SURVEY OF CORAL LAGOONS OF LAKSHADWEEP ATOLLS USING LINE INTERCEPT TRANSECT (LIT) TECHNIQUE

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BY
NOWSHAD M.

DEPT. OF MARINE BIOLOGY, MICRO BIOLOGY AND BIOCHEMISTRY

SCHOOL OF MARINE SCIENCES
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
COCHIN – 682 016

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Dedicated
to the People of Lakshadweep

CERTIFICATE

This is to certify that this thesis is an authentic record of research work entitled " **Survey of coral lagoons of Lakshadweep Atolls using line intercept transect (LIT) technique"** carried out by Shri. Nowshad . M under our supervision and guidance in the department of Marine Biology, Cochin University of Science and Technology in partial fulfilment of requirements for the degree of Doctor of Philosophy and no part thereof has been submitted for any other degree.

Dr. V. J. Kuttyamma,
(Supervising guide)
Reader
Marine Biology Dept.
School of Marine Science
Cochin University of Science and Technology

Dr. N. R. Menon,
(Co - Guide)
Director
School of Marine Sciences
Cochin University of Science
and Technology.

January 1998.

DECLARATION

I hereby declare that this thesis entitled **"Survey of Coral Lagoons of Lakshadweep Atolls Using Line Intercept Transect (LIT) Technique"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

NOWSHAD M.

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CONTENTS

PREFACE

Coral reefs are typical, biologically highly productive, tropical marine ecosystem which exhibit exceptionally diverse fauna and flora and a complex food web and trophic organization. In view of the general oligotrophic nature of tropical waters, the luxuriant richness and high specific diversity of coral reef assemblage appear paradoxical seeming to challenge evaluations of standing crop and production. Reliable data on the production of coral reef is available only at the primary level. The different pathways of energy transfer from the primary to the secondary trophic level is so complex and hence remains poorly understood. The different pathways of transfer include the energy derived through Zooxanthellae in hermatypic corals, cellular release by Zooxanthellae under particular environmental conditions and ' para-primary ' production (Peres and Picard, 1969) at the lowest level of trophic pyramid, which is essentially represented by suspended particulate organic aggregates consisting of mucus released by coral, zoantharians and other animals.

Coral reefs are economically vital in many developing countries in tropics, providing an essential source of commercially important fishes and income through tourism industry. Perhaps, the greatest importance of reefs to ourselves , however, is not economic or utilitarian but philosophical and spiritual. They are a lesson by nature on life itself. Wilkinson (1993), has cautioned that around 70% of the world's coral reefs may collapse by global climatic changes.

The development and growth of coral reefs are closely controlled by environmental factors and therefore is highly essential that possible change in coral *reefs are monitored. Curiously enough most of the studies of coral reef communities deal with systematics, physiology or behaviour. Seldom scientists have ventured in the past on quantitative description of coral reef communities. Quantitative analysis by methods which would help in understanding the structural typology of the entire benthic communities is the need of the day. With this in view a study employing Line Intercept Transect technique (LIT) to assess the structural typology which would help in understanding the impact of natural and anthropogenic disturbances on the coral reefs was undertaken. It is expected that the findings of the present investigations would help us in establishing an economical method to understand easily the ecology of the coral reef as an entity.*

CHAPTER 1

GENERAL INTRODUCTION

The coral reef complex in the world represent the most diversified floristic and faunistic assemblage. It is understood that this is owing to species richness mainly related to congenial environmental conditions and presence of diversified ecological niches.

A coral reef can be defined as a ridge or mound of limestone, the upper surface of which lies, or lay at the time of its formation near the level of the sea, and is predominantly composed of calcium carbonate secreted by organisms of which the most important ones are corals (Vaughan, 1911).

The coral reefs of the world cover an estimated area of 6×10^5 km^2, equivalent to 0.17% of the world ocean area. Over half of this (54%) lies in the Asiatic Mediterranean and Indian Ocean. Of the remaining, Pacific reefs account for 25%, Atlantic reefs account for 6%, Caribbean reefs for 9%, Red sea reefs for 4% and Persian Gulf reef for 2% (Smith, 1978). Majority of the coral reefs are concentrated in the western parts of the 3 major oceans.

Coral growth along the sub-continent of India is limited to a fringing reef in Palk Bay, a chain of islands bordered with fringing reefs in the Gulf of Mannar, many islands in the Gulf of Kutch around which are shallow reefs and to patches in intertidal zones along the west coast of India. On the other hand Lakshadweep

Archipelago in the Arabian sea has a chain of well developed atoll reefs, and the Andaman and Nicobar islands have extensive well developed fringing reefs.

The term `coral' refers to coelenterates secreting a massive calcareous skeleton, particularly of the order Scleractinia (Class: Anthozoa). The scleratinian corals are divided into two groups: the 'ahermatypic' or non-reef building and the `hermatypic ' or reef building corals. While structurally these two groups are similar, major differences between them lie in the presence of endosymbiotic *Zooxanthellae* in the hermatypic corals and the extent of their distribution in the seas. The ahermatypic corals are widely distributed at all latitudes, down to several thousand meters depth, whereas the hermatypic corals are stenotypic, limited to warm saline waters, essentially between the tropics of Cancer and Capricorn, where minimum water temperature do not fall below 20^0 C. The depth distribution of reef-building corals is restricted to illuminated layers of the sea, a condition clearly associated with the endosymbiotic *Zooxanthellae* of the coral polyps which require light for photosynthesis. Thus corals are primary reef frame-builders. The secondary reef frame-builders include other calcareous organisms, notably the encrusting coralline algae, which greatly assist in the strengthening of frame-work. Reef building is an interaction between biological and geological processes, the former represented by primary and secondary reef frame work growth, and the latter by sedimentation and early cementation (Wafer, 1986).

The ability of corals to construct and maintain a strong habitat affording abundant shelter and attachment for other organisms is the keystone of the reef community's richness and stability. The ability of the reef corals to secrete the billions of tones of limestone necessary to create a reef is itself something special. This capacity is dependent upon the intimate physiological relationship of reef building corals and *Zooxanthellae* which live in their tissues. This symbiotic relationship utilizes the waste products of animal metabolism, provides the coral with much of its nutrition and increase the ability to secrete calcium carbonate (limestone) by 3 to 4 times.

Coral reefs are extremely sensitive to pollution (eg. chronic oil pollution), eutrophication (eg. sewage discharge), excessive concentration of suspended solids, fresh water influx, and low temperature. All over the Indian and Pacific oceans coral reefs are affected by one or several of the above mentioned anthropogenic interference. Because of their stenotypic nature, coral reefs are highly susceptible to changes in their environment. Damage to reefs can occur in two ways, either as a result of natural phenomena or as a consequence of human activities in and around the reefs. Natural causes of reef damage include sea-level changes, hurricanes, exceptionally low tides, microbial parasitation, biological erosion and heavy predation on the corals, as is the case with the now popularly known *Acanthaster* phenomenon. Natural phenomena, though, rarely cause extensive and irreversible damages to reefs. But human activities do, and these come in a number of forms such as collection of corals, shells and ornamental fishes, intensive fishing, resource-destructive fishing methods such as dynamiting and use of poisons, sewage and eutrophication, petroleum hydrocarbons, heavy metal pollution, power plant discharges, nuclear detonations and resultant radioactive spillage, dredging, construction activities, and recreation and tourism. Each one of these has been the singular cause of damage to reefs in one or several countries (Wafer, 1986).

The Union Territory of Lakshadweep internationally known as the Laccadives, consisting of 12 atolls, 3 reefs and 5 submerged banks (Anonymous, 1984) with a total of 36 islands lie between $08^\circ 00'$ N and $12^\circ 00'$ N latitudes and $71^\circ 00'$ E and $74^\circ 00'$ E longitudes. Of these 10 are inhabited islands and are Androth, Amini, Agathi, Bitra, Chetlat, Kadmat, Kalpeni, Kavarathi, Kiltan and Minicoy. Each island except Androth has lagoon on the western side, and the lagoon and the reef provide ideal coral habitat for a variety of animals and plants. This Union territory has land area of 32 sq.km. and the total extent of lagoon is about 420 sq.km. (Mannadir, 1977) and possess 400000 sq.km. of exclusive economic zone.

Lakshadweep is located on the Laccadive-chagos ridge which is supposed to be the continuation of the Aravalli mountains. The islands are believed to be the remnants of the submerged mountain cliffs and formed as result of coral formation. The submarine bank that supports the atolls rises from depth ranging from 1500 meters to 4000 meters. The atolls of the island rest on an underwater platform of about 100 fathom deep. The islands have formed as a result of many thousand years of reef building activity and the geological changes that took place especially during Pleistocene period.

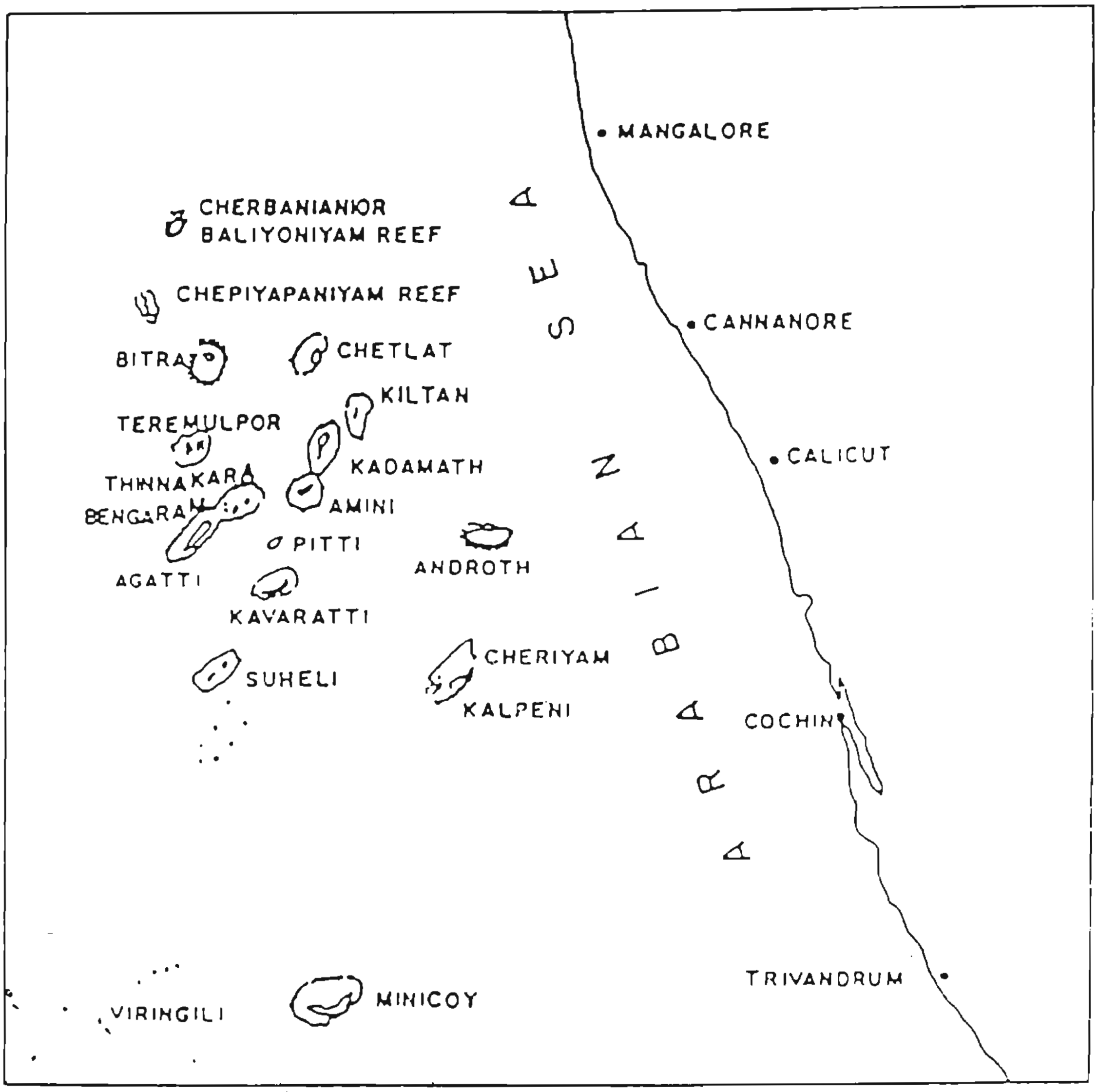


Figure 1: Map indicating relative locations of islands at Lakshadweep

Almost all the atolls of Lakshadweep have north-east south-west orientation with the island on the east, a broad well developed reef on the west and a lagoon in between.

Rapid economic development taking place on the Lakshadweep islands, give room for concern from the environmental point of view. The islanders have been living for years in a delicate ecological balance, that sustain the islands, within these atoll environment. Development taking place at present in the Lakshadweep islands will increase the economic activity between the islands and between the islands and mainland. This increased economic activity will very likely augment the pressure on the island environment.

A new inter-island ferry (IIF) system has been introduced in 1990 connecting all the inhabited islands except Minicoy (photographs 1a,b). Dredging of the navigational channel of lagoon to 1.8 meters at the jetty and widening of the lagoon entrance by blasting, has already been carried out on most of the islands, in connection with introduction of IIF which consists of two flat-bottomed speed boats, 15 meters long with a draft of 1.3 meters.

Blasting and dredging are famous for high coral mortality, because this result in the increase of turbidity and the concentration of suspended solids over a much larger area. Mortality to corals set chain actions and interactions bringing out visible changes in the ecosystems. The loss of live corals directly brings out a depletion of associated organisms as well as an advancement of algae and animals that thrive on dead corals. The coral skeleton, on death, display a whitish colour due to loss of living matter and many remain so, for a few weeks or months. Soon

Photograph 1a & b: The Inter Island Ferry Vessels (IIF) introduced in Lakshadweep.

they get coated by green filamentous algae (turf algae) and assume a dark green colour. Subsequently, coralline algae make an overcoat. Dead corals are more vulnerable to the attack of borers. Bioerosion of the colonies starts at a faster rate and the resulting calcareous sediments cause more sedimentation in the reef habitats. Most of the live coral associates, including fishes, abandon the coral colonies.

The lagoons of Lakshadweep including Minicoy, Kavarathi, Amini, Kadmat and Kiltan were subjected to long term dredging by the Lakshadweep harbour department to permit the entry of the mechanized vessels in to the lagoon (Pillai, 1989). It has to be noticed that the sand balance of the Lakshadweep island is very delicate. It is estimated that the growth of the reef areas is in the order of 3 mm vertical growth per year. Most of the sand is produced in the perimeter of the reef and in the algal pavement behind the reef. Sand production at the south-west part of the reef is the highest. Developments in this area are likely to result in increased sand loss from the coral reef system. An example of such a loss is the transport of sand outside the lagoon into the Indian ocean. If this is to happen, the likely effects on the coral reef would be very adverse and hence, should be undertaken very carefully. Even so developments which will affect the sand production side of the sand balance, like increased mortality of corals, will affect directly the continued physical existence of the Lakshadweep islands. At present, according to information of the Lakshadweep harbour department it seems that at all the islands more sand is being produced than what is leaving the system. This might have been true at present, but for years the dredged sands have been discarded outside the lagoon. Owing to the above it is very likely that a sand deficit during the years where dredging was rampant has happened. This might be one of the reasons for the present lagoon side erosion. At present the dredged sands and coral boulders are kept within the island ecosystem.

On all the islands with the exception of Kiltan, moderate to severe erosion was observed (photographs2a,b). The reasons for this seem to be numerous. In some places the erosion is on the eastern side of the islands. At other places the partial lagoon side beach subsidence has been observed partly caused by channel dredging. Severe erosion has occurred formerly on Kavarathi because of coral mining for construction purposes. On Kavarathi the government itself was in the past one of the main collectors of dead coral heads. Now the administration of Lakshadweep union territory has strictly prohibited the collection of dead coral heads even for the research purpose. However, the local population is still continuing centuries old practice of collecting coral head as there are no alternative cheap construction materials on the islands (see photographs 3a,b,c).

In the lagoons of most of the islands and in the ocean around Lakshadweep no oil pollution exist at present. An indication for this is that oil-tainted fish, which is an easy indicator for serious oil pollution in the marine environment, has not been observed. This indicates that hydrocarbons, with an exception of the lagoons of the bigger islands, are not common in the marine environment of the Lakshadweep islands. However, a study of the petroleum hydrocarbons (PHC) in the water samples collected from selected island lagoons has been included in this study.

Photograph 2a.: Loss of land due to wave action and erosion at Kavarthi lagoon beach.

Photograph 2b.: Concrete tripods against sea erosion at Kavarathi beach.

Photograph 3a: Coral stones used for the construction purpose.

Photograph 3b & c.: Buildings constructed with coral stones.

Periodical survey of extensive areas of coral reefs, is necessary mainly to provide description of the ever changing reef contours as a source of baseline information, to identify and select representative areas for detailed ecological investigations, or to assess and monitor the effects of tropical storms, episodal oil pollution due to increased shipping activities and also to evaluate the effect of anthropogenic interferences manifested in the form of dredging, blasting and removal of natural resources. All these are sure to cause removal, depletion or mass mortality of coral reef fauna.

The present study aims at surveying the coral lagoons of four islands viz. Kavarathi, Kalpeni, Kadmat and Agathi, which include quantitative survey of the major benthic forms using Line Intercept Transect (LIT) technique and hydrographical study of these lagoon waters. The distribution of PHC in the lagoons has also been followed to understand, the effects of introduction of flat bottomed ferry boats to the islands.

From a biological monitoring stand point for the assessment of man-made disturbance of the coral reefs, it is highly essential to identify faunal assemblages which will contain `flag-stones' species as indicators of such disturbances. Among the known faunal assemblages in coral reefs the most diverse groups of sensitive species belongs to bryozoan assemblage. Therefore, the most common species of bryozoans distributed along the atolls and reef flats were collected and described in this work. Along with this, bryozoans associated with coral from other parts of Indian ocean have also been added so as to provide a comprehensive picture of the distribution of bryozoans in the coral reefs.

CHAPTER 2

SURVEY OF CORAL LAGOONS OF LAKSHADWEEP ATOLLS USING LINE INTERCEPT TRANSECT (LIT) TECHNIQUE.

2.1 Introduction

Coral reefs are economically vital to many developed countries in the tropics, providing an essential source of protein for the growing population and income through the tourism industry. The prediction that 70% of the world's coral reefs will collapse in the next 10 to 14 years, with the remainder threatened by global climatic change (Wilkinson C R., 1993) endangers the viability of coral reefs as an economic component of these countries and also the quality of life of the people supported by these resources. The development and growth of coral reefs are closely controlled by environmental factors impacting on the atmosphere, the oceans and the adjacent land masses. Any localised or global changes in these factors will affect coral reefs. It has since long been recognized that coral atoll ecosystems which are compared with tropical rainforests are ecologically very sensitive (Connel, 1978). More and more evidence has been gathered that anthropogenic disturbances are unexpectedly detrimental for the coral reef ecosystem. Negative environmental impacts such as excessive siltation, channel dredging, nutrient enrichment, oil pollution etc. have proven to be very destructive. Owing to their isolated positions negative environmental impacts on coral atolls can be so destructive, and the effects could be almost irreversible. The sensitivity of coral reef habitats and their location on the coast, where most of the human population live, put them under an enormous environmental stress of anthropogenic origin.

Therefore it is essential that possible changes in coral reefs are monitored as soon as possible for the effects of climatic or anthropogenic changes. Most of the studies of coral reef benthic communities deal with their systematics, physiology, behaviour or some qualitative characteristics of their ecology. Very little work has been done in the past on quantitative description of coral reef communities. Problems such as species composition, species abundance and distribution as well as faunal patterns of different species have been, usually qualitatively described. As our knowledge of coral reef benthic communities increases, greater and greater need has been felt by coral reef students for quantitative analysis and description of coral reef communities and for methods to measure the characteristics of these communities. Most of the invertebrate communities of coral reefs are stationary or limited in their mobility. In this sense, there is a great similarity between coral reef invertebrate communities and terrestrial plant communities. It may be therefore, justified to adopt and test concepts and techniques used by plant ecologists for the study of benthic communities of coral reefs.

The atoll environment, in general, is a relatively restricted ecosystem where the impact of interference of man and nature will manifest conspicuously within a short time. The habitat is fragile, diverse and easily vulnerable and the effects of adverse factors on such systems are often of very serious consequences. The Lakshadweep atolls (fig. 1) are no exception to this global phenomenon of deterioration of reefs and their environs.

With population pressure increasing within coral reef ecosystem, investigation enabling description of the current state of the ecosystem, as a base line to monitor man-induced or natural changes through time, should be considered of great importance. Recognizing the similarities between the quantitative classification of coral reef and rain forest community structure, Bradbury, Loya and Reichelt have adopted Webb *et al's* (1970) technique to the reefal system and it is their classification scheme (Reichelt *et al.* in press) that forms the basis of this study.

2.2 Literature Review

Line transect method has been long established in terrestrial plant ecology (Greig-smith, 1964), and has now become a standard sampling technique for all sessile and sedentary organisms (Southwood 1966, Pielon 1977). In the field of coral reef research, Loya and Slobodkin (1971) and Loya (1972) first applied this line transect technique in studies designed to examine community structure of hermatypic corals in the Red sea. The method is generally used to estimate the areal density of different types of organisms. This is achieved by transecting the research area and measuring the point of interception of these organisms with the transect line. Since the proportion of the transect lying over the organisms is an unbiased estimator of the fraction of the total area covered by these organisms irrespective of the shapes, the estimate of areal density may be derived directly (Marsh *et al.* 1984). This technique allows the calculation of percentage cover and total number of occurrence per transect of the organisms under investigation, in this case lifeforms attributes of the macro benthos.

Stoddart (1969,1972) reviewed field methods and quantitative studies of hermatypic corals with special attention to the problems of sampling design, sampling unit and problems of data recording. He divided the linear transect studies done on coral reefs into two main categories. (a) Some form of continuous recording and (b) sampling along transects. However all the publications falling in these categories deal in one way or another with quadrate sampling (Mayer, 1918, 1924; Odum and Odum, 1955; Stoddart *et al.*, 1966). Some of these studies record the number of species or genera per quadrate, but in general, most of them have no usable data for quantitative comparisons of different reef systems, nor do they emphases the importance of studying the various zones of the reef. The transect line in these studies is used only as a reference line for the establishment of quadrates or as a belt transect with specified length and width, all individuals within it being measured. Loya and Slobodkin (1971) and Loya (1972) used for the first time, transect sampling in the sense of category (b) above (sampling along transects) in the line transect methods (i.e. the line transect has specified length but no breadth). This method was especially designed to study the community structure of hermatypic corals in forms of species composition, zonation and diversity patterns in different zones of the reef in the Red sea. Each transect was 10m long and were run underwater to a depth of 30m. Porter (1972 a,b) studied the species diversity of hermatypic corals at the San Blas coral reefs, in the Atlantic coast of Panama, in a somewhat modified methodology. A 10m long chain with links of 1.3cm in length was laid parallel to the depth contour at 3m intervals down the reef surface. Wallace (1974) studied distribution patterns of the coral genus *Acropora* at Big Broradhurst Reef in the

Great Barrier Reef, north east of Townville, Australia. She adopted the methods used by Loya (1972). Ott (1975) has quantitatively analysed the community pattern and structure of a coral reef bank in Barbados, West Indies, using a photographic line transect method. Laxton and Stablum (1974) described a photographic method for estimates of percentage cover of sedentary organisms on coral reefs. Loya (1972, 1975, 1976) has used the line transect described methodology in two quantitative studies: one which deals with possible effects of water pollution on the community structure of Red sea corals (Loya, 1975) and the other sedimentation effects on the community structure of hermatypic corals at Punta Ostiones, the west coast of Puerto Rico (Loya, 1976).

The line intercept transect (LIT) has been used for objectives ranging from large scale spatial problems (Benayahu and Loya, 1977, 1981), to morphological comparisons of coral communities (Brabdury *et al.*, 1986; Mapstone *et al.*, 1989) and studies assessing the impact of natural and anthropogenic disturbances (Moran *et al.*, 1986; Mapstone *et al.*, 1989). Most studies using this method have used similar techniques (a plastic fiber tape, placed on the substratum parallel with the reef crest) with the following variations: Bouchan (1981) used tape tensioned between two pegs; Hughes and Jackson (1985) used 10m chains (the size of the links was not stated).

Despite the early works of Gardiner (1904, 1905) and Pillai (1971a, 1986, 1987) and Pillai *et al.*, (1986) the coral fauna of Lakshadweep, except for Minicoy, remained virtually unknown to the scientific community. A resume of coral and coral reef research from this area is presented by Pillai (1987) along with a discussion on the structure and composition of the fauna. Pillai (1989) noticed the deleterious effects of dredging in several island lagoons of Lakshadweep. A team led by Pillai (1989) made an attempt to estimate quantitatively the percentage coverage of dead and live corals in some sample plots of the islands both in lagoon and reef flat habitats. The sample plots were of the area of approximately 25 sq.m.

Victor *et al.*, (1989) conducted a study to provide first hand information on the nature of substratum, deposition of coral reefs, fauna and flora of the lagoon at selected localities of lagoons of Lakshadweep. Each island was divided in to different sectors and observation was made by diving along a transect line commencing from the low water mark to the outer reef crest.

The details about the oil spill in the Kiltan island from oil tanker `Transhuron' have been described by Qasim *et al.*, (1974). The Minicoy lagoon has undergone visible change in the last decade due to natural causes and human interference (Pillai, 1983a, 1985, 1986). Possible threats to marine environment and ecology of Lakshadweep have been described by Sivadas (1987).

2.3 Materials and Methods

The Line Intercept Transect (LIT) technique which focuses on all types of substrata rather than a single taxonomic group, was used in the present study to estimate the cover of group of objects or lifeform categories within a specified area by calculating the fraction of the length of the line that was intercepted by the object (Gates, 1979, Lyndon M.de vantier, 1986 and UNEP, 1993). This measure of cover, usually expressed as a percentage, is considered to be an unbiased estimate of the proportion of the total area covered by that object.

Eighteen lifeform categories were selected for this investigation which has included both biotic and abiotic attributes designed to cover 100 percent of the benthic topography of the study area. While these categories or attributes were morphologically based, several also possess a taxonomic element, as demonstrated by the "Acropora branching" category, for example . The list of lifeform categories and their codes are given in table 1. Examples of lifeform categories which group benthic communities through the use of morphological characteristics are given in figures 3a to 3c (photographs 5 a to j).

Atolls selected for LIT survey

Four atolls viz. Kavarathi, Kadmat, Kalpeni and Agathi were selected for conducting LIT survey. All these are perfect atolls (Gardiner, 1903, 1906) located between latitude 10^0 05' N and 11^0 13' N and longitude 73^0 39' E and 72^0 47' E (fig. 1) Like most other atolls in the archipelago, they are oriented along a north-south axis, the lagoon to the west and the island to the east. These Indian ocean atolls lie in the path of the monsoons which blow with tremendous force from the south-west from May to about September and with lesser force from the opposite direction from November to about January (Hydrographic office, 1961). Thus the windward and the leeward side of the atoll change from season to season, however, it is the western reefs, exposed to the full fury of the monsoon, that more closely parallels a pacific windward reef (Tranter *et al.* 1972). Irrespective of season, water currents generally move in one direction through the shallow lagoon towards the entrance, accelerating enroute. The flow is created by the surf which breaks across the reef and spills into the lagoon. At low water the top portion of the reefs are exposed.

Table 1: List of Lifeform Categories and Codes

CATEGORIES		CODE	REMARKS
SCLERACTINIAN CORALS			
Acropora	Branching	ACB	at least 2^0 branching, eg. *Acropora palmata, A. formosa.*
	Submassive	ACS	robust with knob or wedge-like form eg. *A. palifera*
	Digitate	ACD	no. 2^0 branching, typically includes *A. humulus, A. digitifera* and *A. gemmifera*
	Tabulate	ACT	horizontal flattened plates eg. *A. hyacinthus*
Non-Acropora	Branching	CB	at leat 2^0 branching eg. *Seriatopora hystrix*
	Encrusting	CE	major portion attached to substratum as a laminar plate, eg. *Montipora undata*
	Foliose	CF	coral attached at one or more point, leaf -like appearance eg. *Merulina ampliata*
	Massive	CM	solid boulder or mound eg. *Porites solida* and *P. lutea.*
	Submassive	CS	tends to form small columns, knobs or wedges eg. *Porites lichen, Psammacora digitatas*
Other Fauna		OT	sessile fauna other than above described corals eg. giant clam, blue coral (Heliopora sp), fire coral, anemones, ascidians etc.
Algae	Algal assemblage	AA	consists of more than one species
	Coralline Algae	CA	eg. *Halimeda sp.*
	Turf Algae	TA	lush filamentous algae.
Abiotic	Sand	S	
	Rubble	R	unconsolidated coral fragments
	Sand/Rubble mixture	S/R	
Recently Dead Coral		RDC	recently dead, white to dirty white
Dead Coral with Algae		DCA	this coral is standing, but no longer white

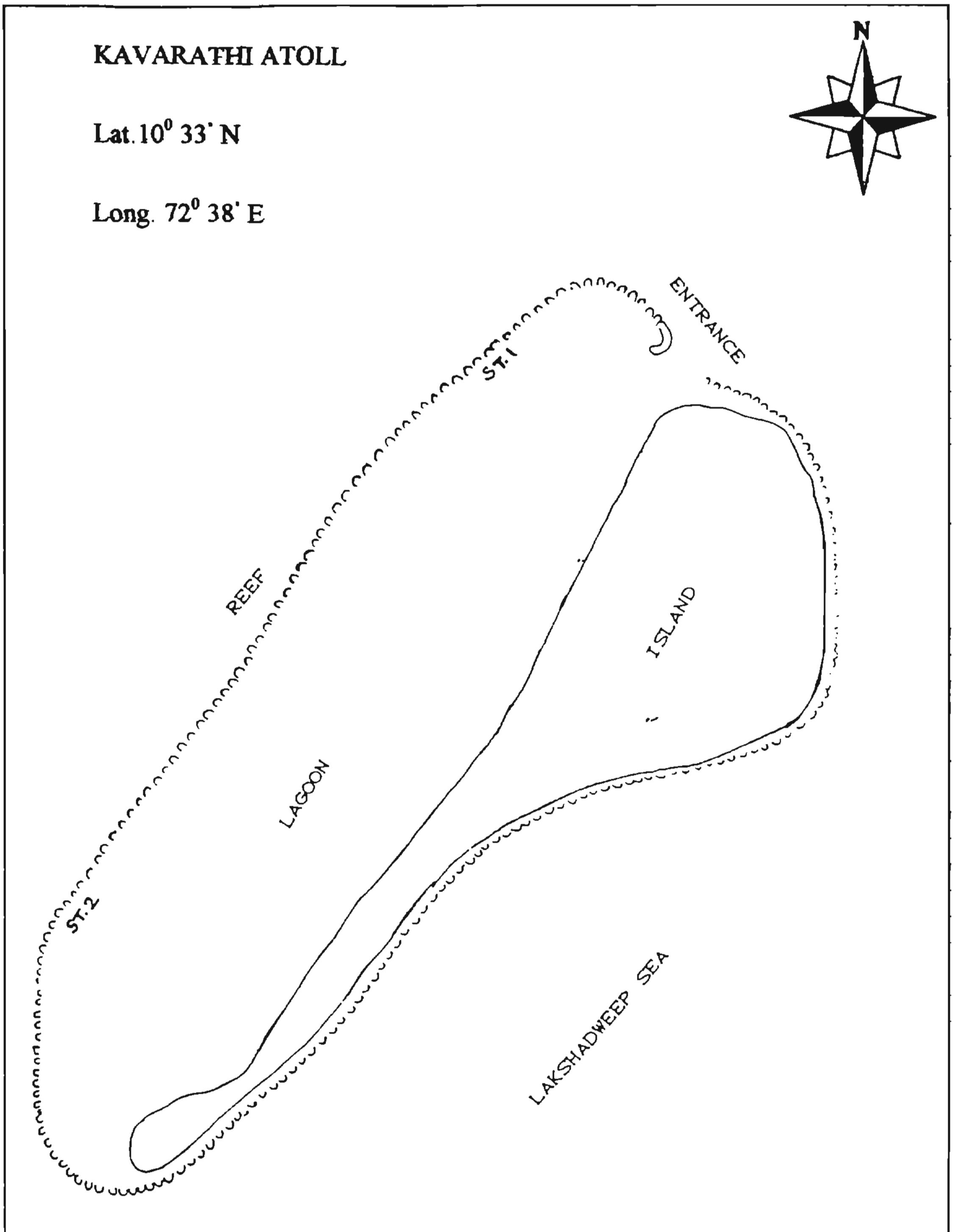


Figure 2a: The different sampling stations in Kavarathi lagoon where the Line Intercept Transect survey was conducted

The eastern side of the islands (seaward) are exposed to high sea. The seaward beach has a steep slope with a substratum of loose coral blocks, coral limestones and debris, in addition to a sublittoral zone of living corals in the reef adjoining the islands. These form break-water to the heavy surf.. The portion of the lagoon towards the reef is characterised by living and dead corals and other fauna with irregular areas of coral rubbles, algal beds and sand.

