

ix. The length of *H. nobilis* at the time of first maturity is between 24.0 - 25.9 cm.

x. An average fecundity is estimated as 9,31,071 eggs.

xi. The temperature and salinity are found to influence the reproduction in H. nobilis. Lower salinity and temperature influence the spawning.

xii. A. mauritiana reproduces asexually by fission. High temperature and salinity trigger the fission.

The Part 3 : Age and growth indicates that :

xiii. The average age of H. nobilis at first maturity is 2.8 years and age at maximum size was 4 years.

xiv. The age at minimum size of A. mauritiana is 0.6 years and maximum size 2.9 years.

8. The Chapter IV deals with the sea-cucumber fishery in Minicoy Island. The processed H. nobilis and A. mauritiana were found "first grade" and "third grade" respectively. These two species on conversion into Beche-de-mer loose their body weight by 85% and 90% respectively.

9. The Chapter V deals with quantitative and seasonal abundance of sea-cucumbers from Minicoy Island. Quarterly collections during 1990-1991 indicates the availability of 9 species in the lagoon as well as reef flat of Minicoy Island viz. H. atra, H. nobilis, B. marmorata, H. cinerscenus, H. hilla, H. impatiens, H. leucospilota. Among these species H. atra from the lagoon and A. mauritiana form the reef flat were found abundantly. It was observed from the present study that in 1990 and 1991, during monsoon period (June to August) the population of above mentioned holothurians are less in their respective habitat and more during September-November, and December-February.

10. The Chapter VI gives the ecology of H. nobilis and A. mauritiana. Monthwise and seasonwise ecological parameters such as temperature, salinity, DO, depth, bottom fauna, sediment grain size and organic carbon from 9 stations at the lagoon (H. nobilis habitat) and 3 stations at the reef flat (A. mauritiana habitat) were analysed and these parameters were correlated with the abundance of these two species. The temperature, salinity, depth, grain size of the sediment and water current are having positive relationship with the abundance of H. nobilis at certain stations in the lagoon and A. mauritiana in the reef flat area.

11. List of literature from all over the world, consulted and cited, are included at the end under "References".

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