Kavarathi atoll is located along lat. 10^0 33' N and long. 72^0 38' E (fig. 2a) and has an island of 3.6 sq.km in area, which is largely covered by coconut palms. The northern end of the island is broad (about 1.2 km) and its southern end long and narrow, only about 40 km wide at the narrowest point. On the western side, it has a shallow lagoon, of about 4500 m long and 1200 m wide, with depths ranging from 1.52 to 83 m at low water and 2.44 to 3.55 m at high water (Qasim *et al.*, 1972). Bordering the western margin of the lagoon, there is a ring-shaped coral reef with a width of about 250 to 300 m, except at the south-west point where it is more than 400 m wide. A gap in the coral reef, about 60 m wide, on the north-west point forms the main navigational entrance to the lagoon.

Kadmat atoll is located along lat. 11^0 13' N and long. 72^0 47' E (fig. 2b) and has a land area of 3.1 sq.km. The island is long and narrow and has a large lagoon with an area of 13.4 sq.km and about 12 km long and 2.4 km wide. The main entrance is situated on the western side of the lagoon about midway between the northern and southern point of the island. Another entrance at north of the lagoon. The average depth of lagoon is 1m low tide.

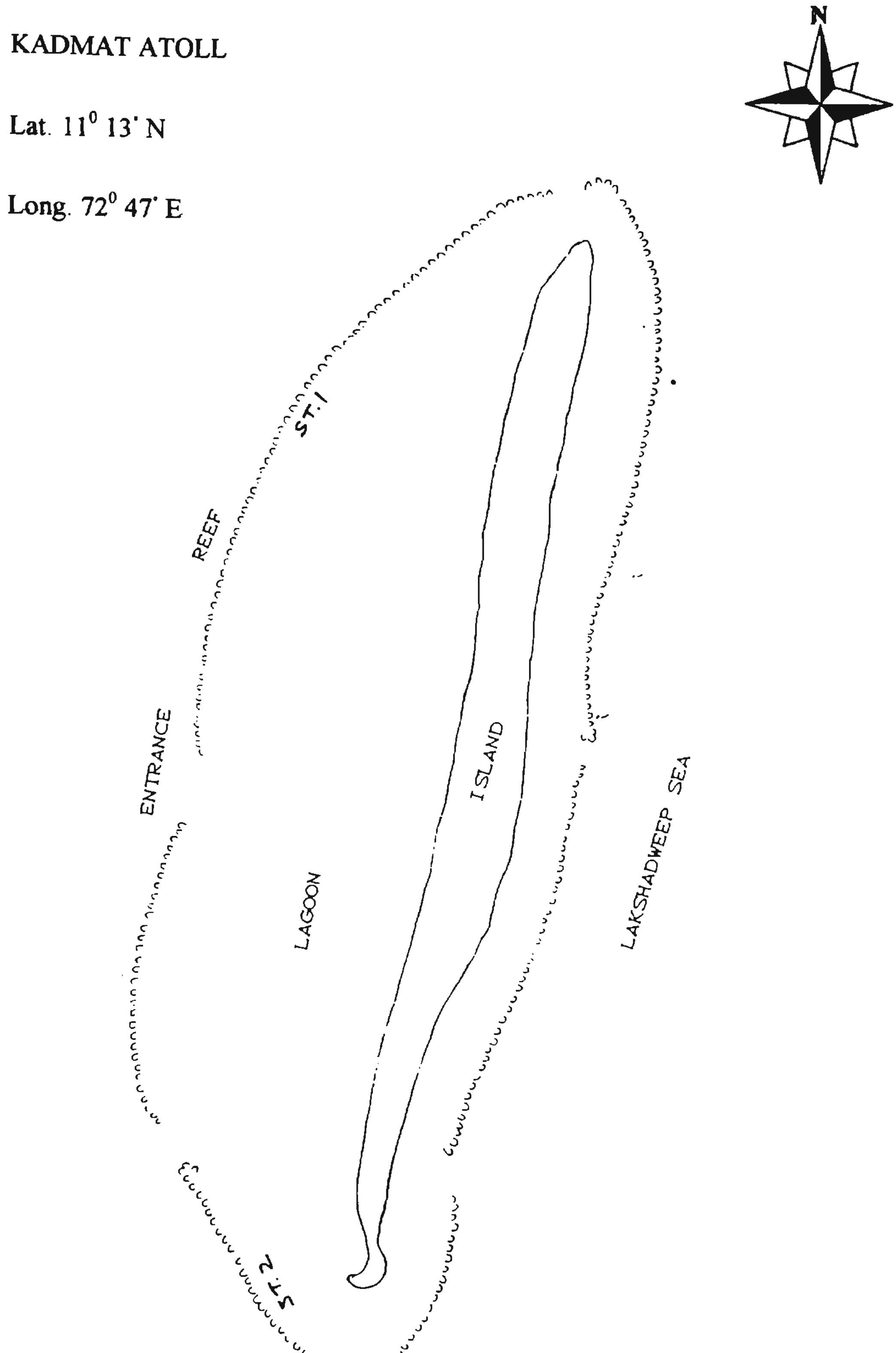


Figure 2b: The different sampling stations in Kadmat lagoon where the Line Intercept Transect survey was conducted

Kalpeni atoll is located along lat. 10^0 05' N and log. 73^0 39' E (fig. 2c) and has a land area of 2.3 sq.km. and is about 1.3 km wide and 5 km long. Cheriyam island, situated north of Kalpeni, is about 2.8 km long and the maximum width is about 300 m. There are two groups of small islands situated in the south western part of the Kalpeni-Cheriyam lagoon. Both islands have their lagoons situated to the west of the island, about 10.5 km long and has a maximum width of 4.3 km in the centre, enclosed by elliptical reefs. The lagoon has a maximum depth of 5 m. Although a western passage through the reef is present, the major entrance is encountered in the north-west part of the reef.

Agathi atoll located along lat. 10^0 51' N and long. 72^0 11' E (fig. 2d) and has land area of 2.7 sq.km. It has a large lagoon with an area of 11.71 sq.km and about 8 km long and a maximum width of 4 km. The average depth is 1.2 m. The main entrance is at north west of lagoon, and another passage at west of the lagoon is also situated.

The reason for the selection of these four atolls was that rapid economic development which give room for concern from the environmental point of view, is taking place on these four islands. Recently (1990) an inter-island ferry system was introduced in Lakshadweep connecting all inhabited islands except Minicoy (see photograph 1a & 1b). This ferry system which consists of two flat-bottomed ferries or speed boats are entering Kavarathi lagoon where facilities such as sufficient channel depth and entrance width exist. There is a proposal of its entry in to the other three above mentioned atolls also. Facilities are being developed in these three atoll lagoons for the entry of the flat bottomed boats.

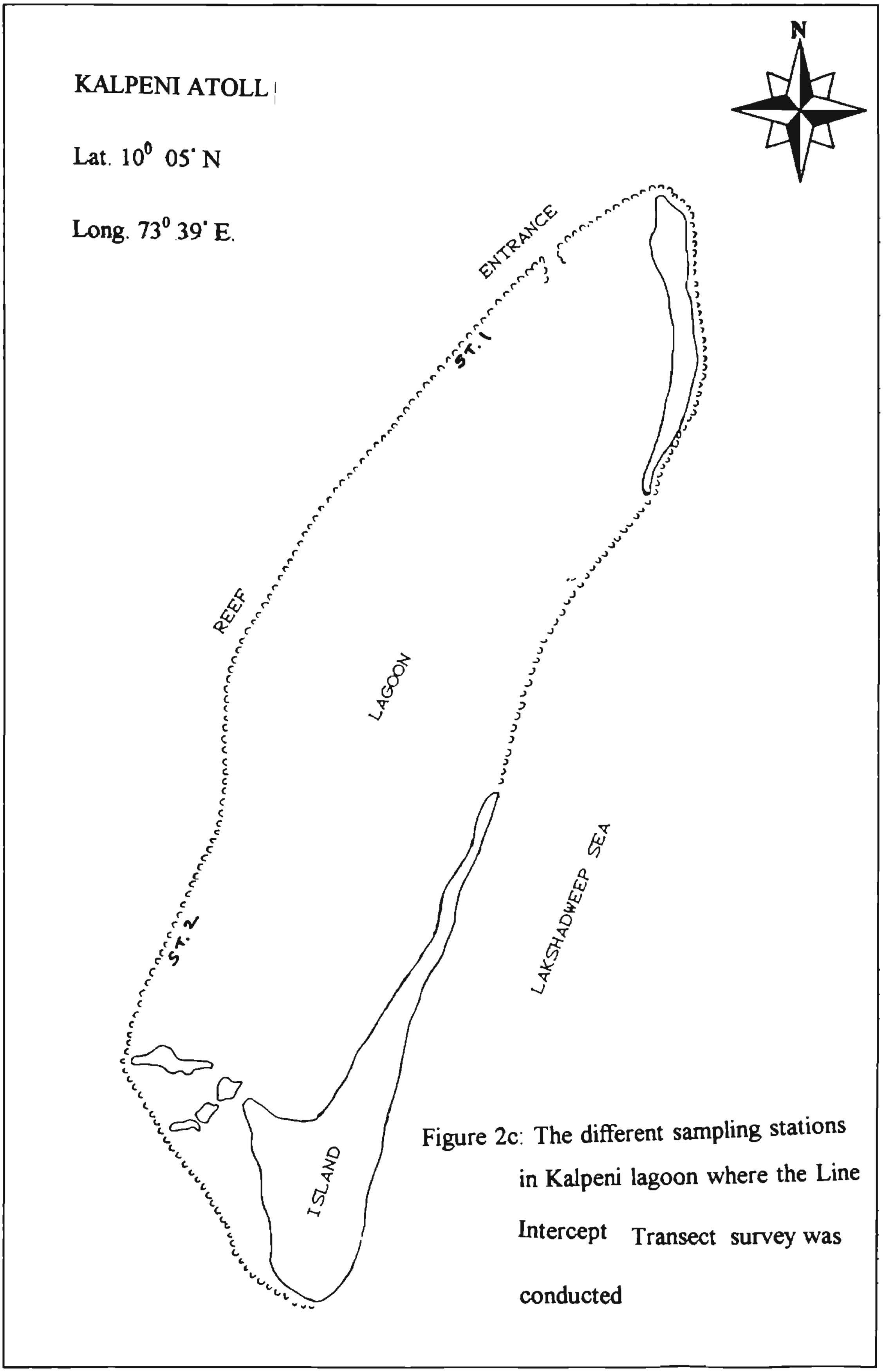


Figure 2c: The different sampling stations in Kalpeni lagoon where the Line Intercept Transect survey was conducted

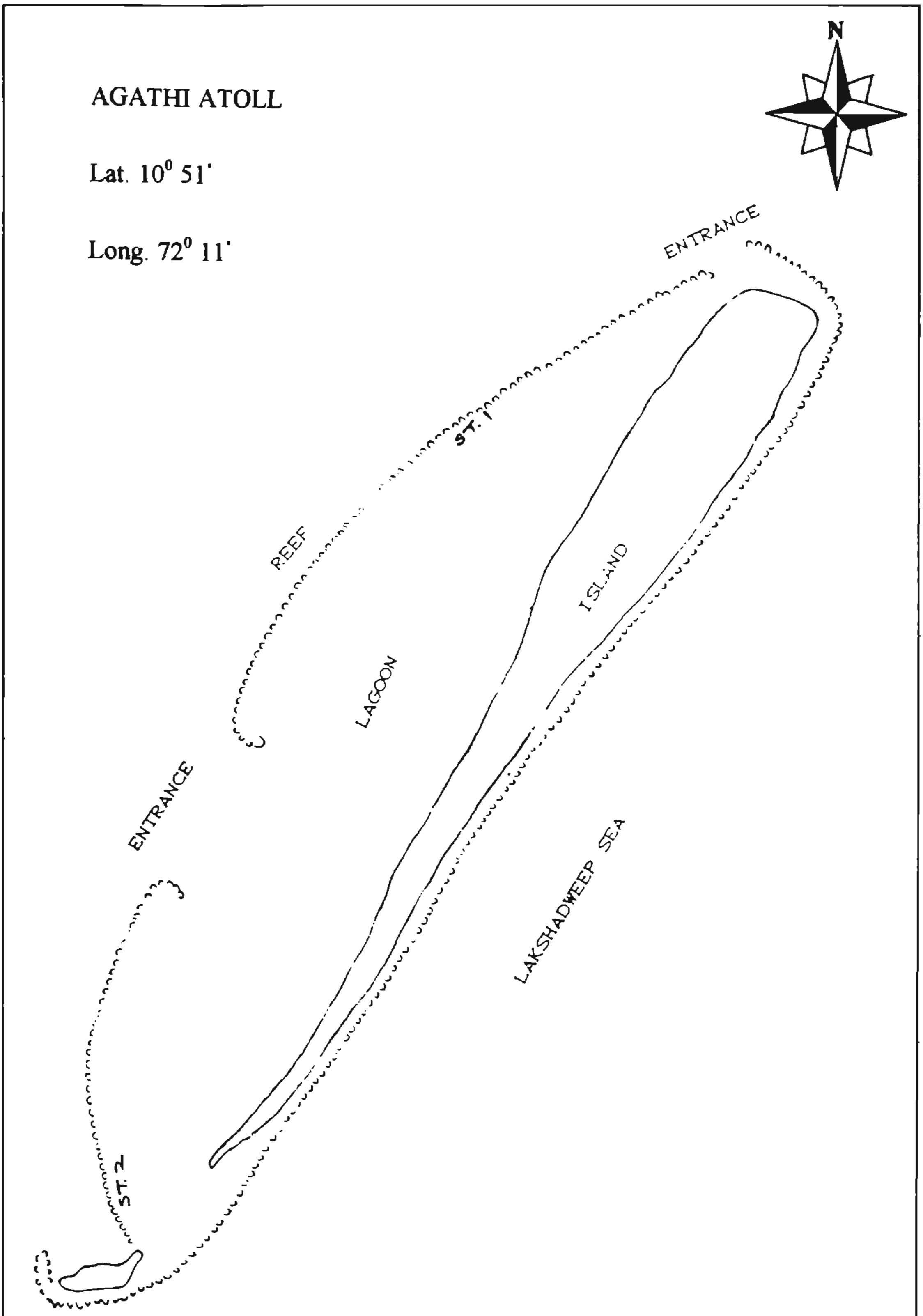
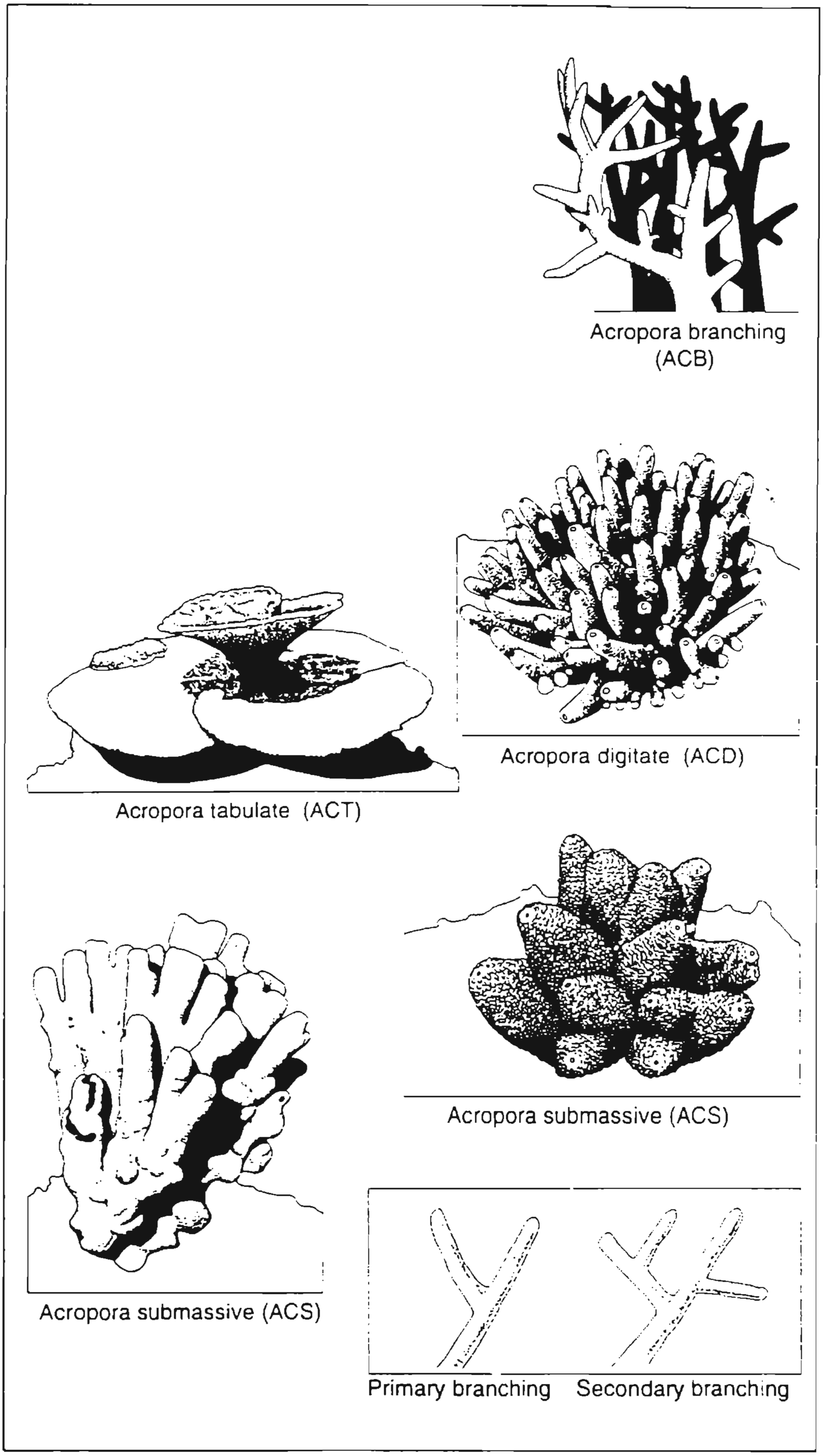
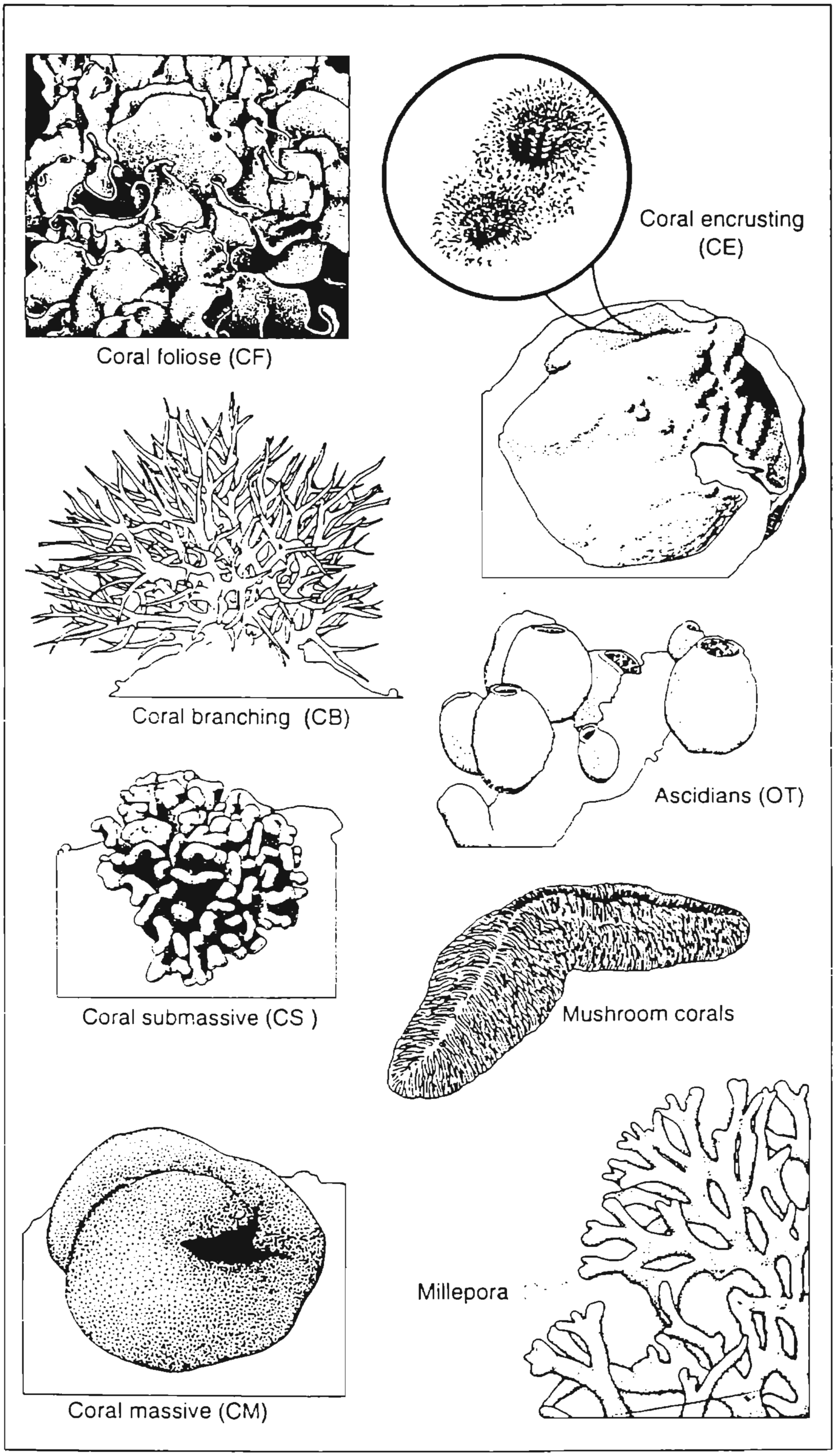


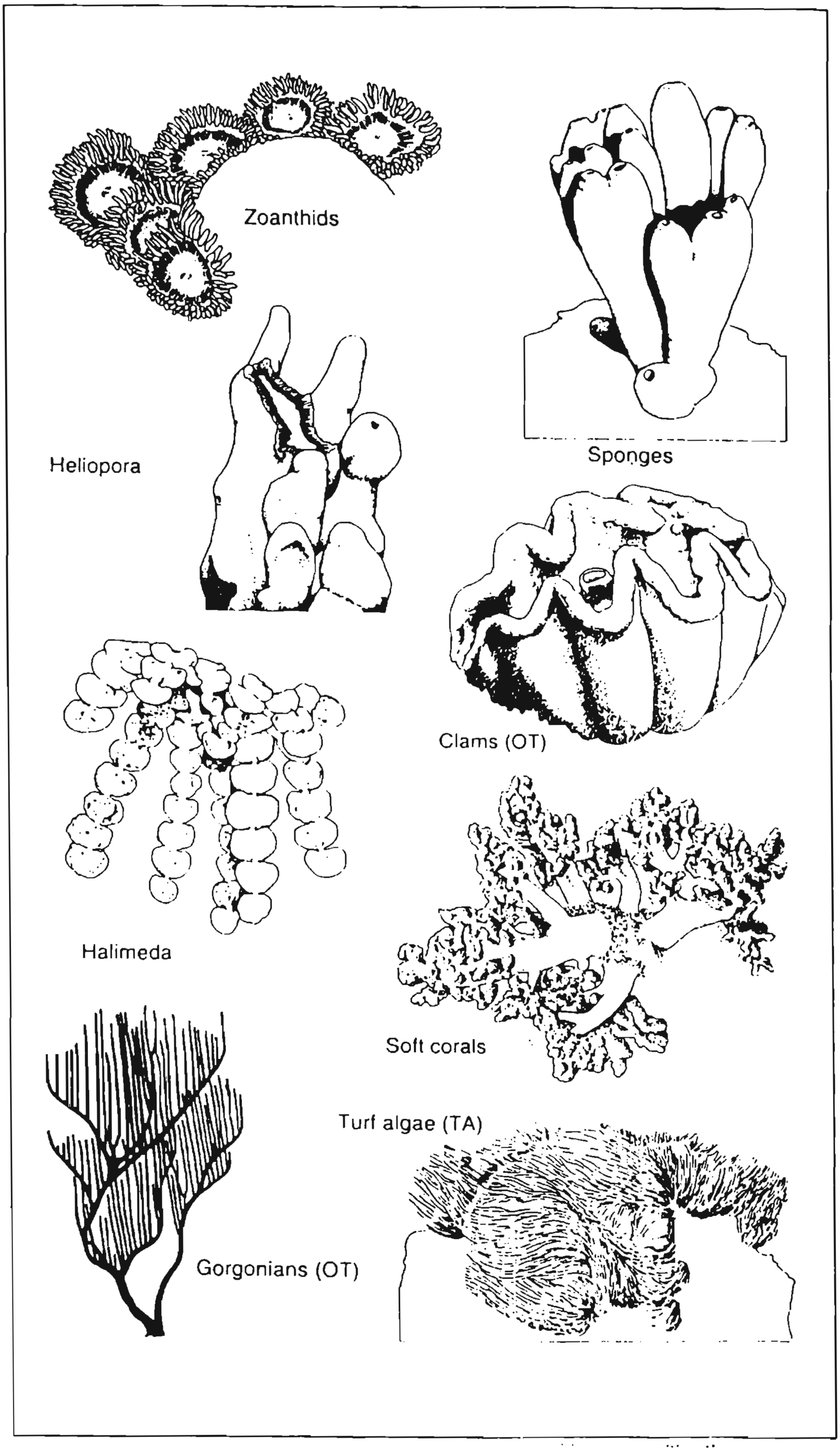
Figure 2d: The different sampling stations in Agathi lagoon where the Line Intercept Transect survey was conducted



Figures 3a: Examples of lifeform categories which group benthic communities through the use of morphological characteristics



Figures 3b: Examples of lifeform categories which group benthic communities through the use of morphological characteristics



Figures 3c: Examples of lifeform categories which group benthic communities through the use of morphological characteristics

These activities will boost the tourism industry further and economic development in these four atolls which will invite environmental stress to this delicate ecosystem. In this situation the survey of these lagoon reefs by Line Intercept Transect (LIT) method would be useful to know the status of the present state of the reefs and the data would be useful as baseline to monitor the coral reefs.

Site selection

Preliminary survey was conducted to select suitable sites on the lagoon reef which are representative of that reef. The existence of lagoon reef which protect the land by breaking the wave action is important for the existence of the land as well as people. So the sites were selected on the reef flat of western reef which encloses a lagoon. Two sites were selected in each atoll from the lagoon reef and the location of the study sites within each reef are shown in figures 2a to 2d. The two sites were located in each atoll at north-west (station 1) and south-west area (station 2) of the reef. The depth of the sites ranges from 1 to 2 m during low tide.

In Kavarathi, station 1 is located north-west, near the entrance of the navigational channel and the station 2 is located at south-west part of the reef. In Kadmat, the entrance is situated at the centre of reef and thus the station 1 is located between the centre and the north of the reef ie N-W of the reef. The position of station 2 is on the S-W part of the reef.

In Kalpeni, station 1 and station 2 are located at N-W and S-W part of the reef. Here the entrance is situated in the N-W of the reef as Kavarathi. In Agathi, differing from the other 3 atolls, the reef has two main passages on the north and west side. The northern reef passage is usually used during high tide and in monsoon. The sites selected in this reef are situated at north-west (between north and west entrances) and south-west of the reef.

For each site, 3 replicate transect lengths of 30 m were sampled and the transects ran at 1 m and 1.5 m depths parallel to reef crest. The survey were carried out 3 times (1991 post monsoon, 1992 pre and post monsoon).

Equipment

a) Small boat with outboard motors

b) Mask and snorkel unit

c) Fibre glass/metal measuring tape-30 m in length with hooks attached to the end of the tape and to the casing.

d) Slates, data sheets (A4 underwater paper), and pencils.

e) Float or other materials (eg. plastic bottles) to be used as markers.

Field technique and data recording

The field technique required the placement of a plastic metric tape measure, positioned by snorkel divers (see photographs 4a & 4b), along various depth contours at selected sites of the reefs. Moving along the transect using snorkel, each benthic lifeform was noted on waterproof paper. Thus with the help of the measuring tape a list of attribute codes and corresponding points of intersection at each site was generated. At each point where the benthic lifeform changes, the transition point in centimeter and the code of the lifeform were recorded. Hence along the length of a transect (XY) (see figure 4) a number of transition points (T) were recorded for each of the lifeform. This type of sampling gives the estimate of percent cover of a category, the relative abundance of

Photograph 4a & b.: Snorkle divers in the lagoon, positioning the transect.

percentage live cover and percentage of dead and live coral. This method has been employed to compare two stations of each atoll reef and to describe a particular reef. The percentage was calculated based on the total linear coverage of 3000 cm (30 m). Linear calculation excludes representation of spatial indices.

Some colonies were encountered which could be recorded as either of two lifeform categories, depending on where the colony was intercepted by the tape. Such colonies were recorded by their dominant lifeform (i.e. the lifeform displayed by more than 50% of the colony). For example, large digitate *Acropora* (ACD) species (*A. digitifera, A. humulis*) may have secondary and tertiary branching at the ends of some of their branches. However, the proportion of the colony which displayed these characteristics relative to the digitate form was small and hence the colony would be recorded as ACD. After calculating the intercept from the transition points recorded along the transect, the percent cover of a lifeform category was calculated.

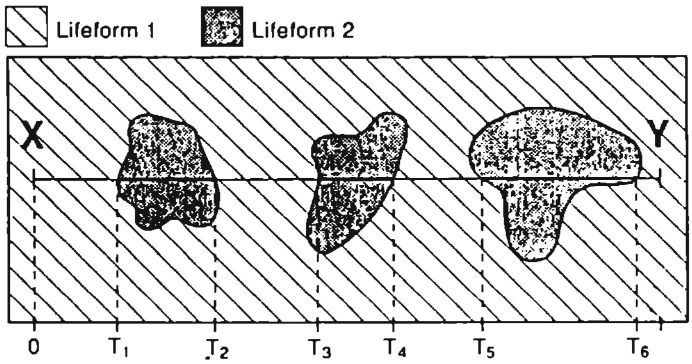
$$\text{Percent cover} = \frac{\text{Total length of category}}{\text{Length of Transect}} \times 100$$

Hence for figure 4 ,

$$\%\ \text{cover Lifeform 1} = \frac{I_1 + I_3 + I_5 + I_7}{Y} \times 100$$

$$\%\ \text{cover Lifeform 2} = \frac{I_2 + I_4 + I_6}{Y} \times 100$$

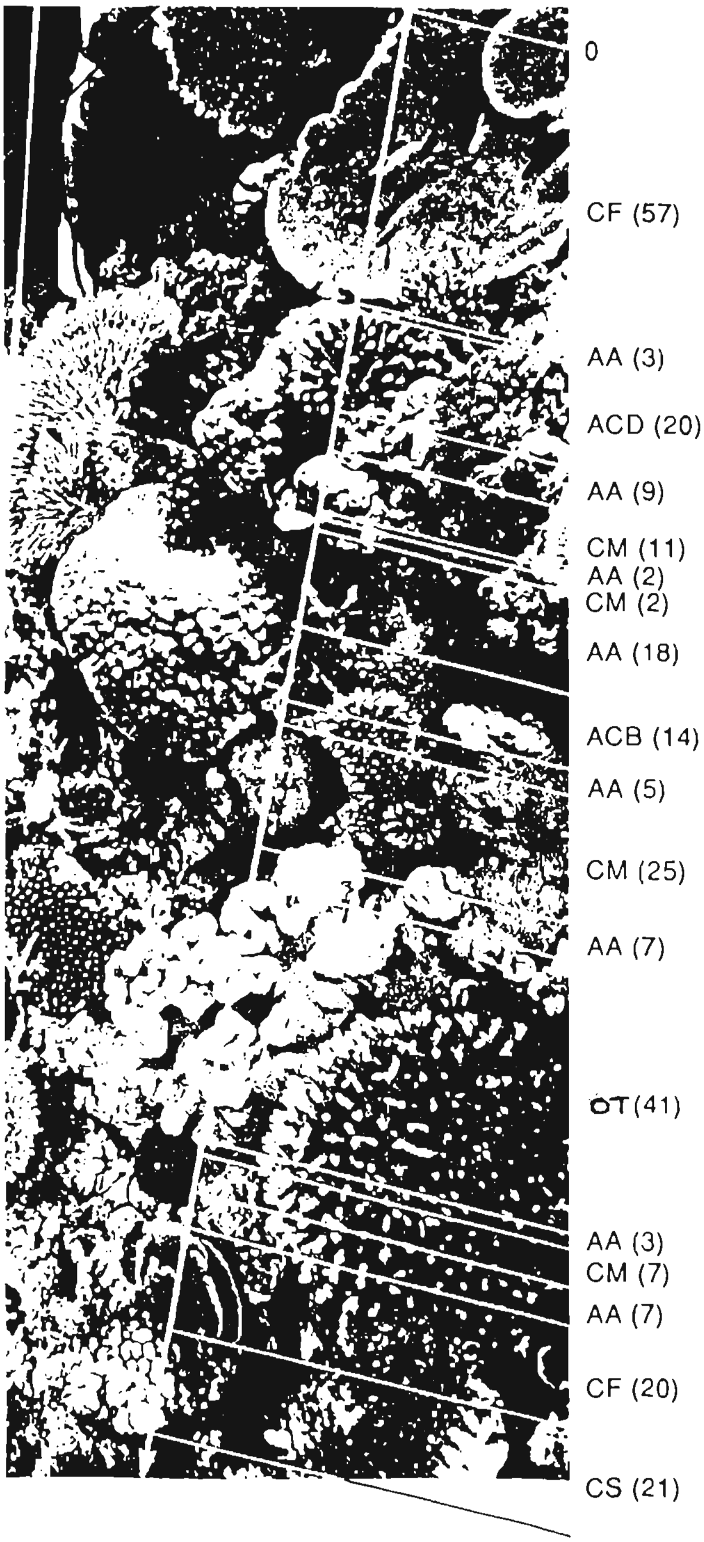
These analyses provide quantitative information on the community structure of the sample sites and the average of all the survey were recorded. The data were compared between two sites in each reef and the state of reefs was compared among the four



Intercept		Category
$T_1 - 0$	=	lifeform 1
$T_2 - T_1$	=	lifeform 2
$T_3 - T_2$	=	lifeform 1
$T_4 - T_3$	=	lifeform 2
$T_5 - T_4$	=	lifeform 1
$T_6 - T_5$	=	lifeform 2
$Y - T_6$	=	lifeform 1

Intercept		Category
$T_1 - 0$	I_1	Lifeform 1
$T_2 - T_1$	I_2	Lifeform 2
$T_3 - T_2$	I_3	Lifeform 1
$T_4 - T_3$	I_4	Lifeform 2
$T_5 - T_4$	I_5	Lifeform 1
$T_6 - T_5$	I_6	Lifeform 2
$Y - T_6$	I_7	Lifeform 1

Figure 4: Schematic diagram of a transect (XY) showing the transition points (T) for each lifeform crossed by the transect. The difference between consecutive transition points is the intercept of the lifeform



Transition	Category
57	CF
60	AA
80	ACD
89	AA
100	CM
102	AA
104	CM
122	A
136	ACB
141	AA
166	CM
173	AA
214	OT
217	AA
224	CM
231	AA
251	CF
272	CS

Figure 5: A section of a length of transect showing the lifeform categories and the intercept recorded from the transect tape.

atolls. A section of length of transect showing the lifeform categories and the intercept recorded from the transect tape is given in figure 5. On-the-spot identification was made for all common and easily identifiable forms. Literature and monographs used for the identification were Gardiner (1903, 1906), Pillai and Scheer (1974, 1976), Scheer and Pillai (1983) and FAO (1984).

2.4 Results

2.4.1 Kavarathi Atoll

Figure 2a indicates the locations of the reef surveyed using Line Intercept transect technique. The transect values listed in Table 2a clearly shows the state of the reefs in the two stations, station 1 and station 2.

All the Acropora categories, such as Acropora branching (ACB), Acropora tabulate (ACT), Acropora digitate (ACD) and Acropora submassive (ACS) were very poorly occupied at station 1 compared to station 2. Every category was represented below 1% and Acropora tabulate was absent at station 1 which was located N-W of the reef and near to entrance of the navigational channel. At station 2 ACB, ACD and ACS occupied higher percentage when compared to that of station 1, but ACT were only 0.75% . Non-Acropora groups also were poorly represented at station 1 when compared to that of station 2. Of the five groups, Coral Massive (CM) were the dominant and occupied 2.15% . The coral branching (CB) and coral encrusting (CE) were below 1% and coral submassive (CS) was slightly above 1% (1.33%). The Coral Foliose (CF) group was absent here. But at station 2 higher percentage abundance of all the categories of non-Acropora except CF were recorded and CM

Table 2a: Average Percentage Abundance of Benthic Forms Based on LIT Technique Conducted at Kavarathi Atoll

Categories	Station 1	Station 2
ACB	0.98	3.90
ACT	0	0.75
ACD	0.46	2.86
ACS	0.76	2.05
CB	0.33	5.33
CS	1.33	6.20
CM	2.15	15.23
CF	0	0.73
CE	0.43	5.83
OT	0.78	3.50
AA	21.01	21.32
TA	3.58	9.18
CA	10.69	7.83
DCA	9.92	2.77
RDC	3.33	0.84
S	13.89	4.27
R	16.01	3.92
S/R	13.93	3.18

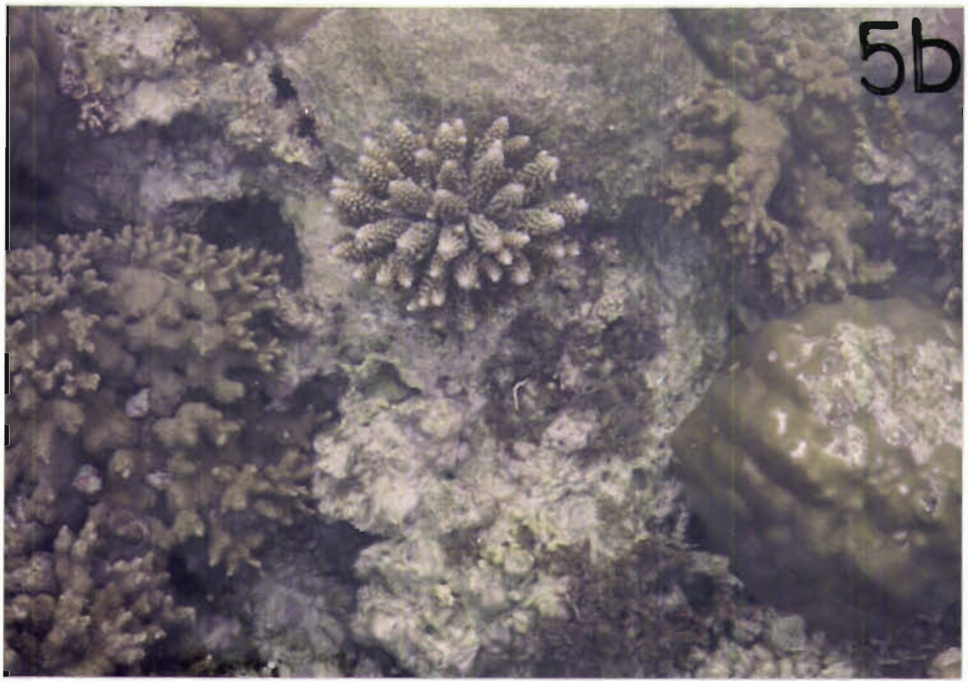
occupied the most conspicuous position, 15.23% followed by CS (6.20%), CE (5.83%) and CB (5.33%). The CF was recorded below 1% (0.73%).

Table 3 shows the average of percentage occurrence of scleractinian corals at two stations. The total of all Acropora groups represented only 2.23% at station 1 and at station 2 it was 9.56% ; the non-Acropora groups were represented 4.14% and 33.32% at station 1 and station 2 respectively. Table 4 shows the difference in occurrence of all scleractinian corals in station 1 and station 2. Only 6.37% of scleractinian corals were recorded from the LIT survey at station 1 whereas 42.88% were recorded at station 2. Average percentage of all coral forms at 2 two stations are given in table 5.

The dominant coral species present at two stations which were spot identified were *Porites spp.* (*Porites solida* and *P. lutea*) (see photographs 5a, 5e & 5f). Large colonies of these two species dominated in percentage occurrence at station 2. However, at station 1, only very small colonies of these two species were recorded. The table 6 shows the important species of corals identified during the survey. All these species were recorded earlier also. Among the Acropora categories, branching types were dominated by four species viz. *A. intermedia*, *A. formosa*, *A. abrotanoides* and *A. corymbosa*.

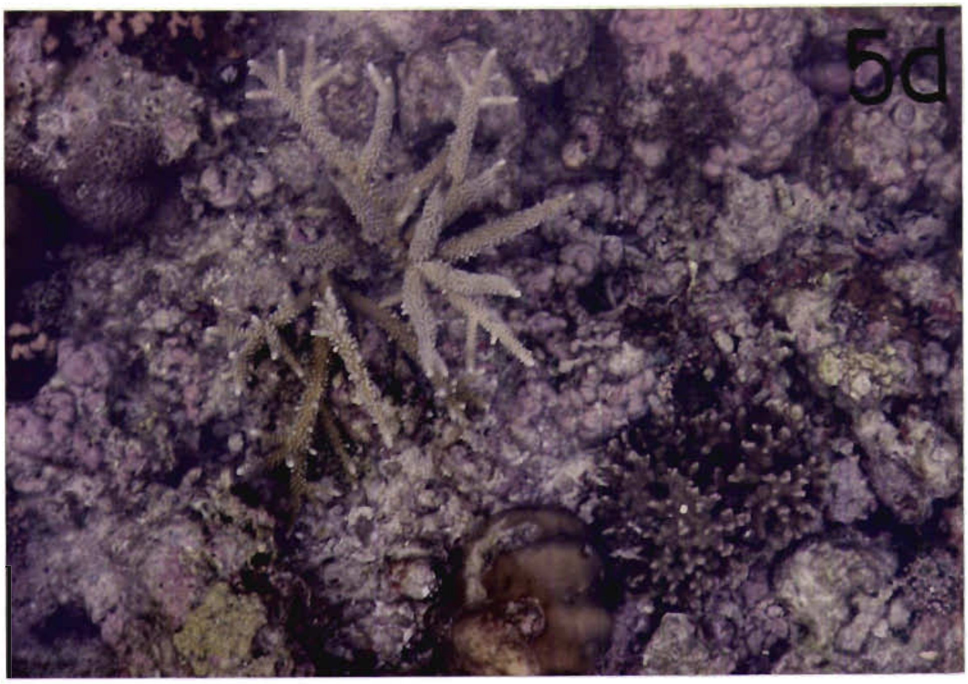
Acropora submassive (ACS), digitate (ACD) and tabulate (ACT) were represented by *A. palifera*, *A. humilis* and *A. hyacinthus* respectively.

The non-Acropora groups were dominated by genera, *Porites*, *Psammacora*, *Pocillopora*, *Montipora*, *Merulina*, *Pavona* and *Platygyra*. But, massive and submassive corals was occupied the most conspicuous position in the



Photograph 5a.: Lifeform categories: *Acropora.* submassive (ACS) and Coral massive (CM).

Photograph 5b.: Dead Corals (DCA) along with small colonies of live corals and algae.



Photograph 5c.: Coral massive (*Porite sp.*) exposed during heavy low tide. Algae and dead corals with algae (DCA) are present.

Photograph 5d.: Small colony of Acropora branching (ACB).

non-Acropora coral assemblage and as a matter of fact among all the coral assemblages. CM was represented by *Porite spp.* and *Platygyra spp.* and CS was represented by *Psammacora spp.* and *Pocillipora sp.* Foliose group were represented by *Montipora sp.*, encrusting group by *Psammocora sp.* and *Pavona sp.* and Coral Branching by *Porites spp.*(Table 6).

The non-Scleractinian hard corals, included under the category `other fauna (OT)' were mainly represented by *Heliopora sp.*. The average percentage of OT showed great differences at the two stations, station 2 recording higher percentage (3.5%) while station 1 registered only 0.785% Giant clam, *Tridacna spp.* (see photograph 5j) was the dominant group besides *Heliopora sp.* in the OT categories.

The algal assemblage (AA) consisting of more than one species of algae, apart from Coralline Algae (CA), and Turf Algae (TA) were the dominant group occupied more or less the same percentage at the two stations (21.01 and 21.32 at station 1 and station 2 respectively). *Halimeda sp.* representing coralline algae (CA) occupied 9.18% at station 2 whereas it was only 3.58% at station 1.

Turf algae which consists of lush filamentous algae, were 10.69% at station 1 and 7.83% at station 2 (Table 2a). The representation of all algal categories was more or less equal at the two stations (Table 3).

Turbinara sp. and *Surgassum sp.* were the dominant species recorded among the algal assemblages. *Gelidiella sp.* and *Gracilaria sp.* also were recorded.

Recently Dead Coral (RDC) were identified as pure white to dirty white and Dead coral with algae (DCA) (see photograph 5) was standing, but no longer white. The average percentage abundance of these two categories is shown in table 2a. Both

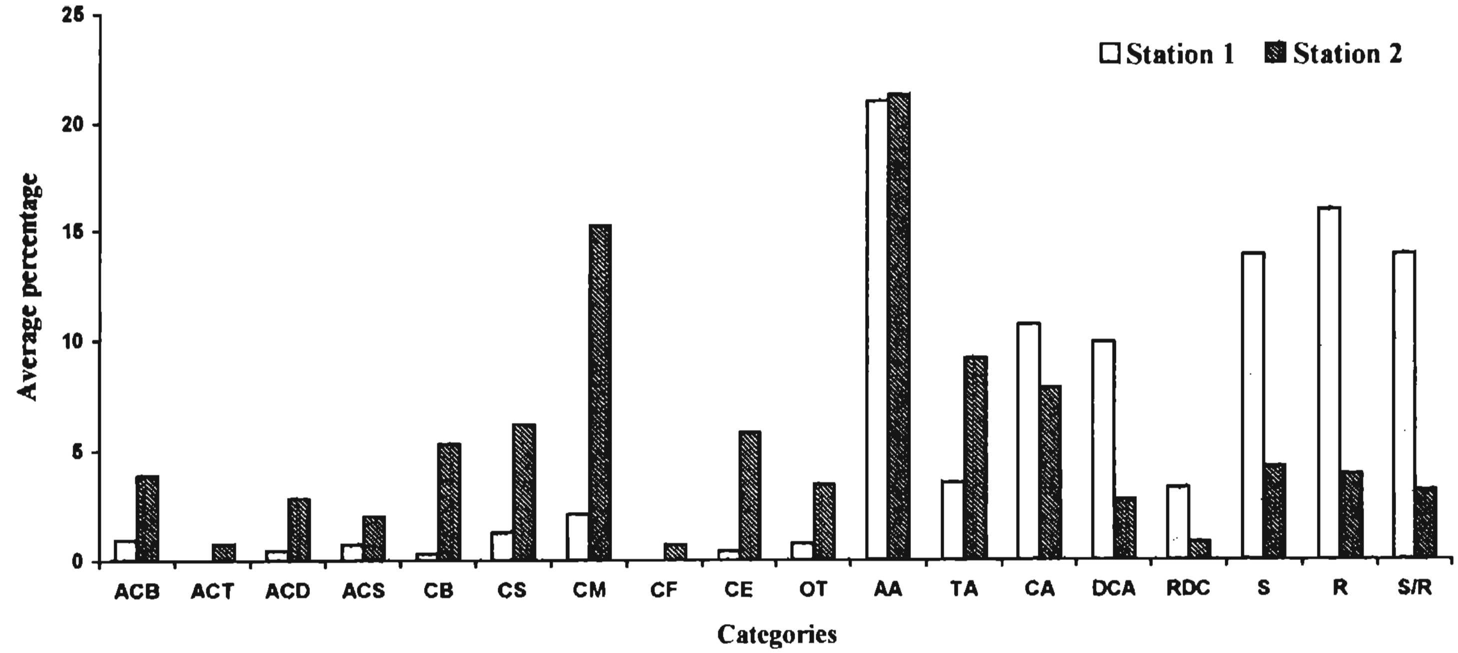


Figure 7a.: Graph Showing Distribution of Different Lifeform Categories in Station 1 and Station 2 at Kavarathi Atoll.

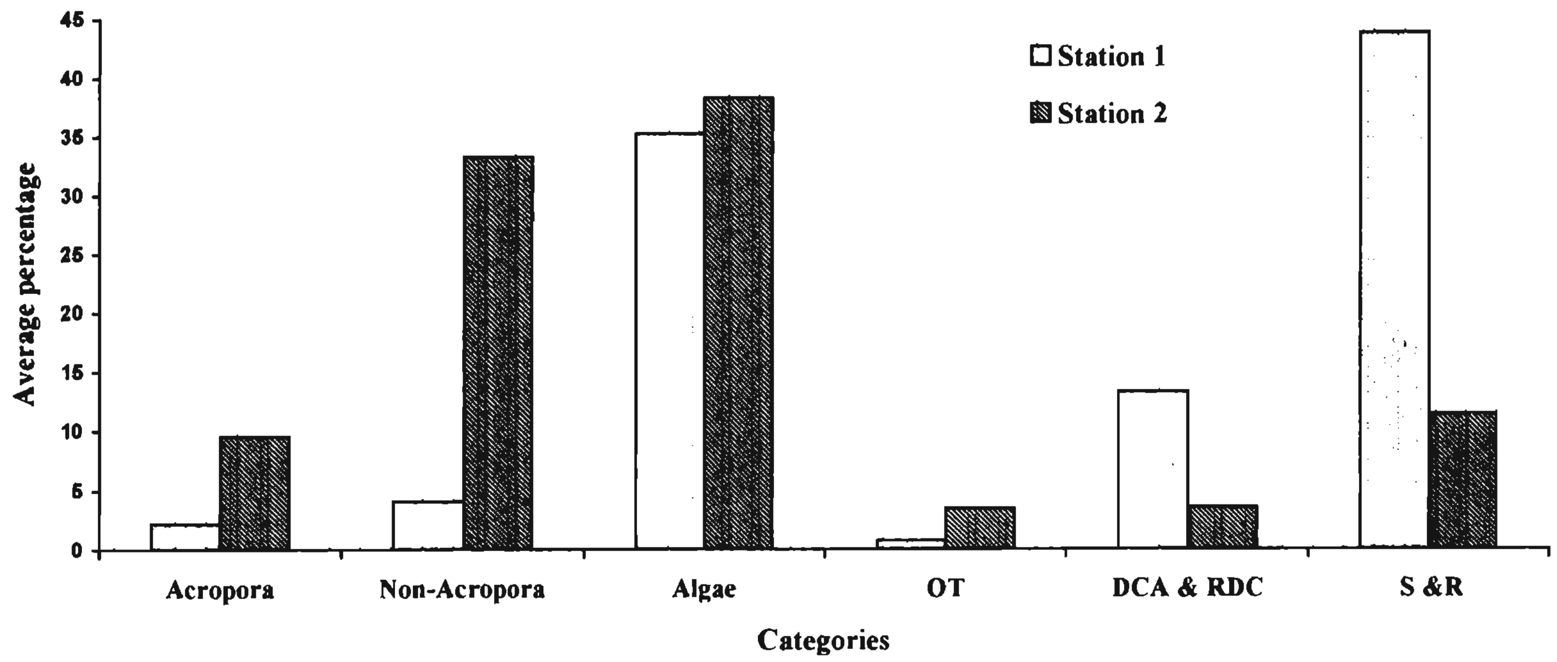


Figure 7b.: Graph Showing Percentage Abundance of Major Benthic Forms in Station 1 and Station 2 at Kavarathi Atoll.

the categories occupied higher values at station 1 compared to station 2. Station 1 has 9.93% of DCA and 3.33% of RDC, while station 2 has 2.77% (DCA) and 0.84% (RDC). Table 4 shows the total of these two groups at the two stations. Among other abiotic components, sand, rubble and sand/rubble mixture were also recorded. These components were high at station 1 compared to station 2. Table 5 shows the total percentage occurrence of these 3 abiotic categories.

The distribution of lifeform categories in the two stations are represented by graphs(fig. 7a & 7b).

2.4.2 Kadmat Atoll

The areas in the reefs surveyed, employing Line Intercept Transect technique are shown in figure 2b. The average percentage occurrence of each benthic form at the two sites are given in the table 2b.

Except ACB, all other Acropora forms were more or less equally distributed at the two stations. ACB was 2.99% at station 1 and 4.3% at station 2 (Table 2b). Average percentage of total Acropora forms at station 1 was 10.72% and 12.54% at station 2 (Table 3).

All non-Acropora forms except encrusting corals showed more or less equal abundance at the two stations very similar to the trend exhibited by Acropora forms (Table 2b).

Total of all non-Acropora forms which is given in the table 3 also indicates more or less same percentage abundance at the two stations. Station 1 was occupied by 26.1% of non-Acropora forms while it was 27.27% at station 2.

Table 2b: Average Percentage Abundance of Benthic Forms Based on LIT Technique Conducted at Kadmat Atoll

Categories	Station 1	Station 2
ACB	2.99	4.30
ACT	0.71	4.30
ACD	3.96	3.56
ACS	3.06	3.98
CB	2.58	2.50
CS	3.46	3.33
CM	16.35	16.41
CF	1.0	1.03
CE	2.71	4.0
OT	1.23	1.72
AA	14.67	13.05
TA	7.85	8.66
CA	4.06	4.07
DCA	8.84	9.19
RDC	3.61	3.11
S	7.33	5.10
R	7.97	6.34
S/R	7.55	8.89

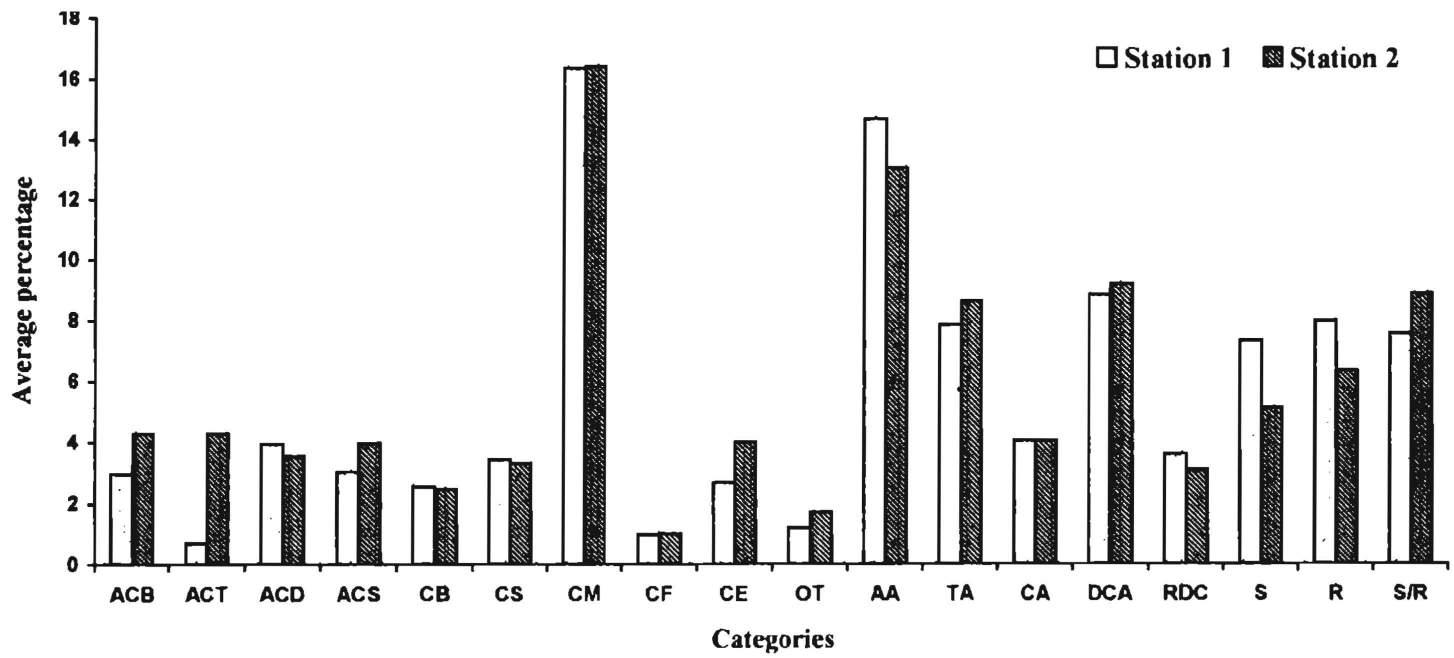


Figure 8a.: Graph Showing Distribution of Different Lifeform Categories in Station 1 and Station 2 at Kadmat Atoll.

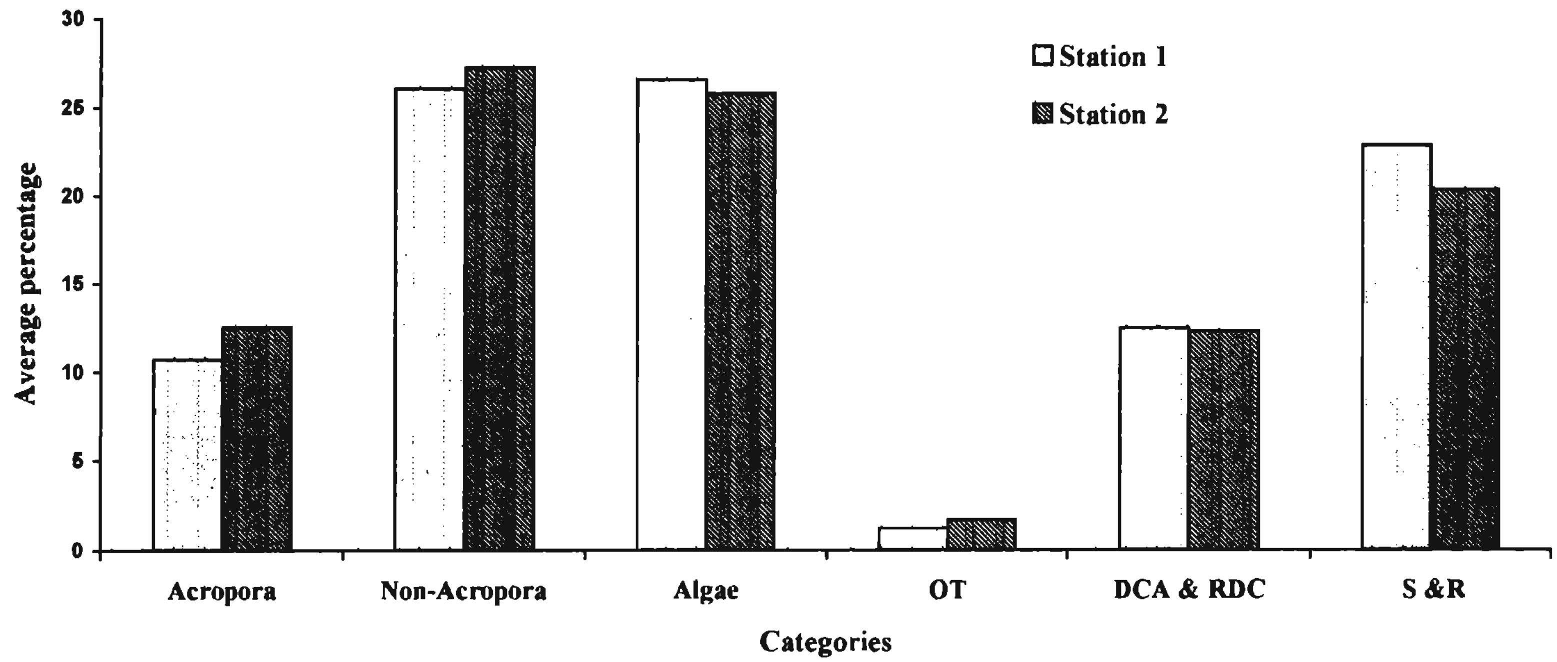


Figure 8b.: Graph Showing Percentage Abundance of Major Benthic Forms in Station 1 and Station 2 at Kadmat Atoll.

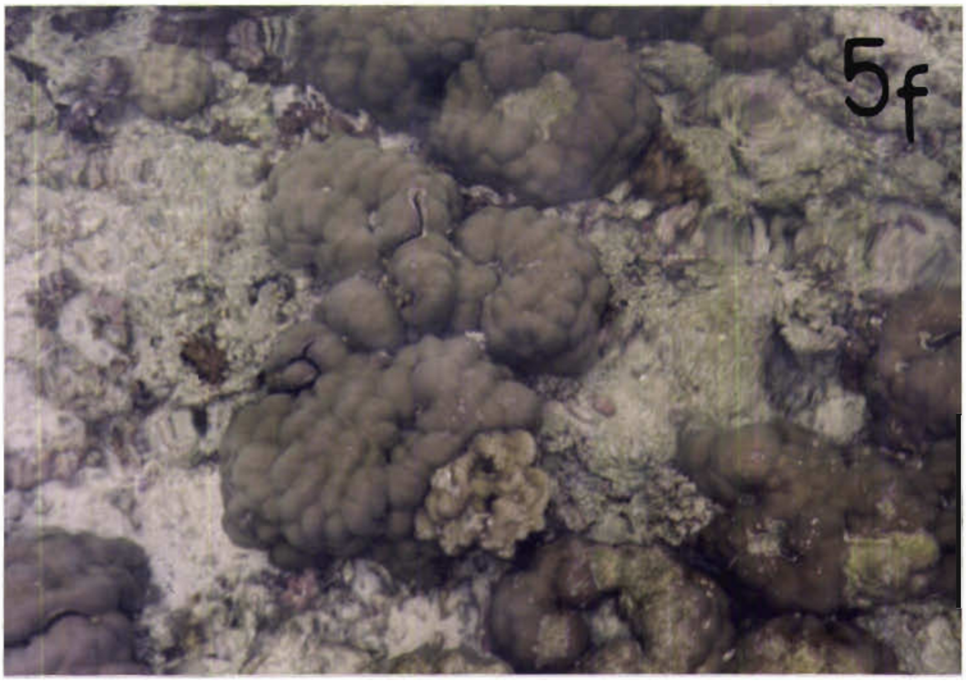
Coral massive (CM) were dominant among the non-Acropora forms and were mainly represented by *Porites spp.* and was more or less equally represented at two stations (16.35% and 16.41% at station 1 & station 2 respectively). The large share of the coral forms was controlled by the sub-massive (CS) and massive (C M) forms at both the stations (Table 3).

Table 4 shows total percentage occurrence of all scleractinian corals at the two stations of Kadmat atoll. It was 36.82% at station 1 and 39.81% at station 2.

The important species of coral fauna identified from the two stations are given in the table 6. *Acropora formosa*, *A. abrotanoides*, *A. corymbosa* and *A. tere* are the dominant species in the fauna belonging to the branching categories of corals. However, all the other categories such as ACS, ACD and ACT were represented by only one species from each group as was obtained in the case of Kavarathi atoll.

The non-Acropora groups were dominated by genera, *Porites*, *Psammacora*, *Pocillopora*, *Montipora*, *Merulina*, *Pavona* and *Platygyra*. But, massive and submassive corals occupied the most conspicuous position in the non-Acropora coral assemblages and also among the all coral assemblage. *Porite spp.* and *Platygyra spp.* were represented in CM and *Psammacora spp.* and *Pocillipora sp.* were represented in CS. Foliose group was represented by *Montipora sp.* and *Merulina sp.*, encrusting group by *Psammocora sp.*, *Pavona sp.* and *Montipora spp*, and CB by *Porites sp.* (Table 6).

Other fauna was also distributed more or less in a uniform manner at the two stations (1.23% at station 1 and 1.72% at station 2). The dominant representation in their faunal assemblage was by *Heliopora sp.* and *Tridacna sp.*



Photograph 5e & f.: Massive Corals (*Porite spp.*).

Algal assemblage which consists of more than one species of algae, were dominant among the category- algae, resembling Kavarathi atoll. The total percentage of occurrence of algae was more or less same at the stations (26.58% at station 1 and 25.78% at station 2) Algal assemblage (AA) the dominant category was also more or less equally distributed at the two stations (14.67% and 13.05%) and the other groups such as CA and TA were also more or less of equal percentage of abundance at the two stations (see table 2b).

Turbinaria sp. and *Surgassum sp.* were the dominant species among the AA as was the case with this assemblage in Kavarathi atoll. *Halimeda sp.* was the dominant member in CA.

Dead corals covered with algae were more or less equally distributed in quantity at the two stations (8.84% and 9.19%). Recently dead corals were 3.61% at station 1 and 3.11% at station 2.

Table 3 shows the total percentage occurrence of both categories at two stations, ie. 12.47% at station 1 and 12.30% at station 2. This means that the percentage occurrence of these two categories were more or less equal at S-W and N-W portions of the lagoon.

Among the other abiotic components S, R and S/R mixture were also more or less equally distributed at the two stations (see table 2b). Table 3 shows the total percentage occurrence of all these categories at the two stations.

All categories of both living and non-living components were more or less equally represented at the two stations of Kadmat lagoon (Table 4).

The distribution of lifeform categories in the two stations are shown in graph (fig. 8a & 8b).

2.4.3 Kalpeni Atoll

The location of the reefs surveyed using LIT is indicated in the figure 2c. The status of the reef at the two stations selected could be assessed from the percentage occurrence of the different faunal and floral categories.

All the Acropora forms were more or less equally distributed at the two stations. The branching forms (ACB) were dominant at two stations. 9.59% of ACB was recorded from station 1 while 11.58% from station 2. ACT was 1.5% and 2.51% at station 1 and station 2 respectively. ACD was 2.5% at station 1 and 2.68% at station 2. The ACS was 4.31% and 5.09% at station 1 and station 2 respectively (Table 2c).

Table 2c shows average of percentage occurrence of the total Acropora forms at the two stations. 17.90% and 21.86% were recorded at station 1 and station 2 respectively.

Almost all non-Acropora forms were distributed more or less equally at the two stations (Table 2c). Here also, coral massive occupied higher percentage of abundance. Branching forms were 4.39% at station 1 and 4.31% at station 2. Coral encrusting forms were 6% at station 1 and 4.66% at station 2. Coral foliose were very less at two stations when compared with the other forms.

The total percentage of all non-Acropora forms is shown in the table 3. 26.85% was recorded at station 1 and 25.06% at station 2. Table 4 shows total percentage

Table 2c: Average Percentage Abundance of Benthic Forms Based on LIT Technique Conducted at Kalpeni Atoll

Categories	Station 1	Station 2
ACB	9.59	11.58
ACT	1.50	2.51
ACD	2.50	2.66
ACS	4.31	5.09
CB	4.39	4.31
CS	4.85	4.83
CM	10.49	9.30
CF	1.45	1.50
CE	6.00	4.66
OT	2.70	3.75
AA	9.75	10.68
TA	8.03	6.28
CA	3.05	2.50
DCA	4.65	4.69
RDC	3.36	3.47
S	8.05	6.68
R	7.18	7.59
S/R	8.06	8.05

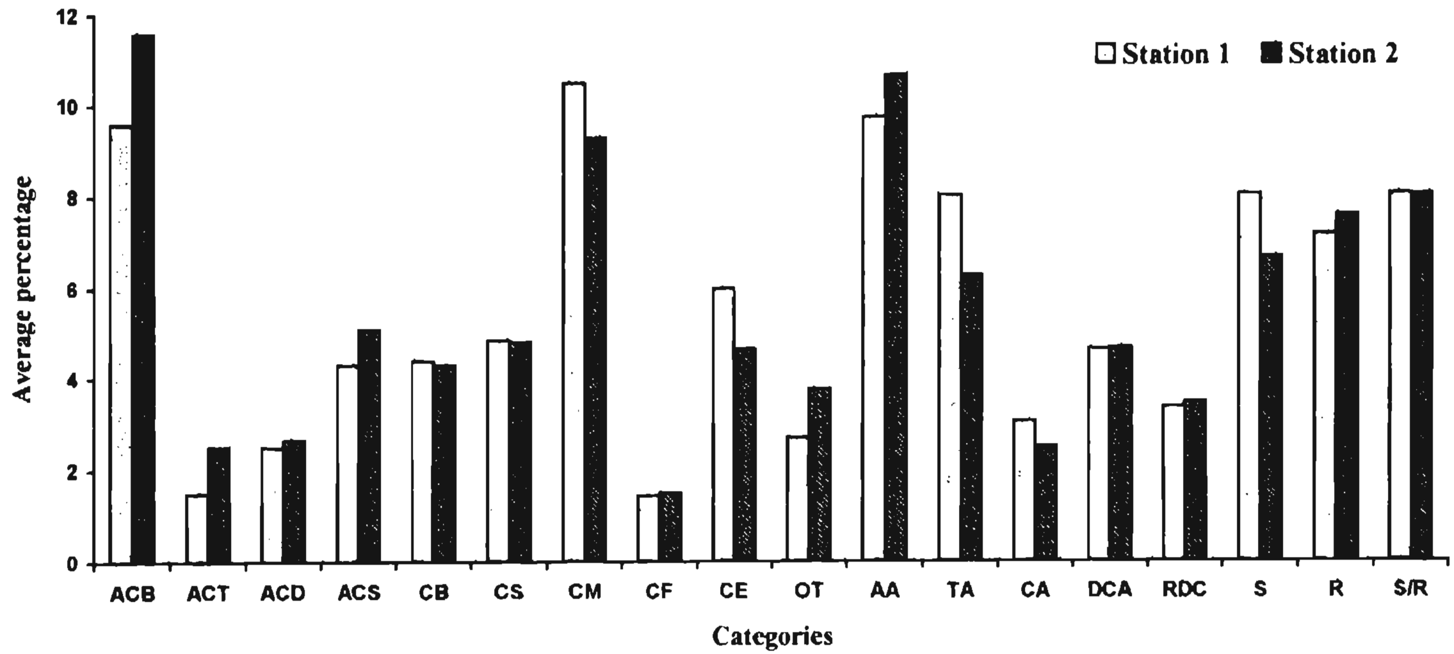


Figure 9a.: Graph Showing Distribution of Different Lifeform Categories in Station 1 and Station 2 at Kalpeni Atoll.

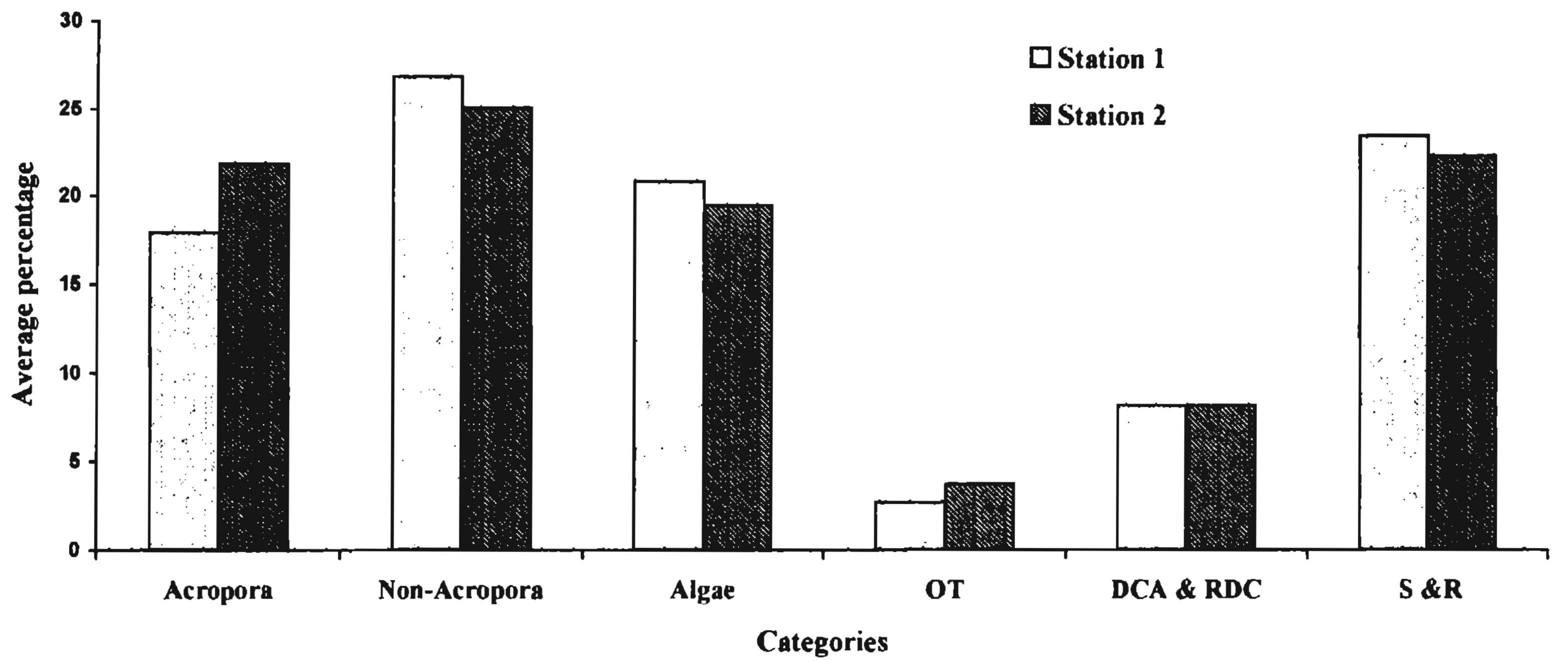


Figure 9b.: Graph Showing Percentage Abundance of Major Benthic Forms in Station 1 and Station 2 at Kalpeni Atoll.

occurrence of all scleractinian corals at the two stations. 44.75% of scleractinian corals was recorded at station 1 whereas it was 46.92% at station 2.

The coral fauna identified at the two stations are listed in the table 6. Acropora branching forms identified were, *A. intermedia*, *A. formosa*, *A. corymbosa*, and *A. tere*. ACS were represented by *A. palifera*, ACD by *A. humilis* and ACT was represented by *A. hyacinthus*.

The dominant forms among non-Acropora forms were coral massive (CM). Four species such as *Porites lutea*, *P. solida*, *Platygyra daedalea* and *P. sinensis* were represented for CM. Of these *Porites spp.* claimed the major share. The sub massive forms identified were *Psammacora contigua*, *P. digitaa*, *P. lichen* and *Pocillopora meandrina*. The branching forms were *Porites andrewsi* and *P.(synaraea) canvexa*. The encrusting forms were represented by *Montipora turgescens* and *Pavona varians*. The foliose (CF) forms, which was poorly present at the two stations were represented by *Merulina ampliata*.

Other fauna were 2.70% at station 1 and 3.75% at station 2. *Tridacna sp.*, *Heliopora sp.*, anemones etc. were the dominant forms.

The algal assemblage was the dominant among the algal category (9.75% at station 1 and 10.68% at station 2) followed by CA (8.03% at station 1 and 6.28% at station 2) and TA (3.05% at station 1 and 2.5% at station 2). Total percentage abundance of all algae is given in table 3.

Turbinara spp., *Surgassum spp.*, *Gelidiella spp.* and *Gracilaria spp.* were the major forms in AA. CA was represented by *Halimeda spp.* only.

Dead corals with algae and recently dead corals were more or less equally represented at the two stations. 4.65% and 4.69% of DCA at station 1 and station 2 respectively and 3.36% and 3.47% of RDC at station 1 and station 2 respectively. Table 2c shows the total percentage of both DCA and RDC at the two stations. The quantum equal at the stations, (8.17% and 8.16%).

The quantity of sand was 8.05% and 6.68% at the two stations. Rubble was 7.18% and 7.53% at station 1 and station 2 respectively. Sand/Rubble mixture was equal at the two stations i.e. 8.06% at station 1 and 8.05% at station 2 (Table 2c). Total percentage abundance of all these categories was more or less similar in both the stations (Table 3).

The distribution of lifeform categories in the two stations are shown in graph (fig 9a & 9b).

2.4.4 Agathi Atoll

Figure 2d indicates the location in the reefs subjected to survey using LIT at Agathi. Table 2d shows the average percentage abundance of the 18 assemblages.

Acropora forms were poorly recorded at the two stations station 1 and station 2. Only 0.87% of branching forms were recorded at station 1 whereas at station 2 it was 1.98% . ACT was 0.63% and 0.92% at station 1 and station 2 respectively. While 1.06% of digitate forms were estimated from station 1, it was 1.55% at station 2. 1.38% and 2.06% of ACS was recorded from station 1 and station 2 respectively. Table 3 shows the average percentage occurrence of all Acropora forms at the two stations.

Table 2d: Average Percentage Abundance of Benthic Forms Based on LIT Technique Conducted at Agathi Atoll

Categories	Station 1	Station 2
ACB	0.87	1.98
ACT	0.83	0.92
ACD	1.06	1.55
ACS	1.38	2.08
CB	2.96	3.19
CS	5.21	5.50
CM	13.50	13.34
CF	2.17	2.22
CE	3.10	3.38
OT	1.03	1.55
AA	19.68	19.20
TA	6.60	5.95
CA	7.98	8.82
DCA	8.31	7.80
RDC	6.42	5.91
S	6.83	7.83
R	6.95	6.21
S/R	3.93	2.03

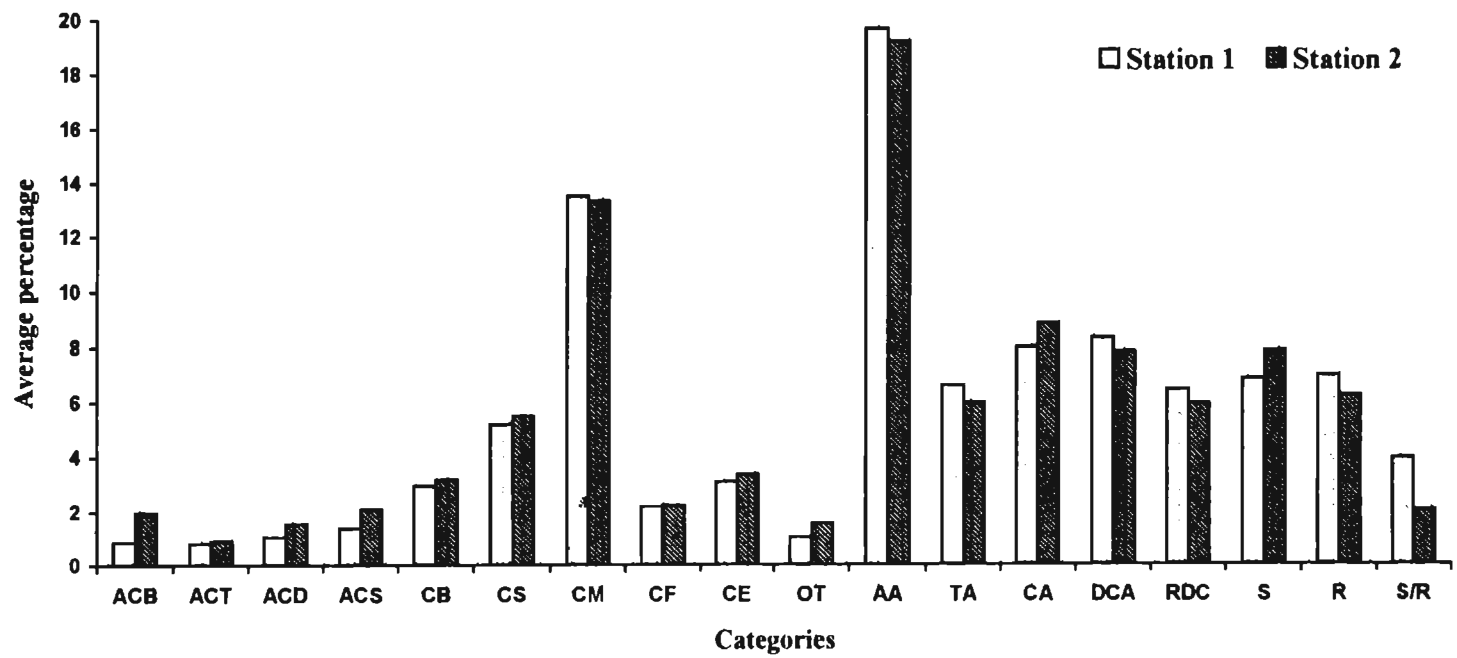


Figure 10a.: Graph Showing Distribution of Different Lifeform Categories in Station 1 and Station 2 at Agathi Atoll.

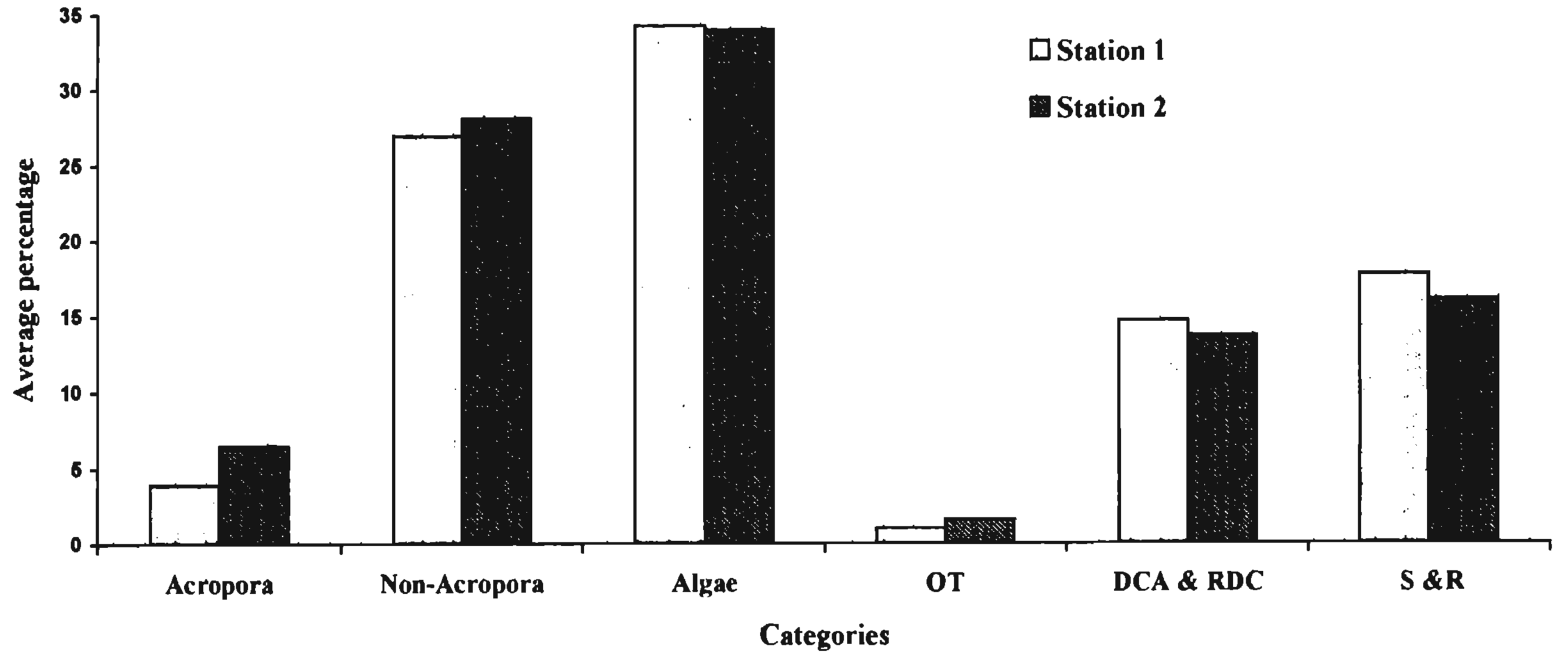


Figure 10b.: Graph Showing Percentage Abundance of Major Benthic Forms in Station 1 and Station 2 at Agathi Atoll.

Non-Acropora forms occupied more or less same percentage at the two stations. The dominant form massive coral (CM), was almost equal at two stations, (13.50% at station 1 and 13.34% at station 2). Coral submassive was 5.21% and 5.50% at station 1 and 2 respectively. Branching forms were 2.96% at station 1 and 3.19% at station 2. Foliose forms were represented at station 2. Table 3 shows the average percentage abundance of all the non-Acropora forms. Table 4 shows the total percentage of all forms of scleractinians at the two stations.

Species of Acropora branching forms identified from the transect were: *A. intermedia*, *A. formosa*, *A. abrotanoides*, *A. corymbosa*, and *A. tere*. Eventhough all these species were present, seldom they were found in abundance. ACS was represented by *A. palifera*, ACD by *A. humilis* and ACT was represented by *A. hyacinthus*.

Quantitatively coral massive was the dominant form at the two stations and the major species were *Porites lutea* and *P. solida*. The other species identified although less in number were *Platygyra daedalea* and *P. sinensis*.

Porites andrewsi was the only one representative of the branching form. CE was represented at two stations by *Psammocora haimaena*. Foliose form was also represented by one species, *Montipora foliosa*. Submassive were represented by *Psammacora contigua*, *P. digitata*, *P. lichen* and *Pocillopora meandrina*.

Other fauna (OT) was 1.03% at station 1 and 1.55% at station 2 and was mainly dominated by *Tridacna sp.* and *Heliopora sp.* and also by simple ascidians etc.

Algal assemblage was dominated by *Turbinaria spp.* and *Surgassum spp.* This was the major contribution among algae and was almost equal at two stations, (19.68%

Table 3
Average of Percentage Occurrence of Major Benthic Assemblage Based on LIT Technique at Lakshadweep

Atolls	Stations	Scleractinian corals		Algae	OT	DCA	S &R
		Acropora	Non-acropora				
KVT	ST.1	2.23	4.14	35.28	0.78	13.25	43.83
	ST.2	9.56	33.32	38.32	3.5	3.61	11.37
KAD	ST.1	10.72	26.1	26.58	1.23	12.47	22.85
	ST.2	12.54	27.27	25.78	1.72	12.3	20.33
KAL	ST.1	17.9	26.85	20.83	2.7	8.17	23.45
	ST.2	21.86	25.06	19.46	3.75	8.16	22.29
AG	ST.1	3.94	26.94	34.26	1.03	14.73	17.71
	ST.2	6.51	28.13	33.97	1.55	13.71	16.07

KAV - KAVARATHI

KAD - KADMAT

KAL - KALPENI

AG - AGATHI

at station 1 and 19.20% at station 2) . Coralline algae were 6.60% at station 1 and 5.95% at station 2. The species recorded was *Halimeda sp*. Turf algae was 7.98% and 8.82% at station 1 and station 2 respectively. Table 2d shows the percentage occurrence of all algal forms and was almost equal at the two stations (34.26% and 33.97% at station 1 and 2 respectively).

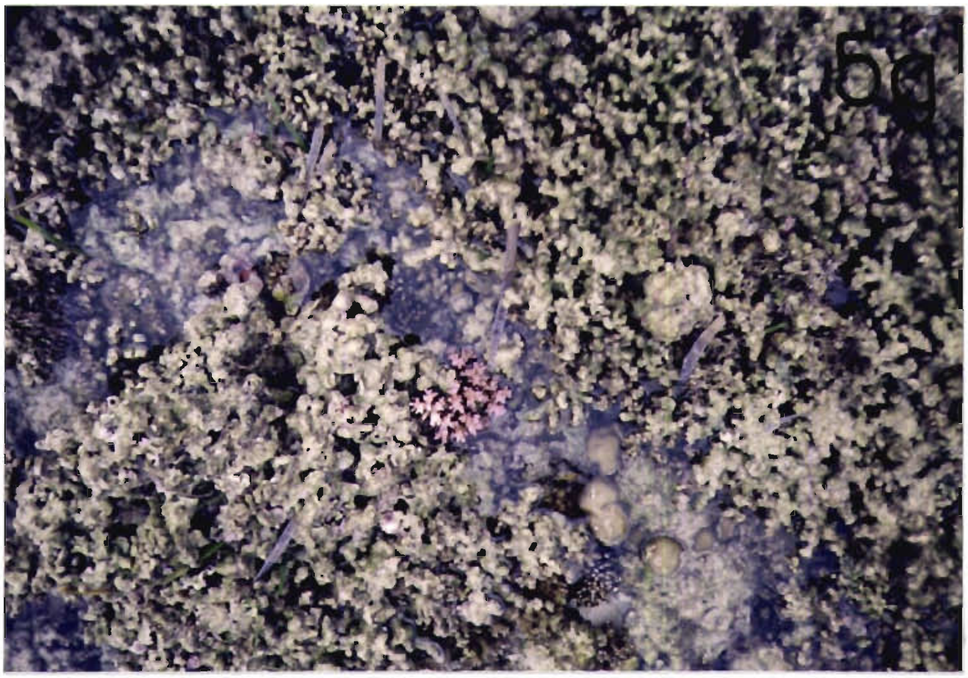
Dead coral with algae (DCA) was 8.31% at station 1 and 7.8% at station 2 while recently dead coral was 6.42% and 5.91% at station 1 and station 2 respectively (Table 2). The total percentage of these two forms is given in table 3 and was 14.73% and 13.71% at station 1 and station 2 respectively.

Sand, rubble and sand/rubble mixture were more or less of the same percentage of abundance at two stations. Rubble was 6.95% and 6.21% at station 1 and station 2 respectively. Sand/rubble mixture was 3.93% at station 1 and 2.03% at station 2. Table 3 shows total percentage of all 3 categories i.e. 17.71% at station 1 and 16.07% at station 2.

The distribution of lifeform categories in the two stations are shown in graph (fig 10a & 10b).

2.5 Discussion

The information gathered on the status of the coral assemblages of the four atolls clearly show that the Kavarathi atoll has been disturbed considerably resulting in drastic variation in the quality and quantity of coral coverage and assemblages. Relatively sparsely distributed live corals in the north-west parts of this atoll indicates deterioration in the ecological condition leading to removal of live corals. This atoll is the capital of the Union Territory and hence anthropogenic activity must have been an



Photograph 5g.: Dead Corals - A common feature of N-W of Lagoon reef at Kavarathi.

Table 4
Average of Percentage Sceleractinian Corals, Algae and Abiotic Components - Comparison of Two Stations in each Atoll

Atolls	Stations	Scleractinian corals	Algae	Abiotic components
KVT	ST.1	6.37	35.28	57.08
	ST.2	42.88	38.32	14.98
KAD	ST.1	36.82	26.58	35.32
	ST.2	39.81	25.78	32.63
KAL	ST.1	44.75	20.83	31.62
	ST.2	46.92	19.46	30.45
AG	ST.1	30.88	34.26	32.44
	ST.2	34.64	33.97	29.78

Table 5
Comparison of Four Atoll Reefs for the Major Benthic Forms

Atolls	Average of Percentage Abundance of Two Stations		
	Live Corals	Algae	Abiotic Components
KAV	24.62	36.8	36.03
KAD	38.31	26.18	33.97
KAL	45.83	20.14	31.03
AG	32.75	34.11	31.11

KAV - KAVARATHI

KAD - KADMAT

KAL - KALPENI

AG - AGATHI

important causative factor in bringing about the above change. The post independent years have witnessed brisk developmental activities in all atolls which have visibly improved the living condition of the inhabitants, but not without side effects on the marine and terrestrial habitats (Pillai, 1983, 1985 & 1986; Pillai and Madan Mohan, 1986). The lagoons of Lakshadweep especially Kavarathi were subjected to long term dredging by the Lakshadweep Harbour Department to permit entry of the mechanised vessels into the lagoon (James *et.al.*, 1989). The very poor state of the reef at the north-west of the lagoon of Kavarathi might be due to dredging and blasting of navigational channels and also due to several other interferences caused by both human and mechanical activities. The dredged soil was deposited on the lagoon shoals and lagoon flat smothering extensive regions in the active coral reefs. Increase in the sediment transport in the lagoon brought about by the development of navigational channels adversely affect the coral growth. Instances of mass mortality of corals are still visible at the northern end of the lagoon reef. Very low percentage of live corals obtained from the LIT survey conducted now gives ample testimony to this state of affair. Pillai (1975) has pointed out that dredging, chronic oil pollution, sedimentation, prolonged exposure, exploitation, predators and over exploitation are some of the major factors that hasten the destruction of recent reef corals. Some of these factors are certainly in operation on the reefs of Lakshadweep and the deleterious effect is apparent, especially during the last two decades, concomitant with developmental activities. Dredging has also a long term consequence on coral growth. The silt and sediments generated by dredging and their excessive transportation over the reefs and into the lagoon coupled with sea erosion slowly kill many corals. The northern

Table 6

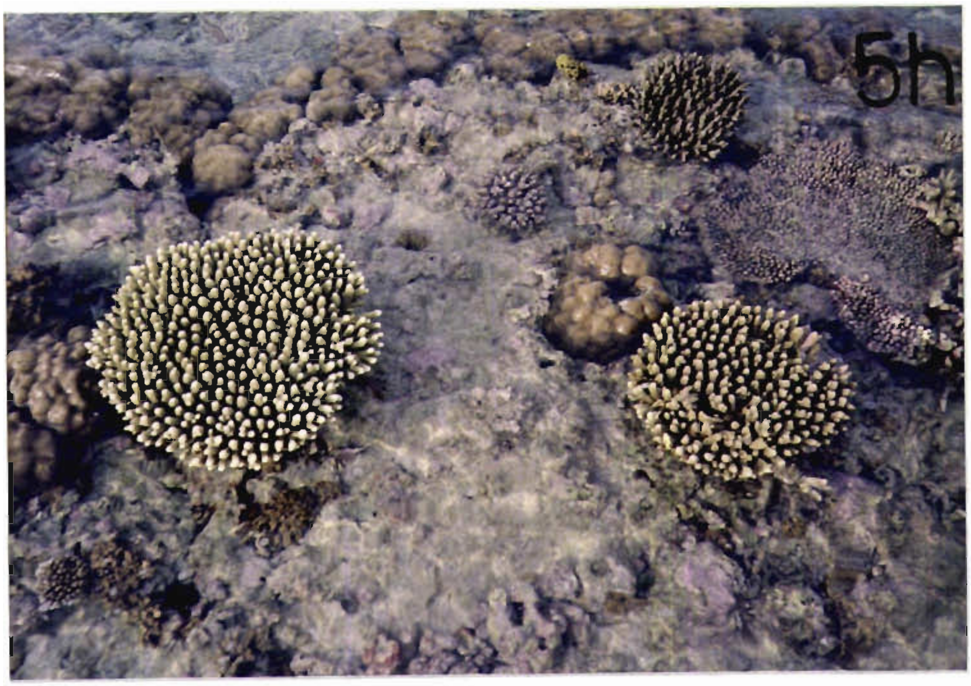
Dominant coral fauna identified during the LIT survey

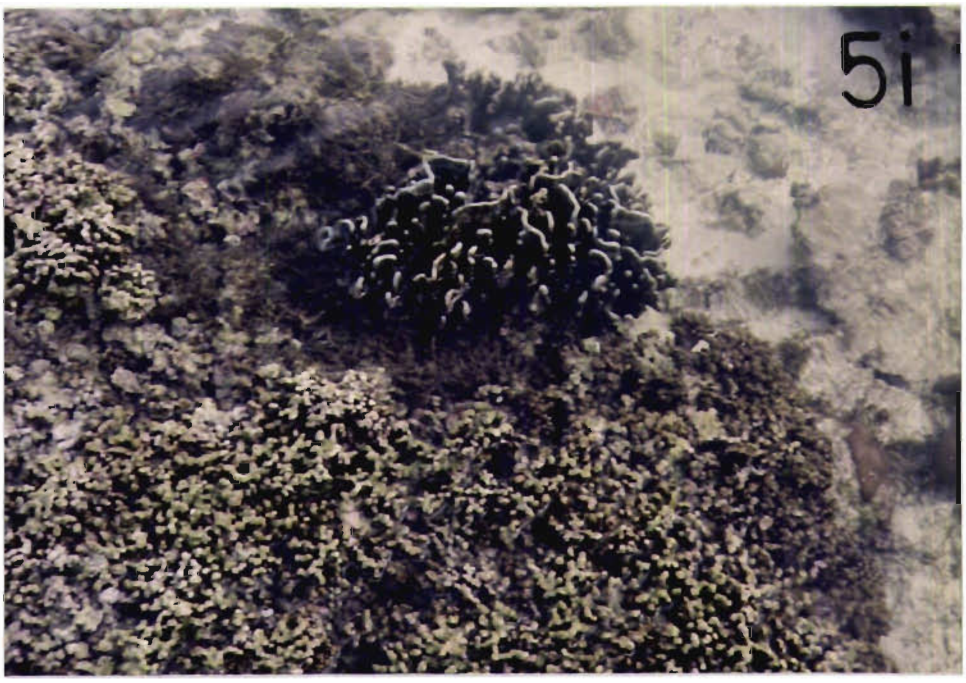
Categories	Species
Acropora Branching	*Acorpora intermedia*
	A. formosa
	A. corymbosa
	A. tere
	A. abrotanoides
A. Submassive	*A. palifera*
A.digitate	*A. humilis*
A.tabulate	*A. hyacinthus*
Coral Massive	*Porites lutea*
	P.solida
	Platygyra daedelea
	P. sinesis
Coral Submassive	*Psammocora digitata*
	P. contigua
	Pocillipora meandrina
Coral Branching	*Porites andrewsi*
	P. (synaraea) canvexa
Coral Foliose	*Montipora foliosa*
	Merulina apliata
Coral encrusting	*Montipora teberculosa*
	M. turgescens
	Pavona varians
	Psammocora haimaena

region of Kavarathi is thickly populated. These inhabitants have exploited the north-west of the lagoon for shells, corals etc. Presently extensive collection of molluscan shell is in progress in this region herein the coral collection is banned. Extensive damage of the live corals in general and the branched corals in particular are caused by the constant usage of the reef access for the collection of shells at present.

The low percentage occurrence of the live corals in the north-west part of the lagoon reef indicated that the destructive activities were more in this area. The higher percentage of live corals at south-west of the reef compared to the north-west might be due to less anthropogenic activities. The physical and biological state of reef at south-west region was excellent when compared with that of the north-west region in Kavarathi. Higher percentage of dead corals and recently dead corals in this area however, invites greater attention for protection and conservation of the reef. The higher percentage of turf algae and algal abundance also shows that the reef at south-west require greater protection. The corals and algae are competitors for food and space and once the latter get dominance the existence of the reef could be threatened. Occurrence of natural calamities might cause extensive damage of the coral reef. However, the damages brought about by human interference and activity should be controlled and if possible maintained at the minimum level.

The survey result shows that the whole lagoon is threatened by human interferences and calls for urgent measures for protection and conservation. The introduction of a new ferry system with the deployment of flat bottomed boats would create environmental problems to the already poor coral ecosystems of Kavarathi. The





Photograph 5h.: Small colonies of Acropora spp. - A scene from N-W of lagoon reef at Kavarathi

Photograph 5I.: Small colonies of coral submassive (CS) along with dead corals, sand and rubbles.

.Photograph 5j Giant clam, *Tridacna sp* the dominant group in the OT categories.

inter island ferry system consisting of two flat bottomed speed boats enter Kavarathi lagoon, where enough depth and width for the channel is maintained. This new facility will further augment the developmental activities of the island in tourism and other connected activities. This would further deteriorate the condition of the reef. So any further development should be undertaken only after considering the effects of such changes in the coral ecosystem.

All the other three atolls such as Kadmat, Kalpeni and Agathi showed more or less similar percentage abundance of corals and other categories of associated fauna and flora . The two stations at each of these reefs showed more or less equal distribution of all categories. Further the LIT survey showed that these three atolls have not faced any localised disturbance or damage as was noticed in the case of Kavarathi. The percentage of live corals and coral categories recorded from these atolls support this assumption.

Of the four reefs surveyed using LIT technique, the Kalpeni ranks first for the occurrence of higher percentage of live corals especially branching and for lower percentage of dead and recently dead corals. It is contemplated that the ferry service recently introduced would be extended to these atolls also. Should this happen, the development of navigational channels and berthing facilities for the boats would deleteriously affect the luxurious coral reef. Since the lagoons of these atolls are shallow extensive dredging would be required and such operations would destroy all the live coral beds of the lagoons.

CHAPTER 3

HYDROGRAPHICAL STUDY OF LAKSHADWEEP ATOLLS

3.1 Introduction

Coral reefs are unique among biological environments in that their inhabitants create and maintain major geological features of the Earth itself. Of all marine ecosystems, coral reefs have the highest productivity and sustain heaviest human use. The "International Union for Conservation of Nature and Natural Resources" identified coral reefs as one of the essential life supporting systems, necessary for human survival and sustainable development (IUCN/UNEP/WWF, 1980).

The development and growth of coral reefs are closely controlled by environmental factors impacting on the atmosphere, the oceans and the adjacent land masses, and any localised or global changes in these factors will affect coral reefs. Therefore, it is essential that possible changes in coral reefs be monitored as soon as possible for the effects of climatic changes (Wilkinson, 1993).

The study of environmental parameters of a lagoon is important because, coral reef atolls, generally lack large buffer zones around them and so any change in the environment is very conspicuously manifested in the lagoon, resulting in ecological stress (Navas, 1993).

3.2 Literature Review

Attempts have been made to study the hydrographical aspects of Lakshadweep atolls and adjacent waters in the past by various authors. Jayaraman *et al.* (1960) identified the existence of four distinct water masses in Arabian sea near Lakshadweep islands and stated that the "Lakshadweep Chagos Ridge" has great influence on the circulation of water in this area. Patil and Ramamirthm (1963) compared winter and summer conditions of Lakshadweep offshore waters and provided some information on the chemical characteristic of the water mass. Rao and Jayaraman (1966) reported upwelling in the Minicoy atoll region of Arabian sea. Physical and chemical characters of water in and around Kavarathi, their diel variation in the lagoon, water circulation in the lagoon, production of algae, seagrass and corals were studied by Qasim *et al.*(1972). Chemical characters like pH, dissolved oxygen, salinity, temperature and their diurnal variation in Kavarathi atoll were investigated by Sankaranarayan (1973). Information on chemical characters and zooplankton occurrence and abundance in and around Kavarathi atoll have been provided by Goswami (1973 & 1979). Lowering of surface temperature with the advance of south west monsoon in the Arabian sea has been studied by Rao *et al.* (1976). Varkey *et al.* (1979) provided information on the physical properties of Lakshadweep sea. Sengupta *et al.* (1979) studied the chemical oceanography of the Arabian sea adjoining the Lakshadweep islands. Girijavallabhan *et al.* (1989) made brief observation on the hydrobiology of Lakshadweep atolls.

Suresh (1991) collected detailed base line information on the hydrobiological environment of Kavarathi atoll. Navas (1993) also looked into the physical and chemical studies of lagoon waters of Minicoy atoll.

3. 3 Materials and Methods

Sampling Stations

Hydrographical parameters such as salinity, pH, dissolved oxygen, temperature and total suspended particles of lagoon water and outer reef of the four atolls viz. Kavarathi, Kalpeni, Kadmat and Agathi were collected at regular interval for a period of two years. This was done by sampling 5 stations fixed at different regions of the lagoon in each atoll (Figures 6a to 6d). Four stations were inside the lagoon and one station outside. The station 1 was located outside the lagoon in the open sea, about 100 m away from the entrance of the lagoon, at a depth of 50 m. Station 2 was situated inside the lagoon at the north-west point of lagoon where faunistic survey using Line Intercept Transect (LIT) technique was carried out. The depth of station was 1.5 m. The middle area of the lagoon having a depth ranging between 2-3 m was represented by station 3. Station 4 was situated near the shore, having an average depth of 1.5 m. The bottom was having luxuriant growth of seagrass and algae. The station 5 located at the south-west part of the lagoon was characterised by rich growth of corals and the depth ranged between 1.5 to 2.5 m.

Sampling Frequency

Sampling was carried out monthly for a period of 2 years from 1991 February. Sampling was carried out always in the morning hours. Monthly collections of station 1 were not covered during rough season (monsoon). The samples were analysed in the laboratory set up at Science and Technology Dept., and Water Quality laboratory of P.W.D. Detailed laboratory studies were conducted in the laboratories

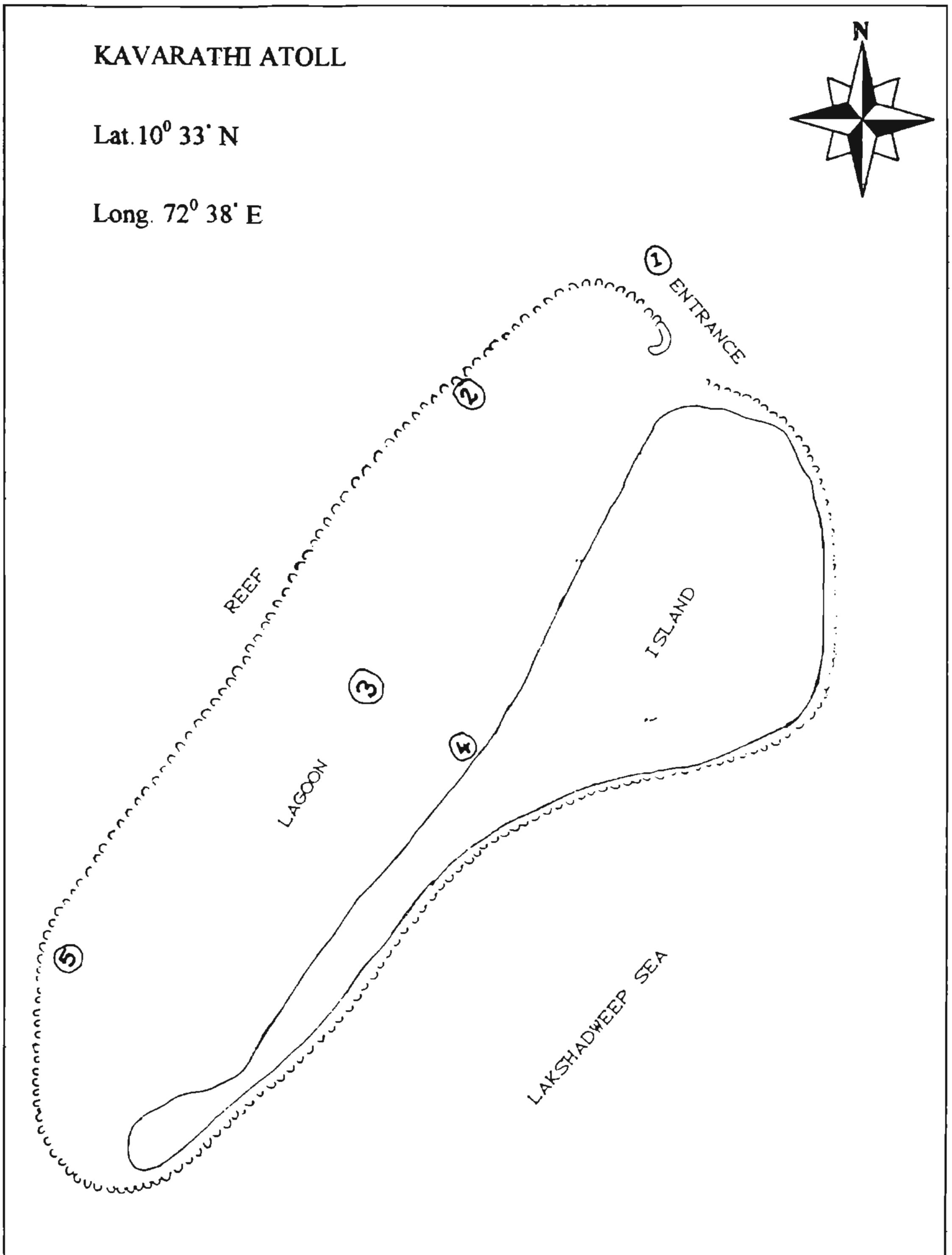


Figure 6a. The different sampling stations in Kavarathi lagoon where hydrographical studies were conducted

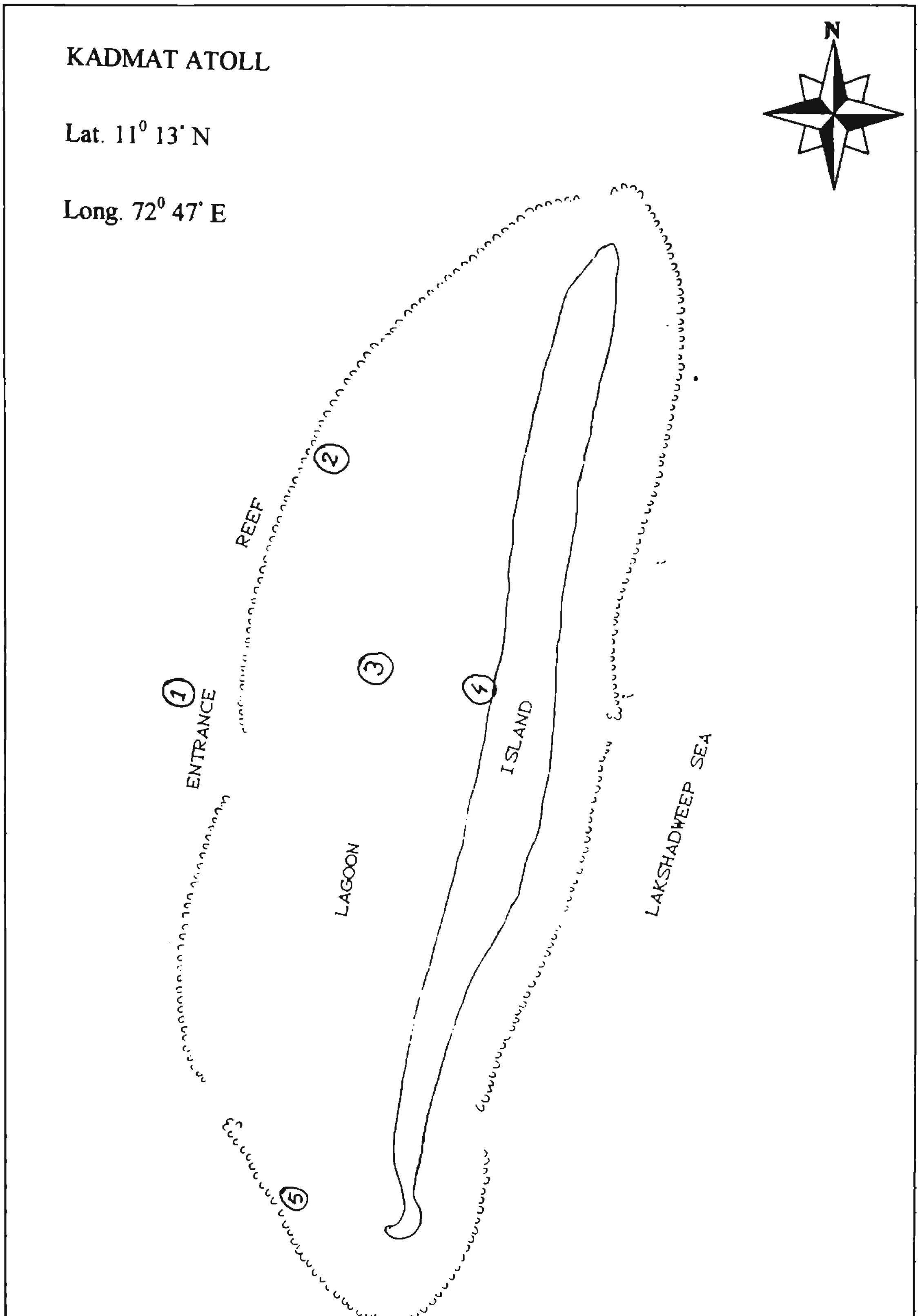


Figure 6b: The different sampling stations in Kadmat lagoon where hydrographical studies conducted

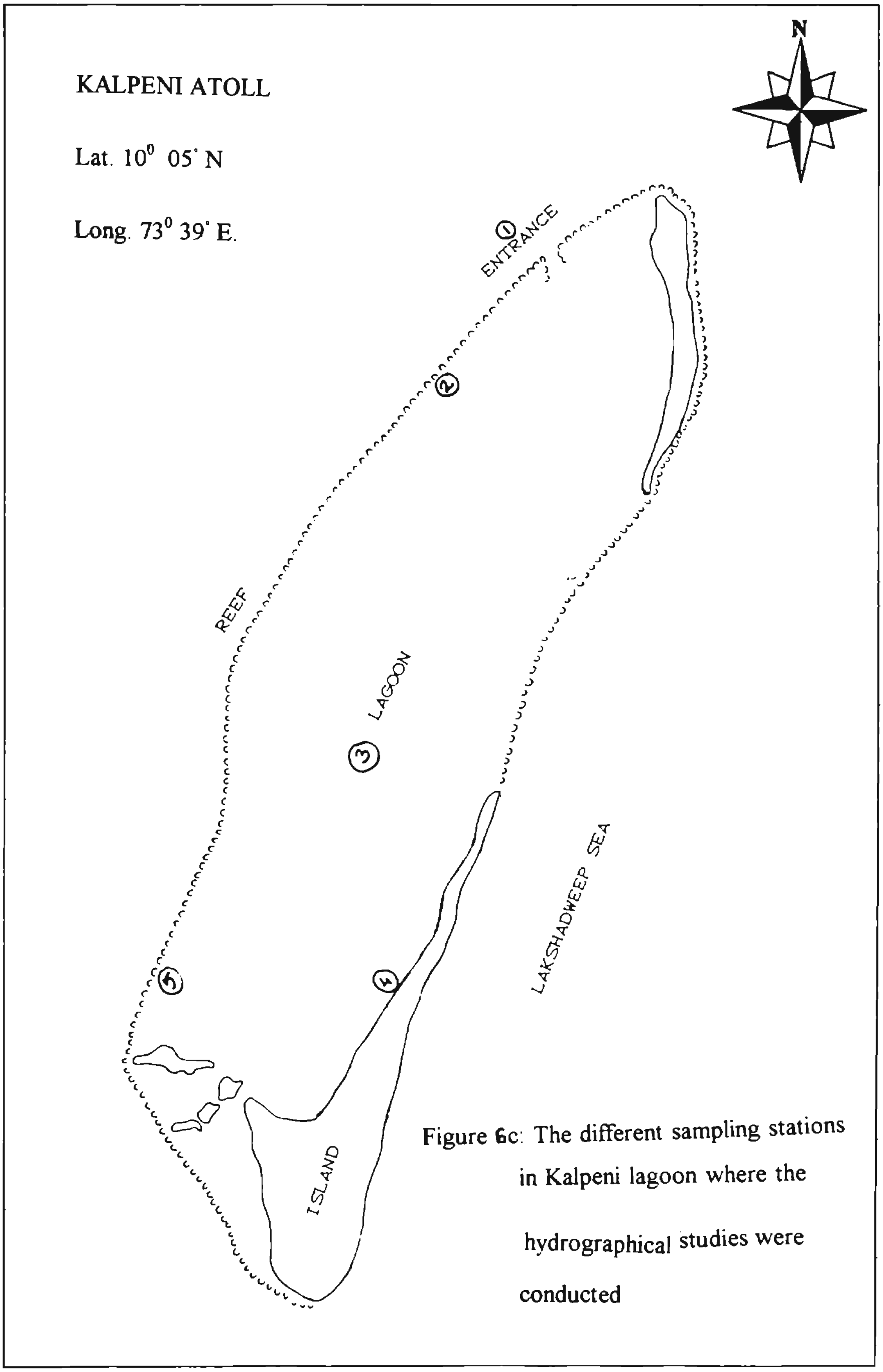


Figure 6c: The different sampling stations in Kalpeni lagoon where the hydrographical studies were conducted

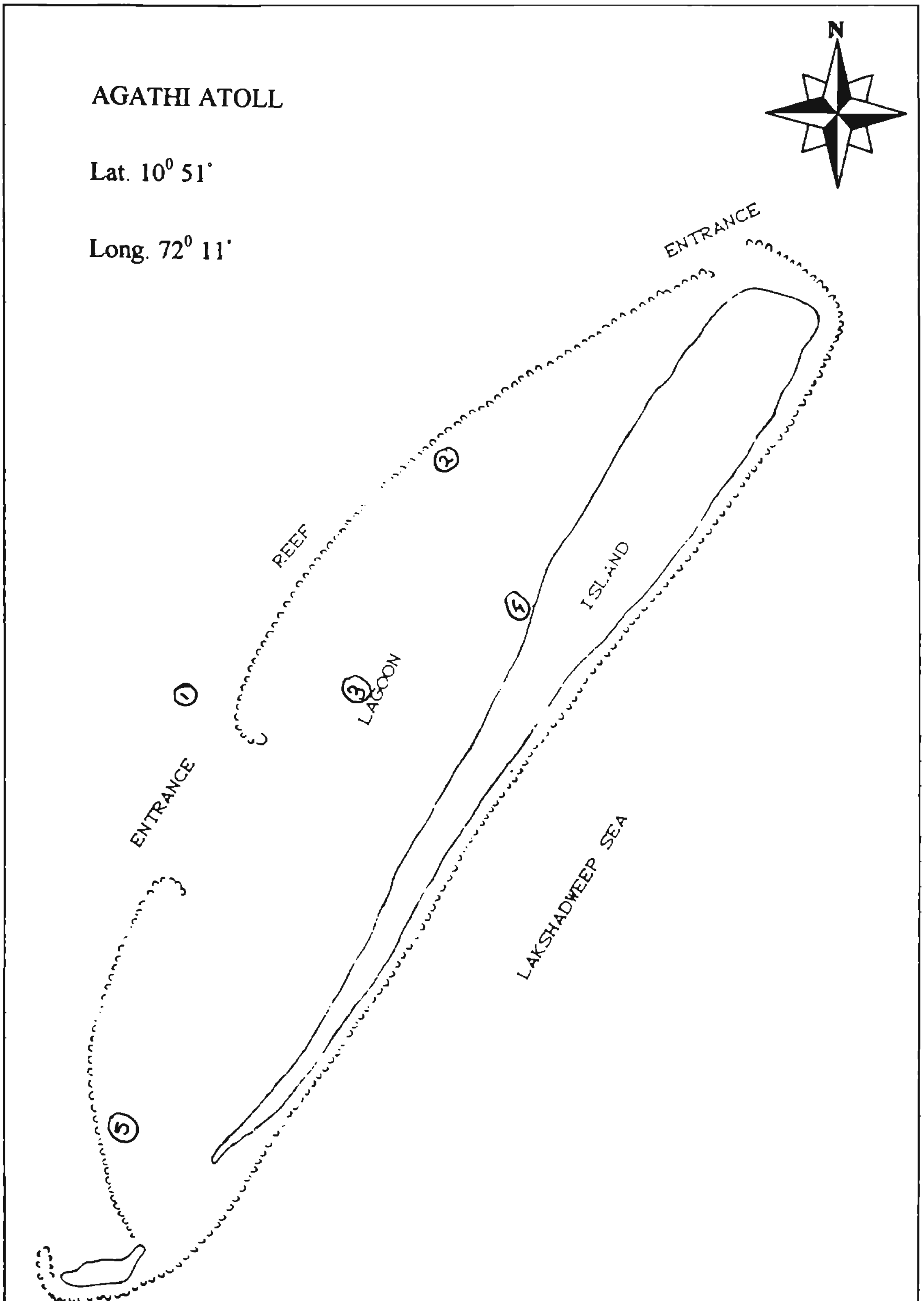


Figure 6d: The different sampling stations in Agathi lagoon where hydrographical studies were conducted

of the School of Marine Sciences. The data has been pooled for seasons based on monsoon. The temporal demarcation was done as follows: Pre-monsoon season is from February to May, Monsoon from June to September and Post-monsoon from October to January.

Temperature

Temperature measurements made with a good mercury filled celsius thermometer with a scale marked for every 0.1° C. Water was collected from the surface in a plastic bucket and the temperature was measured immediately.

Salinity

Duplicate water samples were collected in 100ml clear, air tight, polythene bottles from 5cm below the surface. The samples were stored in insulated box till they were analysed. Analysis was done using `Mohr' titration method (Strickland and Parson, 1968).

pH

The pH of the water samples was determined in the laboratory immediately after sampling. A "BIOCHEM" digital pH meter with combination electrode was used for the purpose. Water samples were collected from about 5cm below the surface, in airtight polythene bottles. The pH meter was standardised with buffers of pH 4.7 and 9.2, prior to pH determination.

Dissolved Oxygen

For estimation of dissolved oxygen, the samples were collected using a plastic bucket causing least agitation. The water from the bucket was then siphoned through a piece of plastic tubing into a glass stoppered BOD bottle of 125ml capacity with no trapped gas. The siphoned water was allowed to overflow and flush the BOD bottle for 30 seconds. Care was taken to exclude bubbles from the siphon tube as well as the sample bottle.

The samples were fixed immediately using 1 ml Winkler A and then Winkler B solution. The samples were stored in insulated box till they were analysed. Analysis of the samples was done using Winkler Method modified by Carritt and Carpenter (FAO, 1975) using 0.02N sodium thiosulphate with starch as indicator. Results are expressed in millitre oxygen per litter (ml/l).

Total suspended particles

A well mixed sample collected in 1 litre polythene bottle was filtered through a weighed standard glass-fibre filter and the residue retained on the filter is dried to a constant weight at 103 - 105 ^{0}C in an oven. The increase in weight of the filter represents the total suspended particles and the values are expressed in mg per litter (mg/l).

Estimation of Petroleum Hydrocarbons in seawater

An attempt has been made in the present study to estimate dissolved petroleum hydrocarbons (PHC) in the water sample collected from selected atoll lagoons.

Estimation of PHC were carried out in two atolls viz. Kavarathi and Kadmat.

The determination of dissolved / dispersed petroleum hydrocarbons in sea water is based on similarities between the fluorescence excitation and emission spectra of non-polar organic substances extracted from seawater and those present in most crude and residual fuel oils. The latter was characterized by a maximum excitation around 310nm and broad peak around 360nm in the emission spectrum. These features are primarily reflections of the complex mixture of compounds containing two or more aromatic rings.

The procedure (UNESCO, 1984) entails the collection of water from 1m depth using a weighted glass bottle, extraction of the non-polar organic substance with pure hexane, and quantification by fluorescence spectrophotometry. However, the material extracted from the seawater is not "oil" but the accumulated products of oil degradation with possible contribution from non-polar aromatic compounds derived from other sources. Chrysene has been used as the primary reference material and data expressed in terms of "chrysene equivalent" with the understanding that it is neither chrysene nor oil that is being measured, but rather a complex mixture of materials better referred to as "Petroleum residues".

3.4.1 Results

3.4.1.1 Kavarathi Atoll

Table 7a to 7e shows the monthly fluctuation in different parameters over the entire period of study. There were no observations at station 1 in June and July.

Table 7a explains the monthly temperature fluctuation for the entire period of study from all the stations. During 1991 (first year), the distribution of temperature in all the station was more or less uniform for the maximum value. The values were 30.5^{0}C, 30.75 ^{0}C , 30.75 ^{0}C , 30.70 ^{0}C and 30.70 ^{0}C in May for station 1 to 5 respectively. The minimum values were 28.72 ^{0}C and 28.50 ^{0}C at station 1 and station 5 respectively in August and 28.50 ^{0}C , 28.50 ^{0}C and 28.75 ^{0}C for station 2 to 4 respectively in July. The distribution of temperature was uniform for 1992 for the maximum and minimum values. Maximum values were 30.60 ^{0}C , 30.75 ^{0}C , 30.70 ^{0}C, 30.50 ^{0}C and

30.75 ^{0}C for station 1 to 5 respectively in May, but maximum value for station 4 (30.50 ^{0}C) were also shown in March and April. The minimum values were 28.28 ^{0}C and 28.25 ^{0}C for stations 1 and 5 in August and 28.0 ^{0}C , 28.25 ^{0}C and 28.3 ^{0}C for station 2 to 4 in July. The minimum temperature (28.25 ^{0}C) for station 5 was also observed in July.

Seasonal average of temperature for all stations are given in table 12a and average and standard deviation in temperature are given in table 14a. The range showing minimum and maximum of temperature is shown in the table 15.

Table 7b shows the monthly fluctuation in salinity for a period of two years. As shown in the table during 1991, maximum salinity observed for station 1 was 35.19‰ in February, and station 2 to 5 showed maximum in March (35.20%., 35.12%., 35.10‰ and 35.01‰ respectively). Minimum values were observed for station 1 in August and September (34‰.) and 33.70 ‰, 33.71‰, 3.73‰ and 3.70‰ in June for stations 2 to 5 respectively. In 1992 the maximum salinity observed was 35.17‰ (February), 35.19‰ (February and March) for station 1 and 2 respectively and 35.18‰, 35.27‰ and 35.28‰ respectively for station 3 to 5 in March and minimum values of 33.98‰ (August) for station 1 and 33.25, 33.19, 33.12 and 33.15 ‰ for station 2 to 5 in June.

Seasonal average of salinity for all stations are given in Table 12a and average and standard deviation are given in Table 14a. The high premonsoon salinity decreased during monsoon and again increased during post monsoon season. The range showing minimum and maximum is shown in the table 15.

Table 7c explains the monthly pH fluctuation for the entire period of study from all stations. During 1991, the maximum pH for station 1, 2, 4 and 5 were 8.34, 8.36, 8.30 and 8.36 respectively in April and for station 3 the value was 8.32 in December. Minimum value noted were 8 (August, October, and January) for station 1 and 7.85, 7.85, 7.84 and 7.85 respectively for station 2 to 5 in June. During 1992, maximum pH observed was 8.32, 8.30, 8.35 and 8.35 for station 1,2,3 and 5 respectively in April and 8.32 for station 4 in December and the minimum were 7.95 for station 1 in August and 7.88, 7.92, 7.91 and 7.90 for station 2 to 5 in June.

Seasonal average values of pH for all the stations are given in table 12a. Table 14a shows averages and standard deviations. The range of minimum and maximum are given in table 15.

Table 7d shows the monthly dissolved oxygen (DO) concentration for the entire period of study for all the stations. During 1991, the maximum DO concentration for station 1 was in September (5.65ml/l), for station 2 to 5 in June and the values were 6, 5.95, 5.90 and 5.93 ml/l respectively. The minimum concentration noted were 5 ml/l for station 1 (in November and December) 4.85 and 4.81 ml/l for station 2 and 5 respectively in November and 4.85ml/l and 4.72ml/l for station 3 and 4 respectively in January. During 1992, the maximum value for station 1 was 5.3ml/l in January, for station 2 to 5 it was 5.90, 5.85, 5.95, 5.92 ml/l respectively in June. The minimum value for station 1 was 3.95 in April and 3.75, 3.8, 4.0 and 3.92 ml/l for station 2 to 5 in November.

Seasonal average values for all stations are given in table 12a. The average and standard deviation are shown in the table 14a. The range of maximum and minimum values are given in the table 15.

Table 7a - 7e: Results of the hydrographical studies conducted at Kavarathi Atoll

Table 7a: Temperature (°C)

	Stations				
Year&Month	1	2	3	4	5
1991 Feb	29.90	29.90	29.98	29.92	29.98
Mar	29.88	29.95	29.90	29.98	30.00
Apr	30.25	30.00	30.50	30.50	30.60
May	30.50	30.75	30.75	30.70	30.70
Jun	ND	ND	ND	ND	ND
Jul	ND	28.50	28.50	28.75	28.75
Aug	28.72	28.90	28.75	28.75	28.50
Sep	28.65	28.85	28.90	28.95	28.90
Oct	28.68	28.75	28.90	28.95	28.95
Nov	28.90	29.00	29.25	29.25	29.00
Dec	29.50	29.50	29.50	29.50	29.25
1992 Jan	29.60	29.75	29.70	29.75	29.50
Feb	29.50	29.75	29.75	29.80	29.75
Mar	30.50	30.60	30.50	30.50	30.50
Apr	30.20	30.50	30.35	30.50	30.50
May	30.60	30.75	30.70	30.50	30.75
Jun	ND	ND	ND	ND	ND
Jul	ND	28.00	28.25	28.30	28.25
Aug	28.28	28.25	28.50	28.50	28.25
Sep	28.70	28.70	28.75	28.75	28.50
Oct	28.68	28.75	28.70	28.75	28.75
Nov	29.10	29.25	29.25	29.25	29.50
Dec	29.80	30.00	29.95	30.00	30.00
1993 Jan	29.95	29.90	29.95	30.00	30.00

Table 7b: Salinity (ppt)

	Stations				
Year&Month	1	2	3	4	5
1991 Feb	35.19	35.10	34.95	35.06	35.00
Mar	34.85	35.20	35.12	35.10	35.01
Apr	34.50	34.95	34.91	34.80	34.90
May	34.75	34.85	34.90	34.91	34.95
Jun	ND	33.70	33.71	33.73	33.70
Jul	ND	33.75	33.80	33.81	33.83
Aug	34.00	33.88	33.89	33.90	33.90
Sep	34.00	33.90	33.93	33.98	33.99
Oct	34.15	33.98	33.95	33.90	33.97
Nov	34.70	34.75	34.85	34.80	34.82
Dec	34.65	34.70	34.78	34.80	34.81
1992 Jan	34.99	34.95	34.89	34.85	35.00
Feb	35.17	35.19	35.10	35.10	35.12
Mar	34.89	35.19	35.18	35.27	35.28
Apr	34.45	34.90	34.97	34.89	34.89
May	34.98	35.10	35.05	35.00	35.10
Jun	ND	33.25	33.19	33.12	33.15
Jul	ND	33.72	33.74	33.70	33.76
Aug	33.98	33.84	33.67	33.78	33.80
Sep	34.10	33.90	33.81	33.78	33.84
Oct	34.12	34.01	34.00	33.98	33.97
Nov	34.71	34.81	34.89	34.88	34.89
Dec	34.60	34.76	34.76	34.75	34.80
1993 Jan	34.50	34.60	34.61	34.60	34.65

Table 7c: Dissolved Oxygen (ml/l)

	Stations				
Year&Month	1	2	3	4	5
1991 Feb	5.01	5.00	5.15	5.20	5.10
Mar	5.31	5.30	5.42	5.40	5.37
Apr	5.25	5.25	5.20	5.30	5.32
May	5.25	5.20	5.18	5.00	5.10
Jun	ND	6.00	5.95	5.90	5.93
Jul	ND	5.50	5.50	5.25	5.30
Aug	5.28	5.90	5.50	5.30	5.50
Sep	5.65	5.78	5.85	5.90	5.80
Oct	5.40	6.00	5.90	5.35	5.48
Nov	5.00	4.85	5.00	5.00	4.81
Dec	5.00	4.90	4.90	5.07	4.80
1992 Jan	5.37	5.00	4.85	4.72	5.00
Feb	4.50	4.35	4.30	4.70	5.00
Mar	4.95	4.90	4.75	4.95	5.00
Apr	3.95	4.00	4.10	4.50	3.98
May	4.00	4.75	4.50	4.75	4.98
Jun	ND	5.90	5.85	5.95	5.92
Jul	ND	5.50	5.00	5.50	5.80
Aug	4.67	4.80	5.00	4.75	4.92
Sep	4.85	5.00	4.90	4.50	5.10
Oct	4.75	4.70	5.00	5.12	5.00
Nov	4.00	3.75	3.80	4.00	3.92
Dec	5.00	4.50	4.70	4.60	4.75
1993 Jan	8.30	4.98	5.01	5.00	4.95

Table 7d: pH

	Stations				
Year&Month	1	2	3	4	5
1991 Feb	8.12	8.10	8.18	8.11	8.16
Mar	8.10	8.15	8.20	8.17	8.18
Apr	8.34	8.36	8.30	8.30	8.36
May	8.30	8.29	8.29	8.30	8.29
Jun	ND	7.85	7.85	7.84	7.85
Jul	ND	7.95	7.95	7.95	7.95
Aug	8.00	8.00	8.05	8.00	8.00
Sep	8.10	8.10	8.15	8.10	8.13
Oct	8.00	8.00	8.10	8.07	8.00
Nov	8.10	8.10	8.10	8.12	8.10
Dec	8.30	8.32	8.32	8.29	8.30
1992 Jan	8.00	8.00	8.10	8.10	8.00
Feb	8.17	8.15	8.20	8.19	8.20
Mar	8.30	8.25	8.25	8.27	8.27
Apr	8.32	8.30	8.35	8.29	8.32
May	8.30	8.26	8.29	8.28	8.26
Jun	ND	7.88	7.92	7.91	7.90
Jul	ND	8.08	8.05	8.06	8.07
Aug	7.95	7.91	7.96	7.99	7.98
Sep	8.00	7.92	7.96	7.99	7.98
Oct	8.00	8.00	8.01	7.99	8.00
Nov	8.15	8.19	8.20	8.20	8.20
Dec	8.31	8.30	8.32	8.32	8.30
1993 Jan	8.30	8.30	8.29	8.30	8.30

Table 7e: Total Suspended Particles (TSP)(mg/l)

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	4.80	5.80	6.60	6.70	6.10
Mar	4.00	6.00	6.80	6.00	6.20
Apr	4.60	5.00	6.50	6.85	6.20
May	4.65	7.00	6.90	6.10	6.00
Jun	ND	8.94	8.99	8.90	8.95
Jul	ND	5.12	5.12	5.70	6.00
Aug	5.80	7.20	6.80	7.00	7.20
Sep	4.50	8.20	6.20	6.00	6.70
Oct	3.00	4.20	5.20	7.12	5.00
Nov	3.50	4.50	3.10	3.00	3.10
Dec	3.75	3.75	2.50	3.00	3.10
1992 Jan	3.10	3.12	4.10	5.00	3.75
Feb	3.80	4.50	5.00	4.80	3.85
Mar	3.20	3.70	3.00	2.50	2.00
Apr	3.00	3.12	3.00	2.15	2.50
May	2.50	2.60	2.10	2.15	2.00
Jun	ND	3.90	2.50	3.00	3.00
Jul	ND	3.10	3.00	3.00	2.75
Aug	1.75	3.00	2.50	2.50	2.70
Sep	2.25	2.50	2.50	2.00	2.00
Oct	3.50	4.00	3.70	3.50	3.20
Nov	1.50	2.75	1.75	1.50	1.75
Dec	2.15	2.75	2.50	2.60	2.55
1993 Jan	1.80	2.85	3.50	3.00	3.50

The monthly fluctuation of total suspended particles (T.S.P) is given in table 7e. The maximum values for 1991 were 5.8mg/l for station 1 in August, 8.94, 8.99, 8.90 and 8.95 mg/l for station 2 to 5 in June. The minimum value were 3mg/l for station 1 in October, 3.12mg/l for station 2 in January, 2.5, 3.0, and 3.10 mg/l for station 3 to 5 in December. The maximum value during 1992 were 3.8, 4.5, 5.0, 4.8 and 3.85 mg/l in February for station 1 to 5 respectively. The minimum values were 1.5, 1.75, 1.5 and 1.75 mg/l for stations 1, 3, 4 and 5 respectively in November and 2.5mg/l in September for station 2. Thus drastic variations in temporal, spatial and quantity were noticed in T.S.P between the two sampling years.

Table 12a shows the seasonal average values for all stations and its average and standard deviations are shown in table 14a. The range of minimum and maximum are given in table 15.

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Table 8a to 8e shows the monthly fluctuation in different parameters over the entire period of study. There were no observations at station 1 in June and July. At all stations observations were not made for temperature in June during the years.

Table 8a explains the monthly temperature fluctuations for the entire period of study from all the stations. During 1991, maximum temperature observed for stations 1,3,4, and 5 was 30 ^{0}C in March. The maximum value for station 2 was 29.95 ^{0}C (April and May). The minimum temperature observed for station 1 was 28.95 ^{0}C (August, September and October). For station 2 to station 5 the minimum value observed was in July and they were 28.60 ^{0}C , 28.65 ^{0}C , 28.60 ^{0}C and 28.65 ^{0}C respectively. During 1992, the distribution of temperature in all the stations was uniform for the maximum value. The values were 29.95, 29.90, 30, 30, and 29.95 ^{0}C in May for station 1 to 5. The minimum value observed during second year was 28.85 ^{0}C for station 1 in August and for stations 2 to 4 was 28.50, 28.45 and 28.50 ^{0}C respectively in July. The minimum value observed for station 5 was 28.60 ^{0}C in October.

Table 12b shows the seasonal average values for all stations and average and standard deviations are shown in table 14b. The range of minimum and maximum are given in table 15.

Table 8b shows the monthly fluctuation in salinity for a period of two years. During 1991, maximum salinity observed for station 1 was 35.10‰. in February, and minimum 33.25‰. in October. For stations 2 to 5 maximum salinity was observed in January '92 which were 35‰., 35.01‰., 34.98 ‰. and 35 ‰ respectively. Minimum value for station 2 was observed in October (33‰.) and for station 3 and station 4 the minimum value was observed in July (33‰. and 33.1‰. respectively). The minimum salinity observed at station 5 was in October (33.12‰). In 1992 the maximum salinity observed was 35.26‰. (May) and minimum was 33.25‰. (August) for station 1. The maximum value was distributed uniformly for stations 2 to 4 and values were 35.2‰., 35.11‰ and 35.17‰. respectively. The minimum value was also uniformly distributed for stations 2 to 5 and were 33‰., 33.05‰., 33.1‰. and 33‰. respectively.

Table 12b shows the seasonal average values for all stations and average and standard deviations are shown in table 14b. The range of minimum and maximum are given in table 15.

Table 8c explains the monthly pH fluctuation for the entire period of study from all stations. During 1991, the maximum pH for stations 1 to 3 were observed in January '92 and the values were 8.25, 8.30 and 8.29 respectively. For station 4, the maximum value observed in February was 8.30 and for station 5, maximum value was observed in April (8.10). The minimum value of pH for station 1 was 7.95 (August) and for stations 2 to 4 the values were 7.8, 7.7 and 7.8 respectively observed in June. 7.82 was the minimum pH observed for station 5 (October). During 1992, the maximum pH for station 1 was 8.29 (April) and minimum was 7.95 (October). The maximum value for station 2 was observed in April as 8.25 and minimum as 7.8 in July. For station 3, maximum value of 8.22 (February) and minimum value 7.88 (July) were observed. For stations 4 and 5, the maximum and minimum values were observed in April and June respectively. The maximum values were 8.31 and 8.30 for stations 4 and 5 respectively and minimum value were 7.89 and 7.90 for stations 4 and 5 respectively. 7.90 was also observed in July for station 5.

Table 12b shows the seasonal average values for all stations and average and standard deviations are shown in table 14b. The range of minimum and maximum are given in table 15.

The monthly dissolved oxygen concentration for the entire period of study from all stations are shown in table 8d. During 1991, the maximum DO concentration for station 1 was 6ml/l in January '92 and minimum was 4.75ml/l in August and 8ml/l in September. For station 2 the maximum DO observed was 5.9 ml/l in December and minimum was 5ml/l observed in March. For station 3 the maximum DO was 5.66ml/l (April) and minimum was 5.12 (March). For station 4 and station 5 the maximum values observed were 5.95 and 5.92ml/l respectively in January and minimum values observed were 5.02 and 5 ml/l respectively in April. During 1992 maximum value for station 1 was 5.75 in January '93, for stations 2 to 4 were 5.5, 5.4 and 5.5 ml/l respectively in November and for station 5 it was 5.5 ml/l in March. The minimum value for station 1 and 2 was 4.7ml/l in December, for station 3 it was 4.85ml/l in October , for station 4 it was 4.9ml/l in December and for station 5 it was 4.9ml/l in September.

Table 12b shows the seasonal average values for all stations and average and standard deviations are shown in table 14b. The range of minimum and maximum are given in table 15.

Table 8e shows the monthly fluctuation of T.S.P. in Kadmat atoll. During 1991, distribution of temperature in all the stations was uniform for the maximum value. The values were 8.5, 7.5, 7.8, 8.0, and 8.0 mg/l respectively in August for stations 1 to 5. The minimum value observed in station 1 was 1.75mg/l (February '93), in station 2 was 2.50mg/l (March and May), in station 3 was 1.75mg/l (April),in station 4 was 2mg/l (March) and the minimum value observed for station 5 was 2.15mg/l (May). During 1992 maximum value for station 1 was 6 mg/l observed in September. The maximum value for stations 2 to 4 was observed in August and was 6, 6.2 and 6.5 mg/l respectively. The maximum value for station 5 was 7.2mg/l observed in September. The minimum value observed in station 1 was 2mg/l (January '93), in station 2 was 1.75mg/l (October), in station 3 was 2mg/l (October), in station 4 was 2mg/l (May) and the minimum value observed for station 5 was 2 (April, May, October, November and December).

Table 8a - 8e: Results of the hydrographical studies conducted at Kadmat Atoll

Table 8a: Temperature (°C)

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	29.80	29.88	29.90	29.95	29.85
Mar	30.00	29.90	30.00	30.00	30.00
Apr	29.90	29.95	29.95	29.90	29.95
May	29.90	29.95	29.95	29.90	29.95
Jun	ND	ND	ND	ND	ND
Jul	ND	28.60	28.65	28.60	28.65
Aug	28.95	28.90	28.90	28.88	28.80
Sep	28.95	28.85	28.90	28.90	28.85
Oct	28.85	28.80	28.80	28.85	28.90
Nov	28.90	28.95	29.00	29.00	29.00
Dec	28.90	29.00	29.00	29.00	29.00
1992 Jan	29.50	29.75	29.70	29.70	29.75
Feb	29.50	29.90	29.80	29.90	29.90
Mar	29.50	29.80	29.80	29.80	29.80
Apr	29.90	29.90	29.85	29.90	29.95
May	29.95	29.90	30.00	30.00	29.95
Jun	ND	ND	ND	ND	ND
Jul	ND	28.50	28.45	28.50	28.65
Aug	28.85	28.80	28.75	28.70	28.80
Sep	28.85	28.80	28.70	28.75	28.85
Oct	28.90	28.55	28.60	28.55	28.60
Nov	28.90	29.00	29.00	29.00	29.00
Dec	29.00	29.00	29.00	29.00	29.00
1993 Jan	29.20	29.50	29.50	29.50	29.50

Table 8b: Salinity (ppt)

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	35.10	34.90	34.95	34.85	34.92
Mar	34.70	34.40	34.30	34.30	34.10
Apr	34.60	34.70	34.60	34.80	34.50
May	34.85	34.80	34.90	34.85	34.80
Jun	ND	33.75	33.65	33.40	33.50
Jul	ND	33.20	33.00	33.10	33.25
Aug	33.85	33.50	33.96	33.74	33.75
Sep	33.98	33.60	33.75	33.95	33.90
Oct	33.25	33.00	33.00	33.20	33.12
Nov	34.25	34.50	34.40	34.40	34.35
Dec	34.45	34.60	34.75	34.90	34.70
1992 Jan	34.95	35.00	35.01	34.98	35.00
Feb	35.17	35.20	35.11	35.17	35.10
Mar	34.98	35.00	35.00	35.01	35.00
Apr	35.00	35.10	35.00	35.10	35.10
May	35.26	35.10	35.01	35.00	35.15
Jun	ND	33.00	33.05	33.10	33.00
Jul	ND	33.15	33.29	33.25	33.20
Aug	33.25	33.10	33.15	33.10	33.18
Sep	33.50	33.25	33.45	33.40	33.20
Oct	33.35	33.33	33.20	33.28	33.18
Nov	34.85	34.80	34.88	34.90	34.80
Dec	34.50	34.95	34.95	34.85	34.90
1993 Jan	34.40	34.85	34.85	34.90	34.90

Table 8c: Dissolcved Oxygen (ml/l)

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	5.25	5.20	5.22	5.22	5.25
Mar	4.95	5.00	5.12	5.10	5.12
Apr	4.98	5.10	5.66	5.02	5.00
May	5.00	5.12	5.20	5.15	5.18
Jun	ND	5.05	5.20	5.25	5.30
Jul	ND	5.05	5.15	5.25	5.20
Aug	4.75	5.45	5.55	5.50	5.48
Sep	4.75	5.20	5.35	5.45	5.20
Oct	4.80	5.65	5.60	5.75	5.65
Nov	5.50	5.75	5.50	5.70	5.90
Dec	5.60	5.90	5.28	5.45	5.40
1992 Jan	6.00	5.65	5.30	5.95	5.92
Feb	5.20	5.00	5.15	5.15	4.95
Mar	5.00	5.12	5.05	5.25	5.50
Apr	5.10	4.95	4.90	5.10	5.00
May	5.10	5.15	5.22	5.15	5.20
Jun	ND	5.15	5.25	5.30	5.15
Jul	ND	5.00	5.12	5.20	4.98
Aug	4.98	5.40	5.30	5.25	5.22
Sep	4.95	4.95	5.10	4.98	4.90
Oct	4.95	4.95	4.85	5.00	4.95
Nov	5.00	5.50	5.40	5.50	5.20
Dec	4.70	4.70	4.90	4.90	4.95
1993 Jan	5.75	4.95	4.98	5.07	5.00

Table 8d: pH

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	8.10	8.12	8.15	8.30	8.25
Mar	8.19	8.25	8.30	8.29	8.30
Apr	8.19	8.25	8.28	8.30	8.31
May	8.20	8.25	8.22	8.15	8.18
Jun	ND	7.80	7.70	7.80	7.85
Jul	ND	8.15	8.09	8.10	8.12
Aug	7.95	8.10	8.08	8.10	8.09
Sep	8.00	8.12	8.11	8.15	8.18
Oct	8.00	7.98	8.00	8.10	7.82
Nov	8.10	8.18	8.13	8.20	8.12
Dec	8.12	8.15	8.14	8.16	8.16
1992 Jan	8.25	8.30	8.29	8.25	8.22
Feb	8.17	8.20	8.22	8.22	8.20
Mar	8.15	8.21	8.20	8.25	8.20
Apr	8.29	8.25	8.20	8.31	8.30
May	8.26	8.20	8.22	8.25	8.22
Jun	ND	7.90	7.95	7.89	7.90
Jul	ND	7.80	7.88	7.90	7.90
Aug	8.00	8.05	8.15	8.00	8.01
Sep	8.10	8.12	8.08	8.06	8.05
Oct	7.95	7.90	7.90	7.90	7.95
Nov	8.00	8.12	8.13	8.12	8.15
Dec	8.12	8.17	8.18	8.20	8.20
1993 Jan	8.17	8.19	8.15	8.16	8.18

Table 8e: Total Suspended Particles (TSP)

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	1.75	3.70	3.00	3.50	3.10
Mar	2.60	2.50	2.75	2.00	2.25
Apr	4.75	3.70	1.75	2.50	2.30
May	2.50	2.50	3.00	3.00	2.15
Jun	ND	3.00	3.75	3.00	3.00
Jul	ND	4.50	5.12	6.70	5.50
Aug	8.50	7.50	7.80	8.00	8.00
Sep	7.70	6.50	6.70	6.70	6.00
Oct	8.00	6.50	6.40	5.00	5.50
Nov	4.50	5.00	4.25	3.50	3.00
Dec	2.75	3.50	3.00	3.00	3.00
1992 Jan	3.15	2.50	2.00	2.50	2.50
Feb	2.50	3.00	2.10	2.00	2.25
Mar	2.75	3.00	3.00	2.50	3.00
Apr	3.00	4.00	3.00	2.15	2.00
May	3.50	2.50	2.15	2.00	2.00
Jun	ND	4.50	5.00	5.60	6.00
Jul	ND	5.25	6.00	5.50	5.00
Aug	5.50	6.00	6.20	6.50	6.50
Sep	6.00	4.75	7.00	6.50	7.20
Oct	2.50	1.75	2.00	2.15	2.00
Nov	3.00	2.50	2.50	2.20	2.00
Dec	2.50	2.50	2.50	2.15	2.00
1993 Jan	2.00	3.00	3.00	2.50	2.15

Table 12b shows the seasonal average values for all stations and average and standard deviations are shown in table 14. The range of minimum and maximum are given in table 15.

3.4.1.3 Kalpeni Atoll

Table 9a to 9e show the monthly fluctuation in different parameters over the entire period of study.

Table 9a explains the monthly temperature fluctuations for the entire period of study from all stations. During 1991, the maximum value was 29.92 ^{0}C and 29.95 ^{0}C in May for station 1 and station 2 respectively and for stations 3 to 5 the value was 30 ^{0}C in April (and also in May for station 4 and station 5). The minimum values were 28.70 ^{0}C for station 1 and 28.70 , 28.75 and 28.60 ^{0}C for stations 2, 3 and 5 in July and 28.65 ^{0}C for station 4 in August. During 1992 the distribution of temperature was uniform and the values were 29.98, 30, 30, 29.95 and 29.98 ^{0}C in May for station 1 to 5. The minimum values were 28.90 ^{0}C (August and September) and 28.80 ^{0}C (September) for station 1 and station 2 and for station 3 to 5 the minimum values were 28.8, 28.65 and 28.70^{0}C in July.

Seasonal average temperature for all stations are given in table 12c. The average and standard deviation in temperature are given in table 14c. The range showing minimum and maximum of temperature is shown in table 15.

Table 9b shows the monthly fluctuation in salinity for a period of two years. As shown in the table during 1991 , maximum salinity observed for station 1 was 35.00‰ in January, and station 2 showed maximum in March (35.12‰.). Maximum salinity for station 3 to 5 was 35.20‰.in April. Minimum values were observed for stations 1, 2 and 5 in October and were 33.20., 33.10 and 33.15‰ respectively. For station 3 the minimum value was 33.12‰. in August and for station 4 the value was 33‰ in June. In 1992 the maximum salinity observed was 35.17 , 35.30, 35.34, 5.50 and 35.48‰. for stations 1 to 5 respectively in May. Minimum values observed were 33.30‰ (August) for stations 1 and 33.00, 33.07, and 33.10‰ for station 2, station 4 and station 5 respectively in June. The minimum value for station 3 was 33.10‰ in August.

Seasonal average salinity for all stations are given in Table 12c and average and standard deviation in salinity are given in Table 14c. The high premonsoon salinity decreased during monsoon and again increased during post monsoon season. The range showing minimum and maximum is shown in table 15.

Table 9c explains the monthly fluctuation in pH for the entire period of study from all stations. During 1991, the maximum pH for stations 1 to 5 were 8.20, 8.36, 8.36, 8.32 and 8.36 respectively in May. The maximum value was also observed in March and December. Minimum value noted for station 1 was 7.75 in October and for stations 2 to 5 were 7.90, 7.90, 7.95 and 7.95 respectively in June. The minimum value was also observed in July for stations 4 and 5. During 1992, distribution of maximum pH observed was uniform and the values were 8.32, 8.35, 8.35, 8.35 and 8.35 for stations 1 to 5 in January and the minimum were 7.85 for station 1 and station 2 in August and 7.90, 7.95 and 7.95 for stations 3 to 5 in June. The minimum values were also observed in July and August for station 4 and station 5.

Seasonal average values of pH for all the stations are given in table 12c. Table 14c shows averages and standard deviations. The range of minimum and maximum are given in table 15.

Table 9d shows the monthly fluctuation in dissolved oxygen for a period of two years. During 1991, maximum DO for station 1 was 5.5 ml/l and observed in October and December. For station 2 maximum was 5.75ml/l and observed in July. For stations 3 and 5 maximum DO was obtained in August and were 5.65 and 5.45 ml/l respectively. For station 4 the maximum was 5.75ml/l and observed in June. The minimum value for stations 1 to 3 was observed in May and were 4.85, 4.75 and 4.48 ml/l respectively. For station 4 and station 5 the minimum values were 3.35 and 3.38 ml/l respectively in January '92. During 1992 the maximum value for station 1, 3 and 4 was observed in September and was 5.95, 5.90 and 5.95 ml/l respectively. The maximum value for station 2 was 6.12ml/l in October and for station 5 was 6.12ml/l in July. The minimum values observed during second year were 4.2, 3.85, 4.0 and 4.05 ml/l for stations 1 to 5 respectively in December and for station 1 minimum value was also observed in April.

Seasonal average of DO for all stations are given in table 12c and average and standard deviation in temperature are given in table 14c. The range showing minimum and maximum of temperature is shown in table 15.

Table 9e shows the monthly fluctuations in total suspended particles (T S P). During 1991, maximum value 6ml/l was observed for station 1 (September), for station 2 (July), for station 4 and station 5 (August). The value for station 3 was 6.5 ml/l (August). The minimum T S P value for first year was 1.7mg/l for station 1 (March) and

Table 9a - 9e: Results of the hydrographical studies conducted at Kalpeni Atoll

Table 9a: Temperature (°C)

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	29.85	29.90	29.90	29.90	29.85
Mar	29.00	29.95	29.95	29.90	29.95
Apr	29.90	29.95	30.00	30.00	30.00
May	29.92	29.95	29.95	30.00	30.00
Jun	ND	ND	ND	ND	ND
Jul	ND	28.70	28.75	28.75	28.60
Aug	28.95	28.90	28.95	28.65	28.75
Sep	28.95	28.85	28.98	28.90	28.85
Oct	28.90	28.85	28.80	28.85	28.85
Nov	28.85	29.00	29.00	28.90	29.00
Dec	28.70	28.85	28.90	28.85	28.90
1992 Jan	29.25	29.25	29.50	29.25	29.50
Feb	29.40	29.40	29.45	29.40	29.45
Mar	29.50	29.60	29.60	29.60	29.60
Apr	29.75	29.80	29.80	29.70	29.75
May	29.98	30.00	30.00	29.95	29.98
Jun	ND	ND	ND	ND	ND
Jul	ND	28.85	28.80	28.65	28.70
Aug	28.90	28.90	28.95	28.70	28.80
Sep	28.90	28.80	28.90	28.85	28.95
Oct	28.95	28.95	28.90	28.85	28.90
Nov	29.20	29.20	29.25	29.20	29.30
Dec	29.20	29.20	29.30	29.25	29.30
1993 Jan	29.35	29.35	29.40	29.40	29.40

Table 9b: Salinity (ppt)

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	34.97	35.10	35.00	35.15	35.12
Mar	34.95	35.12	35.12	35.12	35.12
Apr	34.95	35.10	35.20	35.20	35.20
May	34.75	34.85	34.95	34.94	34.95
Jun	ND	33.40	33.62	33.00	33.29
Jul	ND	33.80	33.45	33.25	33.30
Aug	33.80	33.75	33.12	33.12	33.50
Sep	33.75	33.65	33.80	33.65	33.70
Oct	33.20	33.10	33.25	33.00	33.15
Nov	34.70	34.78	34.80	34.80	34.80
Dec	34.72	34.80	34.80	34.80	34.80
1992 Jan	35.00	35.09	35.10	35.12	35.10
Feb	35.15	35.17	35.20	35.20	35.20
Mar	35.00	35.15	35.20	35.20	35.20
Apr	35.00	35.20	35.20	35.20	35.30
May	35.17	35.30	35.34	35.50	35.48
Jun	ND	33.00	33.15	33.07	33.10
Jul	ND	33.60	33.30	33.45	33.30
Aug	33.30	33.20	33.10	33.22	33.17
Sep	33.80	33.75	33.60	33.65	33.58
Oct	33.27	33.10	33.25	33.22	33.18
Nov	34.80	34.81	34.85	34.85	34.84
Dec	34.75	34.80	34.85	34.85	34.85
1993 Jan	34.60	34.65	34.68	34.65	34.64

Table 9c: Dissolved Oxygen (ml/l)

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	5.10	5.25	5.20	5.30	4.95
Mar	4.95	4.80	5.00	5.10	5.00
Apr	5.50	5.10	4.90	5.11	5.10
May	4.85	4.75	4.68	4.95	4.70
Jun	ND	5.55	5.60	5.75	5.10
Jul	ND	5.75	5.60	5.20	5.40
Aug	5.10	5.60	5.65	5.70	5.45
Sep	4.95	5.55	5.10	5.25	5.35
Oct	5.50	5.50	5.30	5.25	5.20
Nov	5.00	5.40	5.25	5.30	5.00
Dec	5.50	5.60	5.45	5.60	5.25
1992 Jan	5.39	5.30	5.40	3.35	3.38
Feb	4.95	4.90	4.89	4.90	4.82
Mar	4.35	4.30	4.15	4.12	4.20
Apr	4.20	4.10	4.00	4.12	4.12
May	4.95	4.90	4.95	5.00	5.10
Jun	ND	5.50	5.40	5.50	5.75
Jul	ND	5.50	5.10	5.40	6.12
Aug	5.65	5.95	5.70	5.60	5.95
Sep	5.95	6.00	5.90	5.95	6.10
Oct	5.75	6.12	5.22	5.12	6.10
Nov	5.10	4.80	4.80	4.72	4.75
Dec	4.20	3.85	3.95	4.00	4.05
1993 Jan	5.20	5.10	5.00	5.12	4.90

Table 9d: pH

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	8.10	8.17	8.15	8.13	8.15
Mar	8.20	8.29	8.29	8.30	8.29
Apr	8.10	8.30	8.30	8.29	8.29
May	8.20	8.36	8.36	8.32	8.36
Jun	ND	7.90	7.90	7.95	7.95
Jul	ND	7.91	7.95	7.95	7.95
Aug	7.98	7.90	7.95	8.00	8.01
Sep	7.95	8.00	8.10	8.15	8.15
Oct	7.75	7.95	8.00	8.05	8.10
Nov	8.00	8.10	8.10	8.10	8.10
Dec	8.20	8.30	8.30	8.18	8.20
1992 Jan	8.00	8.00	8.10	8.00	8.10
Feb	8.10	8.15	8.20	8.20	8.20
Mar	8.29	8.30	8.29	8.29	8.30
Apr	8.15	8.30	8.32	8.32	8.32
May	8.20	8.13	8.15	8.20	8.20
Jun	ND	7.95	7.90	7.95	7.95
Jul	ND	7.97	7.95	7.95	7.95
Aug	7.85	7.85	7.95	7.95	7.95
Sep	8.00	8.10	8.10	8.15	8.15
Oct	8.00	8.15	8.12	8.05	8.00
Nov	8.15	8.20	8.20	8.15	8.20
Dec	8.20	8.29	8.30	8.30	8.30
1993 Jan	8.32	8.35	8.35	8.35	8.35

Table 9e: Total Suspended Particles (TSP)

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	2.50	2.00	2.00	2.25	2.00
Mar	1.70	2.00	2.00	1.75	1.70
Apr	3.50	2.75	2.50	2.70	2.50
May	2.50	3.00	2.50	2.50	2.00
Jun	ND	5.50	4.50	5.00	4.00
Jul	ND	6.00	5.50	4.00	3.50
Aug	5.50	6.00	6.50	6.00	6.00
Sep	6.00	5.50	5.00	4.50	4.00
Oct	4.00	3.50	3.00	3.00	3.50
Nov	3.50	3.00	3.00	2.50	2.75
Dec	2.75	3.00	2.50	2.00	2.20
1992 Jan	1.75	1.50	1.50	1.70	1.50
Feb	2.00	1.50	1.75	1.50	1.50
Mar	1.50	1.75	1.80	2.00	1.75
Apr	2.25	2.00	2.50	2.00	1.75
May	2.0	1.75	1.70	1.85	1.70
Jun	ND	3.50	3.00	3.00	3.00
Jul	ND	3.50	3.00	3.00	3.00
Aug	3.50	2.75	2.50	2.50	2.25
Sep	3.00	2.40	2.65	2.60	2.50
Oct	3.75	2.75	2.50	2.40	2.40
Nov	2.00	1.75	1.50	1.70	1.75
Dec	3.50	2.50	2.00	2.75	2.10
1993 Jan	2.00	1.75	2.00	2.15	1.50

station 4 (January) and 1.5mg/l for stations 2, 3 and station 5 in January '92. During 1992 maximum value was 3.75mg/l in October and minimum value 1.5mg/l in March for station 1. For stations 2 to 5 maximum value was distributed uniformly and were observed in June and July, the values being 3.5mg/l for station 2 and 3mg/l for stations 3 to 5. The minimum value for second year was 1.5mg/l for station 1 (March), station 2 (February), station 3 (November), station 4 (February) and station 5 (February and January '93).

Seasonal average of T S P for all stations are given in table 12c and average and standard deviations are given in table 14c. The range showing minimum and maximum of T.S.P. is shown in table 15.

3.4.1.4 Agathi Atoll

Table 10a to 10e show the monthly fluctuation in different parameters over the entire period of study.

Monthly temperature fluctuations for the entire period of study was given in table 10a. During 1991, the distribution of temperature was uniform for both maximum and minimum values. Maximum value was observed in April and was 30 ^{0}C for station 1 and 30.25 ^{0}C for stations 2 to 5. The minimum value was observed in November and was 28.30 ^{0}C for station 1 and station 4, 28.35 ^{0}C for station 2 and 28.25 ^{0}C for station 3 and station 5. In 1992, maximum value for station 1 was observed in May (29.85 ^{0}C) and for station 2 to 5 in April (29.95 ^{0}C for stations 2, 3 and 5 and 29.9 ^{0}C for station 4). Minimum value for station 1 was 28.4 ^{0}C observed in August and minimum value for stations 2 to 5 was observed in July (28 ^{0}C for stations 3 to 5 and 28.1 ^{0}C for station 2.).

Table 10a - 10e: Results of the hydrographical studies conducted at Agathi Atoll

Table 10a: Temperature (°C)

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	29.60	29.69	29.70	29.71	29.70
Mar	29.25	30.00	29.75	29.75	29.75
Apr	30.00	30.25	30.25	30.25	30.25
May	29.50	29.85	29.80	29.80	29.80
Jun	ND	ND	ND	ND	ND
Jul	ND	28.65	28.65	28.60	28.65
Aug	28.90	28.90	28.90	28.95	28.95
Sep	28.80	28.80	28.75	28.75	28.80
Oct	28.95	28.95	28.90	28.90	28.95
Nov	28.30	28.35	28.25	28.30	28.25
Dec	28.50	29.00	29.00	29.00	29.00
1992 Jan	29.00	29.25	29.45	29.45	29.40
Feb	29.50	29.75	29.75	29.70	29.75
Mar	29.50	29.90	29.90	29.85	29.90
Apr	29.80	29.95	29.95	29.90	29.95
May	29.65	29.75	29.80	29.70	29.80
Jun	ND	28.40	28.40	28.30	28.40
Jul	ND	28.10	28.00	28.00	28.00
Aug	28.40	28.30	28.30	28.25	28.30
Sep	28.95	28.90	28.90	28.80	28.90
Oct	28.80	28.80	28.80	28.70	28.80
Nov	28.25	28.50	28.45	28.45	28.50
Dec	28.00	28.00	28.10	28.00	28.10
1993 Jan	29.00	29.00	29.00	29.00	29.00

Table 10b: Salinity (ppt)

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	35.01	34.95	35.20	35.22	35.00
Mar	35.00	34.95	35.00	35.20	35.00
Apr	34.49	34.61	34.54	34.18	34.61
May	35.45	35.75	35.80	35.64	35.71
Jun	ND	33.90	33.90	33.50	33.75
Jul	ND	33.00	33.20	33.15	33.10
Aug	33.65	33.45	33.50	33.45	33.60
Sep	33.98	34.00	33.95	34.10	33.98
Oct	33.25	33.00	33.10	33.09	33.05
Nov	34.50	34.60	34.50	34.20	34.60
Dec	34.65	34.74	34.80	34.71	34.75
1992 Jan	35.32	35.32	35.85	35.32	35.32
Feb	35.10	35.15	35.25	35.30	35.40
Mar	35.15	35.17	35.28	35.30	35.25
Apr	35.50	35.95	35.90	35.70	35.80
May	35.20	35.28	35.29	35.30	35.25
Jun	ND	33.55	33.56	33.60	33.60
Jul	ND	33.10	33.15	33.18	33.19
Aug	33.92	33.90	33.88	33.75	33.90
Sep	33.65	33.69	33.70	33.71	33.59
Oct	33.65	33.60	33.49	33.51	33.55
Nov	34.25	34.20	34.40	34.35	34.40
Dec	34.90	34.90	34.85	34.80	34.85
1993 Jan	34.95	35.00	35.10	35.10	35.15

Table 10c: Dissolcved Oxygen (ml/l)

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	5.60	5.70	5.75	5.70	5.30
Mar	5.75	5.50	5.34	5.10	5.30
Apr	5.80	5.75	5.60	5.65	5.70
May	5.40	5.35	5.27	5.30	5.32
Jun	ND	4.90	4.98	5.00	5.00
Jul	ND	5.15	5.20	5.18	5.18
Aug	5.00	5.45	5.55	5.50	5.48
Sep	4.90	5.65	5.60	5.60	5.55
Oct	4.95	5.75	5.80	5.78	5.70
Nov	4.97	4.80	4.85	4.90	4.85
Dec	4.98	4.78	4.35	4.70	4.70
1992 Jan	5.00	5.10	4.98	4.75	5.51
Feb	5.75	5.50	5.40	5.35	5.40
Mar	5.80	5.95	5.80	5.60	5.60
Apr	5.10	5.20	5.25	5.30	5.10
May	5.10	5.00	5.07	5.10	5.15
Jun	ND	5.10	5.17	5.15	5.20
Jul	ND	5.25	5.40	5.30	5.15
Aug	4.80	5.60	5.47	5.50	5.60
Sep	4.75	5.17	5.20	5.35	5.40
Oct	4.90	5.00	5.15	5.12	5.17
Nov	4.90	4.95	5.00	4.85	5.00
Dec	4.95	4.85	4.90	4.80	4.95
1993 Jan	5.00	4.95	4.98	4.95	5.10

Table 10d: pH

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	8.29	8.25	8.24	8.26	8.24
Mar	8.30	8.29	8.30	8.30	8.30
Apr	8.20	8.25	8.25	8.20	8.25
May	8.30	8.30	8.31	8.29	8.29
Jun	ND	7.80	7.79	7.81	7.80
Jul	ND	7.69	7.60	7.65	7.68
Aug	7.98	7.90	7.98	7.95	7.93
Sep	7.95	7.60	7.58	7.58	7.59
Oct	8.00	7.98	7.96	7.96	7.94
Nov	8.10	8.11	8.15	8.13	8.15
Dec	8.21	8.20	8.25	8.24	8.25
1992 Jan	8.17	8.16	8.20	8.21	8.22
Feb	8.15	8.19	8.17	8.15	8.17
Mar	8.20	8.20	8.21	8.22	8.20
Apr	8.19	8.15	8.16	8.16	8.14
May	8.22	8.21	8.20	8.22	8.22
Jun	ND	7.60	7.62	7.65	7.60
Jul	ND	7.65	7.69	7.70	7.65
Aug	7.90	7.71	7.75	7.71	7.72
Sep	7.92	7.88	7.88	7.90	7.91
Oct	7.85	7.75	7.80	7.79	7.79
Nov	8.00	8.10	8.08	8.10	8.10
Dec	8.10	8.11	8.05	8.09	8.09
1993 Jan	8.08	8.10	8.10	8.09	8.10

Table 10e: Total Suspended Particles (TSP)(mg/l)

Year&Month	Stations				
	1	2	3	4	5
1991 Feb	1.75	1.70	1.50	1.75	1.60
Mar	2.20	1.85	2.00	1.80	1.75
Apr	3.00	1.50	1.70	1.50	1.70
May	3.00	2.00	2.10	2.00	2.00
Jun	ND	3.75	4.00	4.10	4.00
Jul	ND	3.50	3.75	3.00	3.50
Aug	5.00	5.50	5.00	4.50	4.00
Sep	5.00	5.00	4.00	3.50	4.00
Oct	4.50	4.75	4.50	4.00	4.50
Nov	5.10	5.50	5.00	4.50	4.00
Dec	3.50	2.50	3.00	2.75	2.00
1992 Jan	2.50	2.50	2.00	2.50	2.10
Feb	1.75	2.00	2.50	2.50	2.25
Mar	2.50	2.00	2.00	1.75	1.50
Apr	2.00	1.75	1.50	1.75	1.50
May	2.50	2.00	2.25	2.00	2.00
Jun	ND	4.00	3.50	3.00	3.00
Jul	ND	4.50	3.00	3.50	3.00
Aug	3.00	2.50	2.00	2.00	2.00
Sep	2.50	2.00	2.25	2.00	2.25
Oct	1.75	1.50	1.50	1.50	2.00
Nov	2.00	1.75	2.00	1.50	2.00
Dec	2.25	2.00	2.00	1.75	2.00
1993 Jan	2.00	2.20	2.00	2.25	2.00

Seasonal average of temperature for all stations are given in table 12d and average and standard deviation are given in table 14d. The range showing minimum and maximum is shown in table 15.

Table 10b shows the monthly fluctuations in salinity for a period of two years. During 1991 maximum salinity was observed in May for station 1 (35.45‰), station 2 (35.75‰), station 4 (35.64‰) and station 5 (35.71‰) and for station 3 maximum value (35.85‰) was observed in January '92. The minimum salinity distribution was uniform in 1991. The minimum value observed in October and were 33.25, 33.0, 33.1, 33.09 and 33.05‰ for stations 1 to 5 respectively. During second year (1992), the distribution was uniform for maximum value and was observed in April and the values were 35.50, 35.95, 35.70 and 35.80 ‰ for stations 1 to 5. The minimum was 33.65‰ for station 1 (September and October) and for stations 2 to 5 the minimum value was observed in July and the values were 33.1, 33.15, 33.18 and 33.19‰ respectively.

Seasonal average of salinity for all stations are given in table 12d and average and standard deviations in salinity are given in table 14d. The range showing minimum and maximum of salinity is shown in table 15.

Table 10c shows monthly pH fluctuations in pH during the entire period of study. During 1991 the distribution of pH was uniform for maximum and minimum values. The maximum values was observed in May and the values were 8.30, 8.30, 8.31,8.29 and 8.29 for stations 1 to 5 respectively. The minimum values were observed in September for all stations and the values were 7.95, 7.60, 7.58, 7.58 and 7.59 for stations 1 to 5. During 1992, the maximum value was distributed uniformly and the values were observed in May and were 8.22, 8.21, 8.20 and 8.22 for stations 1 to 5 respectively. For station 4 maximum value was also observed in March. The minimum values were 7.85 for station 1 in October and for stations 2 to 5 the minimum value was in June and the values were 7.60, 7.62, 7.65 and 7.60 respectively.

Seasonal average of pH for all stations are given in table 12d and average and standard deviations in pH are given in table 14d. The range showing minimum and maximum of pH is given in table 15.

Table 10d shows the monthly fluctuations of dissolved oxygen (DO) for the period of two years. During 1991, maximum value was obtained in April for station 1 and station 2 and was 5.80 ml/l and 5.75 ml/l respectively. For station 3 and station 4 maximum value was observed in February and was 5.75 ml/l and 5.70 ml/l respectively. The maximum value for station 5 was 5.70 ml/l observed in April and October. The minimum value for station 1 was 4.9 ml/l in September and for station 2 to 5 the values were observed in December and was 4.78, 4.35, 4.70 and 4.70 ml/l respectively. During 1992 the maximum value for stations 1 to 5 was observed in March and values were 5.8, 5.95, 5.80, 5.60 and 5.60 ml/l respectively. Maximum value for station 5 was also observed in August. The minimum value for station 1 was 4.75ml/l in September and for station 2 to 5 was 4.85, 4.90, 4.80 and 4.95 ml/l respectively.

Seasonal average of DO for all stations are given in table 12d and average and standard deviation are given in table 14d. The range showing minimum and maximum is shown in table 15.

The monthly fluctuations in total suspended particles for the entire period of study is given in the table 10e. During 1991 the maximum T S P values were observed in August for stations 1 to 4 and values were 5 mg/l (station 1), 5.5 mg/l (station 2), 5 mg/l (station 3) and 4.5 mg/l (station 4). For station 1 maximum value also observed in September. For station 5 maximum value 4.5 mg/l was observed in October. The minimum values observed was 1.75 mg/l for station 1 in February and 1.5 for station 2 (April), station 3 (February) and station 4 (April). The minimum for station 5 was 1.70 mg/l in April. During 1992, the maximum was 3.0 mg/l (August) and minimum was 1.75 mg/l (October and November) for station 1. For stations 2, 3 and 4 maximum was observed in June and value were 4 mg/l (station 2), 3.5 mg/l(station 3) and 3 mg/l (station 5). Maximum for station 5 was also observed in July. The value for station 4 was 3.5 mg/l in July. The minimum value for second year was observed in October for stations 1 to 4 and values were 1.75 mg/l (station 1) and 1.5 mg/l (for station 2 to 4). The minimum value for station 4 was also observed in November. For station 5 minimum value was 1.5 mg/l and observed in March and April.

Seasonal average of T S P for all stations are given in table 12d and average and standard deviation are given in table 14d. The range showing minimum and maximum is shown in table 15.

Statistical Analysis

The data were subjected to statistical analysis using 2-way analysis of variance. The model employed was $xij = m + ai + bj + eij$, where xij is the observation on a parameter at i station, in the j season, m is the general effect, ai is the i station effect, bj is the j season effect and eij is the random error. The ANOVA tables are given in tables 16a to 16d. In all the tables there are no significant differences between stations, but there are significant differences between seasons. The least significant difference (lsd) at 5%

level were calculated and the significant means were separated. The results are given in the table 17a to 17d.

3.4.2 Results of estimation of Petroleum Hydrocarbons (PHC)

3.4.2.1 Kavarathi atoll

Table 11a shows the monthly fluctuation of petroleum hydrocarbons (PHC) over the entire period of study. There were no observations in June. The values are expressed in ppb.

During 1991 the maximum petroleum hydrocarbons (PHC) value observed was 0.95 for station 1 (March and April) and station 2 (May). For station 3 maximum value was observed in March and was 1.0. The maximum value observed for station 4 was 0.95 in October and for station 5 the value was 0.8 observed in October, November, December. The minimum values observed was 0.016 (August) for station 1, 0.40 for station 2 (August and September), 0.8 for station 3 (July, August and September), 0.60 for station 4 (August) and 0.011 for station 5 (August and September). In 1992, the maximum was 0.95 (March and April) for station 1, for station 2 (March and May) and for station 4 (November). Maximum value observed for station 3 was 1.0 (January, March, October, November, December and January 1993) and for station 5 was 0.8 (October, November, December and January 1993). The minimum values observed in 1992 were same as the previous year.

Seasonal average of PHC for all stations average of two years are given in table 13a.

Table 11a : Results of Estimation of Petroleum Hydrocarbons (PHC) at Kavarathi Atoll

Year & Month	Stations				
	1	2	3	4	5
1991 Feb	0.85	0.85	0.90	0.65	0.65
Mar	0.95	0.90	1.0	0.75	0.60
Apr	0.95	0.90	0.95	0.70	0.70
May	0.85	0.95	0.95	0.70	0.65
Jun	ND	ND	ND	ND	ND
Jul	0.50	0.60	0.80	0.65	0.014
Aug	0.016	0.40	0.80	0.60	0.011
Sep	0.60	0.40	0.80	0.70	0.011
Oct	0.45	0.90	1.0	0.9	0.8
Nov	0.60	0.90	1.0	0.9	0.8
Dec	0.70	0.90	1.0	0.90	0.80
1992 Jan	0.85	0.90	1.0	0.90	0.80
Feb	0.85	0.85	0.90	0.70	0.55
Mar	0.95	0.90	1.0	0.75	0.60
Apr	0.95	0.90	0.95	0.70	0.70
May	0.85	0.95	0.95	0.65	0.75
Jun	ND	ND	ND	ND	ND
Jul	0.50	0.60	0.80	0.65	0.014
Aug	0.016	0.40	0.80	0.60	0.011
Sep	0.60	0.40	0.80	0.70	0.011
Oct	0.45	0.90	1.0	0.9	0.8
Nov	0.60	0.90	1.0	0.9	0.8
Dec	0.95	0.90	1.0	0.90	0.80
1993 Jan	0.60	0.90	1.0	0.90	0.80

Table 11 b : Results of Estimation of Petroleum Hydrocarbons (PHC) at Kadmat Atoll

Year & Month	Stations				
	1	2	3	4	5
1991 Feb	0.80	0.80	0.80	0.60	0.60
Mar	0.85	0.85	0.80	0.80	0.80
Apr	0.85	0.85	0.80	0.70	0.70
May	0.90	0.90	0.80	0.70	0.70
Jun	ND	ND	ND	ND	ND
Jul	0.035	0.80	0.45	0.45	0.45
Aug	0.035	0.80	0.45	0.45	0.45
Sep	0.035	0.80	0.45	0.50	0.45
Oct	0.60	0.50	0.50	0.50	0.50
Nov	0.55	0.50	0.70	0.70	0.70
Dec	0.65	0.30	0.60	0.60	0.60
1992 Jan	0.65	0.40	0.60	0.60	0.60
Feb	0.80	0.85	0.80	0.60	0.60
Mar	0.85	0.85	0.80	0.80	0.80
Apr	0.85	0.85	0.80	0.70	0.70
May	0.90	0.90	0.80	0.70	0.70
Jun	ND	ND	ND	ND	ND
Jul	0.035	0.80	0.45	0.45	0.45
Aug	0.035	0.80	0.45	0.45	0.45
Sep	0.035	0.80	0.45	0.50	0.45
Oct	0.60	0.50	0.50	0.50	0.50
Nov	0.60	0.50	0.70	0.70	0.70
Dec	0.70	0.30	0.60	0.60	0.60
1993 Jan	0.80	0.40	0.60	0.60	0.60

3.4.2.2 Kadmat atoll

Table 11b shows the monthly fluctuation of petrolium hydrocarbons (PHC) over the entire period of study. There were no observations in June.

During 1991 the maximum petroleum hydrocarbons (PHC) value observed was 0.90 for station 1 and 2 in May. For station 3 maximum value was observed in February, March, April and May and the value was 0.80. The maximum value observed for station 4 and 5 was observed in March (0.80). The minimum values observed was 0.035 for station 1, 0.80 for station 2, 0.45 for station 3, 4 and station 5 in July, August and September. In 1992, the values were same for maximum and minimum for all stations as 1991.

Seasonal average of PHC for all stations average of two years are given in table 13b.

3.5 Discussion

Jayaraman *et.al.* (1960) identified 3 types of water masses in the Lakshadweep area. They were characterized as the Arabian sea upper subsurface water mass, Arabian sea lower subsurface water mass and the Indian ocean equatorial water mass. In the present investigation sampling was conducted only in the Arabian sea upper subsurface, which is characterized by sharp salinity gradient and very small temperature range. The occurrence of eddies around the islands and practically all levels was also noticed. Regarding the pattern of nutrient distribution and the nutrient -oxygen relationship the trend maintained in waters is very similar to those of other parts of Arabian sea. It is

Table 12a
Hydrographical Parameters of Kavarathi Atoll (Seasonal Average)

Parameters	Seasons	Stations				
		1	2	3	4	5
Temperature	Pre-mon	30.16	30.27	30.30	30.28	29.74
	Mon	28.58	28.53	28.60	28.65	28.52
	Post-mon	29.27	29.36	29.39	29.43	29.36
Salinity	Pre-mon	34.84	35.05	35.02	35.01	35.09
	Mon	34.02	33.73	33.71	33.72	33.74
	Post-mon	34.55	34.56	34.58	34.56	34.61
pH	Pre-mon	8.24	8.23	8.25	8.23	8.25
	Mon	8.01	7.95	7.98	7.98	7.98
	Post-mon	8.14	8.14	8.17	8.17	8.11
D.O	Pre-mon	4.77	4.84	4.82	4.97	4.98
	Mon	5.11	5.54	5.44	5.37	5.53
	Post-mon	4.97	4.83	4.87	4.85	4.84
T.S.P	Pre-mon	3.8	4.71	4.95	4.65	4.35
	Mon	3.57	5.14	4.69	4.76	4.9
	Post-mon	2.66	3.48	3.26	3.59	3.24

Table 12b
Hydrographical Parameters of Kadmat Atoll (Seasonal Average)

Parameters	Seasons	Stations				
		1	2	3	4	5
Temperature	Pre-mon	29.8	29.89	29.70	29.91	29.91
	Mon	28.9	28.74	28.62	28.76	28.76
	Post-mon	28.89	29.06	29.07	29.07	29.06
Salinity	Pre-mon	34.95	34.9	34.85	34.88	34.83
	Mon	33.64	33.31	33.41	33.37	33.37
	Post-mon	34.24	34.87	34.38	34.42	34.36
pH	Pre-mon	8.19	8.21	8.22	8.25	8.24
	Mon	8.01	8.01	8	7.99	8.01
	Post-mon	8.08	8.12	8.11	8.13	8.1
D.O	Pre-mon	5.07	5.07	5.19	5.14	5.14
	Mon	4.85	5.15	5.25	5.27	5.17
	Post-mon	5.21	5.35	5.22	5.41	5.36
T.S.P	Pre-mon	2.91	3.1	2.59	2.45	2.38
	Mon	6.92	5.24	5.94	6.06	5.83
	Post-mon	3.55	3.4	3.2	2.87	2.76

Table 12c
Hydrographical Parameters of Kalpeni Atoll (Seasonal Average)

Parameters	Seasons	Stations				
		1	2	3	4	5
Temperature	Pre-mon	29.77	29.81	29.82	29.8	29.82
	Mon	28.92	28.83	28.88	28.8	28.77
	Post-mon	28.04	29.07	29.13	29.06	29.14
Salinity	Pre-mon	34.99	35.12	35.14	35.17	35.19
	Mon	33.66	33.51	33.36	33.29	33.36
	Post-mon	34.37	34.38	34.44	34.41	34.41
pH	Pre-mon	8.16	8.25	8.25	8.25	8.26
	Mon	7.94	7.82	7.87	7.9	7.9
	Post-mon	8.07	8.16	8.18	8.14	8.16
D.O	Pre-mon	4.85	4.76	4.71	4.82	4.74
	Mon	5.41	5.92	5.75	5.8	5.77
	Post-mon	5.32	5.33	5.29	5.05	4.95
T.S.P	Pre-mon	2.24	2.09	2.09	2.06	1.86
	Mon	4.5	4.39	4.01	3.52	3.52
	Post-mon	2.9	2.46	2.25	2.2	2.2

Table 12d
Hydrographical Parameters of Agathi Atoll (Seasonal Average)

Parameters	Seasons	Stations				
		1	2	3	4	5
Temperature	Pre-mon	29.59	29.88	29.86	29.82	29.86
	Mon	28.76	28.6	28.58	28.54	28.6
	Post-mon	28.59	28.72	28.74	28.72	28.75
Salinity	Pre-mon	35.1	35.22	35.28	35.23	35.25
	Mon	33.79	33.57	33.6	33.55	33.58
	Post-mon	34.43	34.41	34.5	34.38	34.45
pH	Pre-mon	8.23	8.22	8.22	8.17	8.22
	Mon	7.93	7.72	7.73	7.74	7.73
	Post-mon	8.06	8.06	8.07	8.07	8.08
D.O	Pre-mon	5.53	5.45	5.43	5.38	5.35
	Mon	4.86	5.28	5.32	5.32	5.31
	Post-mon	4.95	5.01	4.99	4.98	5.12
T.S.P	Pre-mon	2.3	1.84	1.93	1.88	1.75
	Mon	3.87	3.84	4.18	3.19	3.15
	Post-mon	2.95	2.87	2.74	2.59	2.57

Table 13a: Seasonal Average of Petroleum Hydrocarbons (PHC) in ppb at Kavarathi Atoll

Seasons	Stations				
	1	2	3	4	5
Pre-mon	0.90	0.90	0.95	0.7	0.65
Mon	0.372	0.466	0.80	0.65	0.012
Post-mon	0.65	0.90	1.0	0.9	0.8

Table 13b: Seasonal Average of Petroleum Hydrocarbons (PHC) in ppb at Kadmat Atoll

Seasons	Stations				
	1	2	3	4	5
Pre-mon	0.85	0.85	0.80	0.70	0.70
Mon	0.0035	0.80	0.45	0.46	0.45
Post-mon	0.61	0.42	0.60	0.60	0.60

Table 14 a -d.
Average and Std.deviation of hydrographical parameters

Table 14a: Kavarathi

Parameters	Stations				
	1	2	3	4	5
Temperature	29.33 ± 0.64	29.38 ± 0.71	29.43 ± 0.69	29.45 ± 0.66	29.20 ± 0.50
Salinity	34.47 ± 0.33	34.44 ± 0.54	34.43 ± 0.54	34.43 ± 0.53	34.48 ± 0.55
pH	8.13 ± 0.09	8.10 ± 0.11	8.13 ± 0.11	8.12 ± 0.10	8.11 ± 0.11
D.O	5.23 ± 0.43	5.07 ± 0.33	5.04 ± 0.28	5.06 ± 0.22	5.11 ± 0.29
T.S.P	3.34 ± 0.49	3.44 ± 0.70	4.30 ± 0.74	4.33 ± 0.52	4.16 ± 0.69

Table 14 b: Kadmat

Parameters	Stations				
	1	2	3	4	5
Temperature	29.19 ± 0.42	29.23 ± 0.48	29.13 ± 0.44	29.24 ± 0.48	29.25 ± 0.48
Salinity	34.27 ± 0.53	34.36 ± 0.74	34.21 ± 0.59	34.22 ± 0.63	34.18 ± 0.60
pH	8.09 ± 0.07	8.11 ± 0.08	8.11 ± 0.08	8.12 ± 0.10	8.11 ± 0.09
D.O	5.04 ± 0.14	5.19 ± 0.11	5.22 ± 0.02	5.27 ± 0.11	5.22 ± 0.09
T.S.P	4.46 ± 1.75	3.91 ± 0.94	3.91 ± 1.45	3.79 ± 1.61	3.65 ± 1.54

Table 14 c: Kalpeni

Parameters	Stations				
	1	2	3	4	5
Temperature	29.24 ± 0.37	29.23 ± 0.41	29.27 ± 0.39	29.22 ± 0.42	29.24 ± 0.43
Salinity	34.34 ± 0.54	34.33 ± 0.65	34.31 ± 0.73	34.29 ± 0.77	34.32 ± 0.74
pH	8.05 ± 0.09	8.07 ± 0.18	8.10 ± 0.16	8.09 ± 0.14	8.10 ± 0.15
D.O	5.19 ± 0.24	5.33 ± 0.47	5.25 ± 0.42	5.22 ± 0.41	5.15 ± 0.44
T.S.P	3.21 ± 0.94	2.98 ± 1.0	2.78 ± 0.86	2.72 ± 0.77	2.52 ± 0.71

Table 14 d: Agathi

Parameters	Stations				
	1	2	3	4	5
Temperature	29.98 ± 0.43	29.06 ± 0.57	29.06 ± 0.56	29.02 ± 0.56	29.07 ± 0.56
Salinity	34.44 ± 0.53	34.40 ± 0.67	34.46 ± 0.68	34.38 ± 0.68	34.42 ± 0.68
pH	8.07 ± 0.12	8.00 ± 0.20	8.00 ± 0.20	7.90 ± 0.18	8.01 ± 0.20
D.O	5.11 ± 0.29	5.24 ± 0.18	5.24 ± 0.18	5.22 ± 0.17	5.26 ± 0.10
T.S.P	3.04 ± 0.64	2.85 ± 0.81	2.95 ± 0.93	2.55 ± 0.53	2.49 ± 0.57

observed that the relatively high productivity of this area is owing to the circulatory water movement prevalent in these islands (Sengupta *et.al* 1979).

Sankaranarayanan (1973) found considerable changes in the DO content of the lagoon controlled by diurnal variations , on the other hand no significant variation in the other hydrographical parameters. Circulatory water movement were prevalent during winter season also. It was found to be of lesser intensity (Nair *et. al.* 1986). The occurrence of high saline water during the winter is supposed to be due to the excess of evaporation over precipitation. By and large the information gathered on all basic hydrographic features at atolls when compared with the existing literature indicates minimal changes that could be attributed to anthropogenic effects.

Suresh (1991) recorded maximum value of total suspanded particles (T.S.P) as 14.36 mg/l from Kavarathi lagoon during mansoon season and a minimum value 1.96 mg/l during post monsoon season. In the present investigation also little high values of T.S.P (9mg/l) during monsoon compared to other seasons were recorded from Kavarathi. In the other three etolls the values were below 8 mg/l. This high value during monsoon may be due to heavy water movement. Normal suspanded particle concentration for coral reefs to be 10 mg/l (Rogers, 1990). But it is still not known, what is the minimal level to evoke a response in growth of corals. In tropical estuarine environment (Cochin), Rasheed *et.al.* (1997) recorded a range of 20-90 mg/l of T.S.P from the surface water.

Nandini Menon (1997) obtained 22 ppb as the average petroleum hydrocarbons (PHC) concentration from coastal waters of Cochin, but she recorded maximum value of

Table 15
Maximum and Minimum Range of Hydrographical Parameters of Lakshadweep Atolls

Parameters	Atolls			
	Kavarathy	Kadmat	Kalpeni	Agathi
Temperature	28.0 - 30.75	28.45 - 30	28.6 - 30.0	28.0 - 30.25
Salinity	34.12 - 35.28	33.0 - 35.26	33.0 - 35.5	33.0 - 35.95
pH	7.84 - 8.36	7.7 - 8.31	7.85 - 8.36	7.58 - 8.31
D.O	3.75 - 5.95	4.75 - 5.75	3.85 - 6.12	4.35 - 5.95
T.S.P	1.5 - 8.99	1.75 - 8	1.5 - 6.5	1.5 - 5.5

Table 16a-d
Two-way ANOVA Tables Showing the Level of Significance in Variation of Different Parameters Between Stations and Over Seasons

Table 16a Kavarathi Atoll

Parameter	Source Of Variation	Sum Of Squires	Degrees Of Freedom	Mean Sum Of squires	Ratio of F
Salinity	Between Station	0.00516	4	0.001390	0.107419
	Between Season	3.81561	2	1.907807	147.4248
	Residual	0.10352	8	0.012940	
pH	Between Station	0.00147	4	0.000367	0.0165196
	Between Season	0.17327	2	0.086635	3.8943729
	Residual	0.17797	8	0.022246	
Temperature	Between Station	0.11503	4	0.028757	1.740543
	Between Season	6.19369	2	3.096847	187.4415
	Residual	0.13217	8	0.016522	
D.O	Between Station	0.06543	4	0.016357	0.153114
	Between Season	0.65392	2	0.326960	3.060659
	Residual	0.85461	8	0.106827	
P.H.C.	Between Station	0.06286	4	0.015715	1.360178
	Between Season	2.32552	2	1.162757	100.6427
	Residual	0.09243	8	0.011553	
T.S.P	Between Station	2.36247	4	0.590617	11.49582
	Between Season	5.64964	2	2.860727	55.68144
	Residual	0.41101	8	0.051377	

Table 16b Kadmat Atoll.

Parameter	Source Of Variation	Sum Of Squires	Degrees Of Freedom	Mean Sum Of squires	Ratio of F
Salinity	Between Station	0.05658	4	0.01414	0.448947
	Between Season	5.64964	2	2.82482	89.66734
	Residual	0.25203	8	0.03150	
pH	Between Station	0.00151	4	0.00037	1.170984
	Between Season	0.11889	2	0.05945	184.8083
	Residual	0.00257	8	0.00032	
Temperature	Between Station	0.26527	4	0.06632	1.54849
	Between Season	2.93052	2	1.46526	34.21373
	Residual	0.34261	8	0.04283	
D.O	Between Station	0.09140	4	0.02285	2.788286
	Between Season	0.10864	2	0.05432	6.628432
	Residual	0.06556	8	0.00819	
P.H.C.	Between Station	0.08553	4	0.02138	0.982944
	Between Season	1.61934	2	0.80967	37.22014
	Residual	0.17403	8	0.02175	
T.S.P	Between Station	1.12073	4	0.28018	1.907978
	Between Season	32.1120	2	16.0560	109.3373
	Residual	1.17479	8	0.14684	

Table 16c Kalpeni Atoll

Parameter	Source Of Variation	Sum Of Squires	Degrees Of Freedom	Mean Sum Of squires	Ratio of F
Salinity	Between Station	0.00487	4	0.00122	0.087362
	Between Season	7.15292	2	3.57646	256.8066
	Residual	0.11141	8	0.01393	
pH	Between Station	0.00503	4	0.00126	0.588144
	Between Season	0.32517	2	0.16259	76.0936
	Residual	0.01709	8	0.00214	
Temperature	Between Station	0.00509	4	0.00127	0.533147
	Between Season	2.50576	2	1.25288	524.5834
	Residual	0.01911	2	0.00239	
D.O	Between Station	0.05711	4	0.01427	0.506954
	Between Season	2.28937	2	1.14469	40.64698
	Residual	0.22529	8	0.02816	
T.S.P	Between Station	0.95723	4	0.23931	5.74559
	Between Season	10.5223	2	5.26113	125.6338
	Residual	0.33501	8	0.04188	

Table 16d Agathi Atoll

Parameter	Source Of Variation	Sum Of Squires	Degrees Of Freedom	Mean Sum Of squires	Ratio of F
Salinity	Between Station	0.01056	4	0.00264	0.385683
	Between Season	6.38497	2	3.19249	466.3969
	Residual	0.05476	8	0.00684	
pH	Between Station	0.01253	4	0.00313	1.127774
	Between Season	0.50817	2	0.25409	91.45291
	Residual	0.02222	8	0.00278	
Temperature	Between Station	0.01736	4	0.00434	0.403909
	Between Season	4.36657	2	2.18329	203.1909
	Residual	0.08596	8	0.01075	
D.O	Between Station	0.04331	4	0.01083	0.561501
	Between Season	0.43682	2	0.21841	11.32717
	Residual	0.15425	8	0.01928	
T.S.P.	Between Station	0.71047	4	0.17762	3.481201
	Between Season	7.28409	2	3.64204	71.38235
	Residual	0.40817	8	0.05102	

The table value (4 and 8 df) at 5% =3.84
The table value (4 and 8 df) at 1% = 4.46

The table value (2 and 8 df) at 5% = 7.01
The table value (2 and 8 df) at 1% = 8.65

Table 17a

Result of significant means and LSD* of hydrographical parameters

Kavarathi

Parameters	Seasons	Mean	LSD
Temperature	Pre-mon Mon Post-mon	30.15 28.57 29.36	0.19
Salinity	Pre-mon Mon Post-mon	35.00 33.78 34.57	0.17
pH	Pre-mon Mon Post-mon	8.24 7.98 8.14	0.22
D.O	Pre-mon Mon Post-mon	4.87 5.39 5.04	0.48
T.S.P	Pre-mon Mon Post-mon	4.49 4.61 3.24	0.33

* Least Significant Difference

Table 17b

Result of significant means and LSD* of hydrographical parameters

Kadmat

Parameters	Seasons	Mean	LSD
Temperature	Pre-mon Mon Post-mon	29.84 28.75 29.03	0.30
Salinity	Pre-mon Mon Post-mon	34.88 33.42 34.45	0.26
pH	Pre-mon Mon Post-mon	8.20 8.00 8.10	0.0
D.O	Pre-mon Mon Post-mon	5.12 5.13 5.31	0.13
T.S.P	Pre-mon Mon Post-mon	2.68 5.99 3.15	0.56

* Least Significant Difference

Table 17c

Result of significant means and LSD* of hydrographical parameters

Kalpeni

Parameters	Seasons	Mean	LSD
Temperature	Pre-mon Mon Post-mon	29.80 28.84 29.08	0.07
Salinity	Pre-mon Mon Post-mon	35.12 33.43 34.40	0.18
pH	Pre-mon Mon Post-mon	8.23 7.88 8.14	0.07
D.O	Pre-mon Mon Post-mon	4.77 5.73 5.18	0.24
T.S.P	Pre-mon Mon Post-mon	2.06 4.04 2.42	0.30

* Least Significant Difference

Table 17d

Result of significant means and LSD* of hydrographical parameters

Agathi

Parameters	Seasons	Mean	LSD
Temperature	Pre-mon Mon Post-mon	29.80 28.61 29.70	0.15
Salinity	Pre-mon Mon Post-mon	35.21 33.61 34.43	0.08
pH	Pre-mon Mon Post-mon	8.21 7.77 8.06	0.12
D.O	Pre-mon Mon Post-mon	5.42 5.21 5.01	0.20
T.S.P.	Pre-mon Mon Post-mon	1.94 3.64 2.74	0.33

* Least Significant Difference

PHC as 816.24 ppb from esturine waters (Cochin). In the present investigation the maximum value obtained was only 1 ppb.

CHAPTER 4

BRYOZOAN FAUNA ASSOCIATED WITH INDIAN CORAL REEFS

4.1 Introduction

Bryozoans (sea mats, lace corals, moss animals) also known as polyzoans or ectoprocts, comprise a phylum of mostly marine invertebrates and a limited number of freshwater inhabitants. While neither the technical nor even the common names are familiar to most people, bryozoans themselves will almost certainly have been encountered by any one fossicking under boulders on a sea shore or by owners of pleasure craft or fishing boats who clean their hulls regularly.

Bryozoans are colonial animals which form coloured encrustation or tufts which superficially resemble other forms of sedentary marine life. The encrusting species form thin, flat, circular or irregular patches (hence, sea mats) that are mostly hard to touch. If the patches should produce erect folds they can give the impression of small corals (and if perforated, `lace corals'). The tufted or bushy species can resemble hydroids or small sea weeds (hence, moss animals, which is what the Greek-derived technical name Bryozoa means).

All bryozoans have in common little box-like units called zooids, each of which comprises a body wall (the box or tube) and a polypide - made up of a simple U-shaped digestive tract and an apparatus of tentacles - a lophophore, that typically has a funnel shape when expanded into the water to feed. The tentacles are densely covered on their inner faces with cilia, which beat in such a way as to generate a current of water towards the mouth at the bottom of the funnel. Food consists of small plankton or non-living organic particles.

Bryozoa colonies begin life when the larva that develops from a fertilized egg attaches to a substratum (rock, piling, seaweed, boat hull etc.) and then metamorphoses into the first zooid of a colony, the ancestrula. The ancestrula buds off one or more daughter zooids, and so the colony grows, either upwards in the case of bushy or tufted colonies, or radially outwards in the case of circular encrusting colonies.

In species diversity the phylum Bryozoa is medium size, with over 4000 extent species and around 15,000 preserved as fossils (Ryland, 1970). The phylum's greatest abundance and diversity is found in shallow coastal waters of the western Indo-Pacific (East and S-E Asia to the Indian ocean) with significant numbers of species having been recorded also from Mexico, western Europe, S-E Australia and polar regions .

The classification of Bryozoans, as in most other group, is in a continuing state of taxa occur throughout the hierarchy even to phylum level. (Ryland 1970, Cuffy 1973), but there seems to be a general consensus among members of the International Bryozoology Association that there are 3 classes - Stenolaemata, Gymnolaemata and Phylactolaemata and for the Gymnolaemata, two orders (both extant, with fossil record)- Ctenostomata and Cheilostomata.

4.2 Literature Review

Information on bryozoans cohabiting with corals along the extensive coral islands of Lakshadweep and Andaman are not properly understood. It is known that bryozoans abounding coral reefs is very diverse and probably comprises several unknown species.

The present investigation has looked into the taxonomy of a few species of bryozoans collected from the coral islands of Indian ocean. Bryozoans of coral islands of other parts of world are known to the work of various scientists who were made collections upon these islands. The Great Barrier Reef (GBR) bryozoans were studied by Busk (1852a), Haswell (1881), and Kirkpatrik (1890a). However, a few papers appeared subsequently during the period 1926 to 1986. A few important works are Silen (1942), Ryland (1974 and 1984), Hall (1984) and Winston(1986). Lack of collection procedure resulted in poor representation of Bryozoans reported by various workers in coral reefs.

Recent work of Ryland and Hayward (1992) has examined the taxonomy of 81 species of Bryozoans from the Heron island of GBR. The Mauritian bryozoans were studied by Hayward. He described 101 cheilostome species from the reefs of Mauritius. This is significant because this study gave an insight into the characterization of coral reef Bryozoan communities. Formerly, the coral reefs are regarded as little significance from a bryozoan distribution stand point. The works of Jackson and Winston (1982) and Winston and Jackson (1984) have shown that the bryozoan fauna of the coral reefs is abundant, diverse and ecologically interested groups of animals. Clearly an enormous amount of basic faunal work remain to be done to understand the significance of coral reef bryozoans in this habitat.

The Indian ocean reef bryozoans were described by Winston and Heimberg in 1986. Areas of collection from Indian ocean include Bali, Lombok and Kamodo islands. These localities were found to contain large number of bryozoans attached to coral rubble, reef flat and along the shelter areas of the Bay.

4.3 Materials and Methods

The collections were made at three localities in Lakshadweep atolls : the western shore, lagoon and western reef. The materials for the taxonomic studies obtained from other parts of coral environment include, Gulf of Mannar, Rameswaram, Tuticorin and Krusadi islands. Corals, shells, oyster beds, stones, polycheate tubes, littoral algae and other under water structures were examined for the collection of bryozoans. Particulars regarding the exact locality and nature of the substratum are given along with the description of the respective species. Measurements (in micron) given following species descriptions include length and width of zooids.

The specimens collected were kept dry after soaking in bleach (sodium hypochlorite) to remove chitinous parts and tissue. The photographs of the specimens collected from the Lakshadweep environment were taken using scanning electron microscope (SEM). Specimens for scanning electron microscopy were cleaned with sodium hypochlorite solution (5%) rinsed in tap water and dried. The dried specimens were sputted with gold for 20 mts. and fixed on the stub using adhesive tape. They were observed and photographed in varying magnifications in JSM 35 c (Jeol, Japan) operated at an accelerating voltage of 12 kv. Drawing of the species were made by using a camera lucida.

4.4 Results

List of species described

ORDER : CHEILOSTOMATA Busk

SUB-ORDER : ANASCA Levinsen

DIVISION : MALACOSTEGA Levinsen

FAMILY : MEMBRANIPORIDAE Busk

GENUS : MEMBRANIPORA de Blaniville

1. *Membranipora arborenscence*

2 *M. membranacea*

3. *M. savartii*

GENUS : CONOPEUM Gray

4. *Conopeum reticulum* (Li)

GENUS : ELECTRA

5. *Electra sp.*

DIVISION : COELOSTEGA Levinsen

FAMILY : THALAMOPORELLIDAE Levinsen

GENUS : THALAMOPORELLA Hicks

6. *Thalamoporella hamata* Harmer

FAMILY : STEGANOPORELLIDAE Smitt

GENUS : LABIOPORELLA Harmer

7. *Labioporella sinuosa* Osburn

GENUS : SMITTIPORA Jullien

8. *Smittipora abyssicola* (Smitt)

DIVISION : CELLULARIA Smitt

FAMILY : FLUSTRIDAE Smitt

GENUS : SPIRALARIA Busk

9. *Spiralaria serrata* (Mac Gillivray)

FAMILY : SCRUPOCELLARIDAE Levisen

GENUS : TRICELLARIA Fleming

10. *Tricellaria peachii* (Busk)

GENUS : SCRUPOCELLARIA van Beneden

11. *Scrupocellaria mansueta* Waters

12. *S. spatulata* (D'Orbiguy)

13. *S. bertholetii* (And.)

14. *S. talonis* (Osburn)

FAMILY : EPISTOMIIDAE Gregory

GENUS : SYNNOTUM Pieper

15. *Synnotum aegyptiacum* (And.)

FAMILY : BICELLARIELLIDAE Levinsen

GENUS : BUGULA Oken

16. *Bugula crosslandi* Hastings.

GENUS : BUGULELLA Verrill

17. *Bugulella clavata* Hincks.

SUB-ORDER : ASCOPHORA Levinsen

FAMILY : ARACHNOPODIIDAE Harmer

GENUS : TREMOGASTERINA Canu

18. *Tremogasterina granulata* Canu and Bassler

19. *T. lanceolata* Canu and Bassler

FAMILY : CELLOPORARIDAE Harmer

GENUS : CELLOPORARIA Lamouroux

20. *Celloporaria pilaefera* Canu and Bassler

21. *C. granulosa* (Haswell)

FAMILY : PETRALIELLIDAE Harmer

GENUS : MUCROPETRALIELLA Stach

22. *Mucropetraliella philippinensis* (Canu and Bassler)

FAMILY : SMITTINIDAE Levinsen

GENUS : PARASMITTINA Osburn

23. *Parasmittina tubula* (Krikpatrick)

24. *P. elongata* (Okada and Mawatari)

25. *P. californica* (Robertson)

GENUS : SMITTINA

26. *Smittina sp.*

FAMILY : RETEPORIDAE Smitt

GENUS : TRIPHYLLOZOON Canu and Bassler

27. *Triphyllozoon turbulatum* (Busk)

GENUS : RHYNCHOZOON Hincks

28. *Rhynchozoon larreyi* (Aud.)

29. *R. globosum* Harmer

SUB-ORDER : CTENOSTOMATA Busk

DIVISION : ARTICULATA Busk

FAMILY : CRISIIDAE Johnston

GENUS : CRISIA Lamouroux

30. *Crisia elongata* Milne Edwards

4.4.1. Description of species

ORDER : CHEILOSTOMATA Busk

SUB-ORDER : ANASCA Levinsen

DIVISION MALACOSTEGA Levinsen, 1902

Frontal membrane retained in its original primitive condition. No conspicous differentiation between the frontal membrane and the operculum.

FAMILY MEMBRANIPORIDAE Busk, 1854

Frontal membrane fills the aperture, an opesia occupying the same area of the frontal membrane or reduced by the development of a cryptocyst. Encrusting in habit. Ovicells are not found in any cheilostome known to possess a cyphonautes larvae, or in which the occurrence of this larva is probable. Hence Harmer thinks that the presence of cyphonautes larva is of great taxonomic importance.

GENUS *MEMBRANIPORA* de Blainville, 1830

1830. *Membranipora* de Blainville, Dict. Sci. Nat.,60, p.411.

1950. *Membranipora* Osburn, Rep. Allan Hancock Pacific Exped., 14, 1, P.19.

Twinned ancestrulae, mural spines wanting, gymnocyst usually wanting, cryptocyst wanting to wall developed, proximadentate tooth and the lateral cryptocystal spinules may be present or absent.

Membranipora arborenscence (Canu and Bassler), 1928

(Photo micrograph 1a and 1b)

1968a. *Membranipora arborenscence* Cook, p. 138

Occurrence

Colonies were collected from polycheate tube, from lagoon of Kalpeni atoll, Lakshadweep.

Measurements

Zooecium

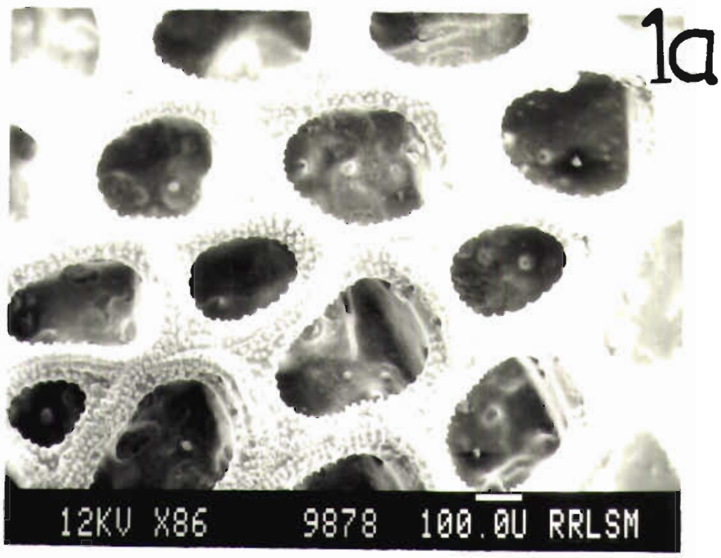
Length - 361.1μ

Breadth -277.7μ

Salient features

Colonies white, encrusting, multilaminar to erect , foliaceous or bilaminar branching. Zooids regularly shaped, subrectangular (distal and proximal walls straight, lateral walls curving), in encrusting colonies. Opesia oval, cryptocyst granular, narrow, slightly wider proximally than laterally with denticles projecting into the opesia giving it a serrated edge. Paired gymnocystal tubercles (occasionally very large and heavy) may occur. Zooids outlined by a dark brown line. Frontal membrane armed with delicate chitinous spicules, oriented into the frontal membrane from its edge and scattered over its surface. Their development variable, some colonies or areas of a colony lacking them entirely, in other colonies or areas of colonies, strongly developed.

This is the first record from Lakshadweep.



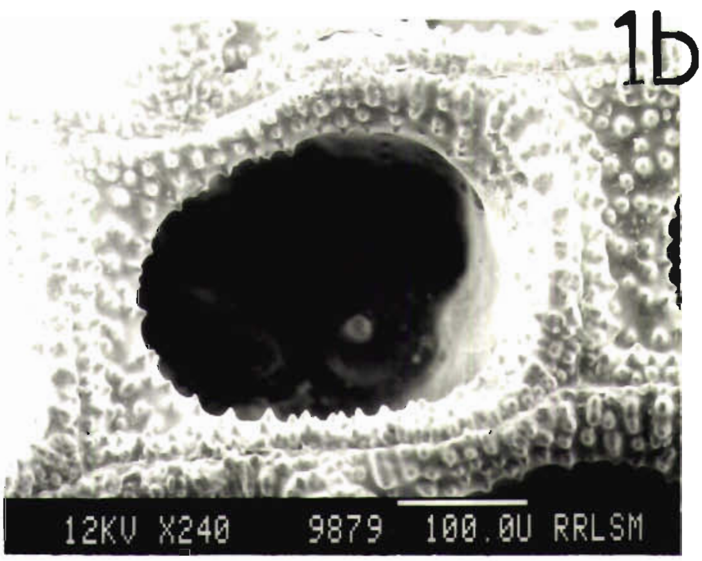


Photo micrograph 1a - *Membranipora arborenscence.* The encrusting portion of a colony.

Photo micrograph 1b - *Membranipora arborenscence.* Enlarged view of a zooecium.

Distribution

Western Atlantic: Cape Hatteras to Brazil. Gulf of Mexico. Also known from West Africa from the pacific coast of America, Mexico to Equador.

Membranipora membranacea (Linnaeus), 1766.

(Fig. 11a-11c)

1950. *Membranipora membranacea* Osburn, *Rep. Allan Hancock Pacific Exped.*, 14, 1, p.21.

1975. *Membranipora membranacea* Menon N R and Nair N B, *J. mar. biol. Ass. India*, 17,3, p.554.

Occurrence

Five small colonies, encrusting on algal fronds were collected at Mandapam from the Gulf of Mannar.

Measurements

Zooecium

Length - 320 - 450 μ

Breadth - 190 - 220 μ

Salient features

Zoarium encrusting. Very simple zooecia elongated. Opesia occupy the whole front. Gymnocyst and cryptocyst vestigial. Operculum membraniporine (Fig.11). Twinned ancestrula present (Fig.11) Spines, avicularia and ovicells absent.

Distribution

Recorded from various parts of the world. The present record extend its distribution to the Indian waters. This has been recorded from the coasts of Europe, along the coast of North America, South of the Caribbean Sea and in the Pacific coast.

Membranipora savartii (Aud.), 1826.

(Fig. 12)

1950. *Membranipora savartii* Osburn, *Rep. Allan Hancock Pacific Exped.*, 14, l, pp.27-28, Pl.2, fig.7.

1975. *Membranipora membranacea* Menon N R and Nair N B, *J. Mar. Biol. Ass. India,* 17,3, p.555.

Occurrence

Four colonies encrusting on gorgonians were collected from the Cape Comorin.

Measurements

Zoecium

Length - 480 μ

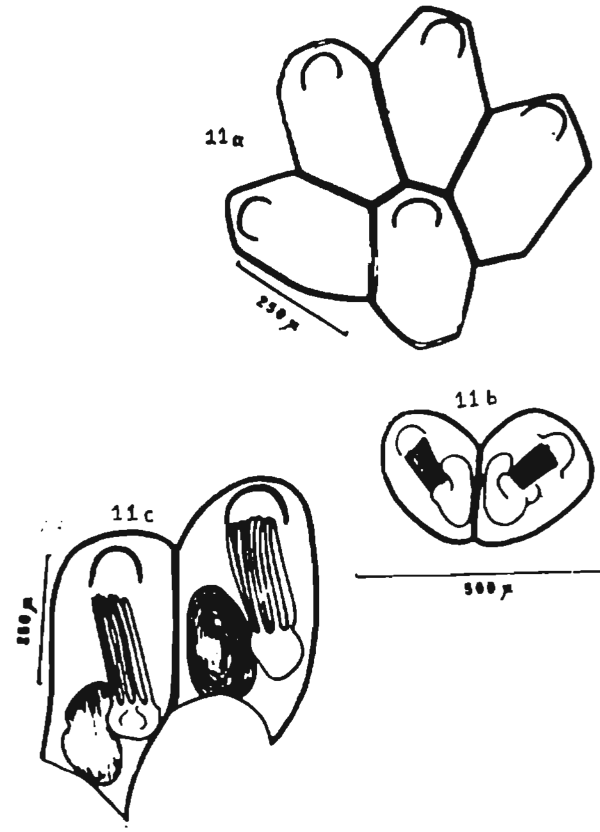
Breadth - 300 μ

Salient features

Encrusting vincularian, zooecia arranged in very regular longitudinal rows. The zooecium from which bifurcation takes place comparatively bigger, than the rest. Zooecia short and wide with slightly curved, and raised distal portion. Gymnocyst absent. Cryptocyst thick and well calcified, with small denticles projecting from the lateral edges. A large and conspicuous proximal denticle projects into the opesium, bearing small conical spines at its edges. Opesia deep and oval divided into two lateral compartments proximally by the large proximal denticle (Fig.12).

Distribution

It is a common species around the world in warmer shallow waters. (Osburn, 1950)



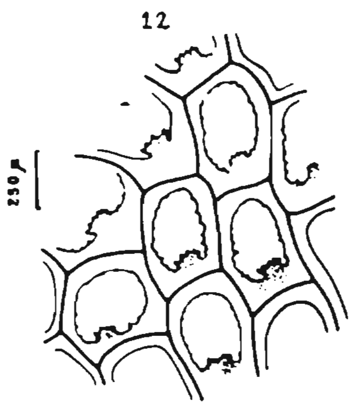


Figure 11a to 11c - *Membranipora membranacea*. 11a. Portion of a colony showing the details of zooecia. 11b. Ancestrula. 11c. Two marginal zooecia.

Figure 12 - *M. savartii*. Portion of a colony showing the details of zooecia.

GENUS : CONOPEUM Gray, 1848

1950. Conopeum Gray, List of the specimens of British Animals in the British Museum, pp.108-146.

Encrusting, with a gymnocyst possessing two triangular depression. Sometimes a gymnocyst is lacking. Tuberculated cryptocyst extends from the entire margin. No avicularia, ovicells or pore-chambers.

Conopeum reticulam (L), 1767

(Photo micrograph 2a and 2b)

1975. Conopeum Menon N.R. , *J. Mar. Biol. Ass. India* 17, 3, pp. 565 Fig. 2 1

Occurrence

This species was seen epizoic on the surface of tarsheet caught from lagoon of Amini island, Lakshadweep.

Measurements

Zoecium

Length - 450 μ

Breadth - 333.33 μ

Salient features

Encrusting, colonies appear as whitish patches with uneven growing margin. Zooecia quincuncial, chitinous outline distinct. Shape of zooecia variable, but generally longer than wide, very much elongated in certain cases. Tuberculated cryptocyst developed all round with tubercles projecting into the opesia. The tubercles more or less of the same length. In addition, small tubercles present in the proximal region of the cryptocyst. Opesia elongate oval. In certain cases the proximal region of the opesia broader than the distal region. Membraniporine operculum occupies three-fourth of the

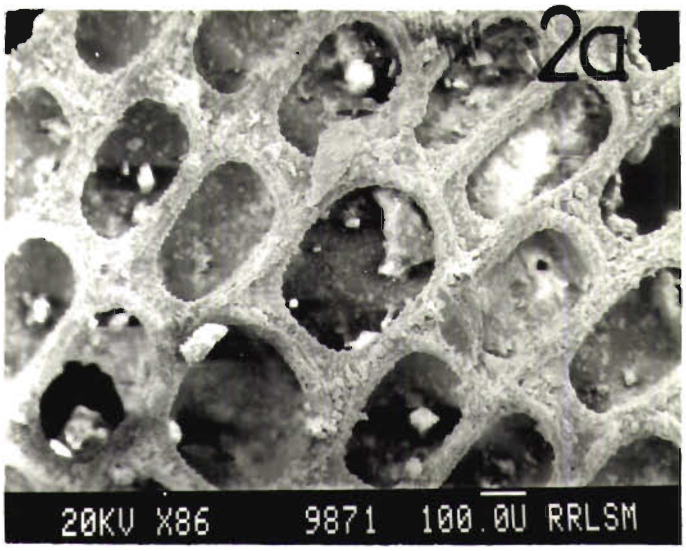


Photo micrograph 2a - *Conopeum reticulum*. The encrusting portion of a colony.

Photo micrograph 2b - *Conopeum reticulum*. Enlarged view of a zooecium distal region. A pair of rounded prominences zooecia. Proximal triangular depression not evident.

This is the first record from Lakshadweep.

Distribution

Tortuges Is., Floridal; California; Bay of Bengal, Chilka lake, Arabian sea

GENUS ELECTRA Lamouroux, 1816

1816. *Electra* Lamouroux, "Histoire des Polypier Coralligenes Flexibles", p.120.

1950. *Electra* Osburn, *Rep. Allan Hancock Pacific Exped.*, 14, I, P. 35.

Colonies encrusting, zooecia pear shaped or rectangular. Proximal gymnocyst may be evanescent distally. Frontal membrane covers an opasium of the same extent. Opesia over arched by marginal spines, sometimes only one spine on the proximal side of the opesia. Cryptocyst wanting or barely indicated. No avicularia, ovicells, or pore chambers.

Electra sp.

(Fig. 13)

Occurrence

A single colony encrusting on an algal frond was collected from Mandapam.

Measurements

Zooecium

Length - 490 μ

Breadth - 250 μ

Salient features

Encrusting. Zooecia pear-shaped. Opesia oval. Spines present, spine number varies from 3 to 7, elongated, arranged along the proximal and proximo-lateral portions of the extensive gymnocyst, over arching the opesia. Operculum membraniporine (Fig 13). Avicularia and ovicells absent.

DIVISION: COELOSTEGA Levinsen, 1909

Raised zooecial margins surround as aperture which is larger than the opesia, owing to the development of a cryptocyst. Cryptocyst frequently with a descending portion which unites near its distal ends with the vertical or basal walls. The horizontal cryptocyst distally possesses in many zooecia a median process which forms the inner margin of the two lateral opesiules, through which the depressor muscles pass to their insertion in the frontal membrane. Marginal and oral spines wanting.

FAMILY THALAMOPORALLIDAE Levinsen, 1909

Unique among Cheilostomata in possessing numerous free, calcareous spicules in the body cavity. Median process highly developed and the closed opesiules are asymmetrical. The opesia, situated near the distal and is much reduced. Large, rounded or acutevicarious avicularia present. Ovicells are bivalvular when present.

GENUS THALAMOPORELLA Hincks, 1887

1887. *Thalomoporella* Hincks, *Ann. Mag. Pat. Hist.*, 5, 19, p.164.

1950. *Thalamoporalla* Osburn, *Rep. Allan Hancock Pacific Exped.*, 14, 1, p.110.

Zooecia with a depressed porous cryptocyst, perforated by two asymmetrical opesiules which are rounded and not slit-like. Opesia and orifice practically co-extensive. Opesiules meeting either the basal or the lateral walls, their median walls assisting in the formation of the characteristic polypide tube, which terminates beneath the orifice. Internal spicules present in the form of compasses or calipers or both. Avicularia vicarious, rounded or pointed type. Ovicells which are not known in all the species very globose and prominent, the cavity between the ectooecium and entooeium divided by a median suture.

Thalamoporella hamata Harmer, 1926

(Fig 14a-14d)

1926. *Thalamoporella hamata* Harmer, *Siboga Exped.*, 28b, pp.301-302, Pl. 20, figs. 17-20.

Occurrence

Four colonies encrusting on stones were collected from the intertidal zone at the Krusadi Island.

Measurements

Zooecium

Length - 520 μ

Breadth - 300 μ

Salient features

Encrusting. Distinct adoral areas with tubercles. The operculum fills almost completely the opesia which is with a straight proximal margin. Frontally, more or less symmetrical opesiules, placed at a distance from the opesia, often reach the basal wall. The insertion, however, shows variations (Fig.14a). Distal wall of the orifice vertical. Operculum with a complete basal sclerite, and the main sclerite marginal (Fig.14b). Avicularian mandible long, acuminate and hooked (Fig..14c). No ovicells found. Compasses and calipers with varying length present (Fig. 14d).

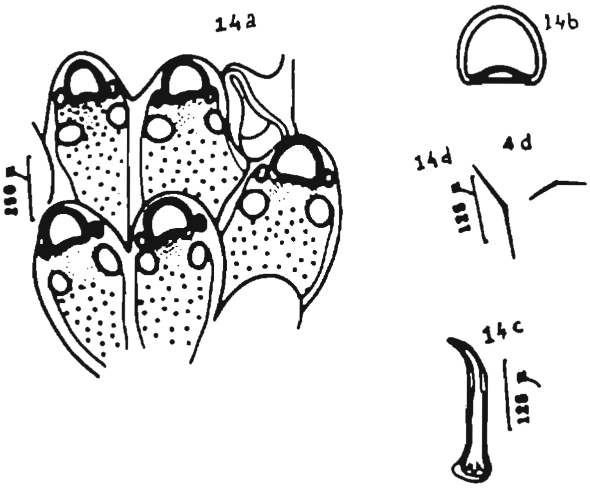


Figure 13 - *Electra sp*. Portion of a colony showing the details of zooecia.

Figure 14a to 14d - *Thalamoporella hamata*. 14a. Portion of a colony. 14b. Operculum. 14c. Mandible. 14d. Internal spicules.

Distribution

North Ubian, Sulu Archipelago, West of north end of New Guinea (Harmer, 1926).

FAMILY STEGANOPORELLIDAE Smitt, 1873

1926. *Labioporella* Harmer, *Siboga Exped* ., 28 b, p.281.

1950. *Labioporella* Osburn, *Rep. Allan Hancock Pacific Expd.*, 14, 1,p.108.

Distinct zooecia arranged in longitudinal rows. Gymnocyst absent. The descending lamina of the cryptocyst meet the basal walls. A complete or incomplete polypide tube present. Porous, horizontal cryptocyst occupies the greater part of the frontal surface. The walls of the lateral recesses join the lateral walls of the zooecium. Large vicerious avicularia present, (absent in *L. sinuosa* Osburn). Ovicells absent. Rosette plates multiporous.

Labioporalla sinuosa Osburn, 1940

(Figs. 15a and 15b)

1940. Labioporella sinuosa Osburn, *New York Acad. Sci.*, 16, 3, p.377.

1950. Labioporella sinuosa Osburn, *Rep. Allan Hancock Pacific Exped.*, 14, 1, pp. 109-110.

Occurrence

Five colonies encrusting on sponges were collected from the pearl oyster bed at Tuticorin, south-east coast of India.

Measurements

Zooecium

Length - 380-450 μ

Breadth - 310 μ

Salient features

Encrusting zoarium brownish in hue. Zooecia distinct, separated by conspicous lines. Mural rim beaded. Gymnocyst wanting. Granulated and porous cryptocyst stops at the origin of the descending lamina. The polypide tube with crenulated and elevated tip, longitudinally rugose distally and disto-laterally. The narrow shelf connecting the tube with the lateral walls, non-porous but finely tuberculated (Fig.15 a). Vertical and straight decsending lamina of the cryptocyst divides the polypide chamber into two unequal compartments. Operculum longer than wide, with a distinct brownish marginal sclerite (Fig.15 c). A large tubercle present beneath the operculum arising from the proximal portion of the distal wall (Fig.15 a). No avicularia noticed. Ovicells absent.

Distribution

Tortugas Is. (Osburn, 1940); Gulf of California, Clarion Id. and Gulf of Panama (Osburn, 1950).

GENUS SMITTIPORA Jullien, 1882

1882. *Smittipora* Jullien, *Bull. Soc. Zool. de France*, 6, p.284.

1926. *Smittipora* Harmer, *Siboga Exped.*, 28 b, pp. 258-259.

More or less hexagonal zooecia with extensive and depressed cryptocyst. Reduced opesia, a little more than the orifice. Sides of the opesia straight or curved, may be trifoliate with open opesiules, which may sometimes be indistinct. Vicarious avicularia symmetrical without a distinct rostrum. Mandible symmetrical with large membraneous expansion on each side of the rachis.

Smittipora abyssicola (Smitt), 1873

(Figs 16a - 16d)

1873. *Vincularia abyssicola* Smitt, *Kough. Svenska Ventenstaps Akadamiens Handlingar*, 11, p.6,

1926. *Smittipora abyssicola,* Harmer, *Siboga Exped.*, 28b, pp.259-260, Pl.16, figs. 10-13.

Occurrence

Two colonies encrusting on a sponge were collected from Gulf of Manaar.

Measurements

Zooecium

Length - 320 μ

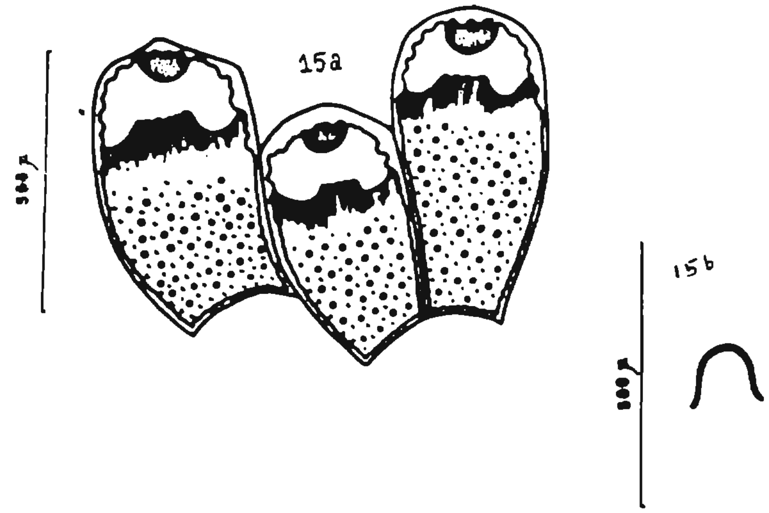
Breadth - 190 μ

Salient features

Zoarium encrusting, distinctly brownish in hue. Zooecia more or less hexagonal with conspicuous mural rims (Fig 16a). Cryptocyst strongly tuberculated, extends well upto the distal end of the front. Opesia trifoliate with more or less distinct opesiules (Fig. 16b). Large and symmetrical avicularia (Fig. 16a). Distinct rostrum wanting. Cordiform mandible with lateral membraneous expansion extending nearly three fourth of the mandibular rachis (Fig. 16c). Rostrum with extensive cryptocyst, denticulate posteriorly (Fig 16b). Ovicells not noticed.

Distribution

Various Siboga stations in the Indo-Australian archipelago (Harmer, 1926); Ceylon (Thornely, 1905).



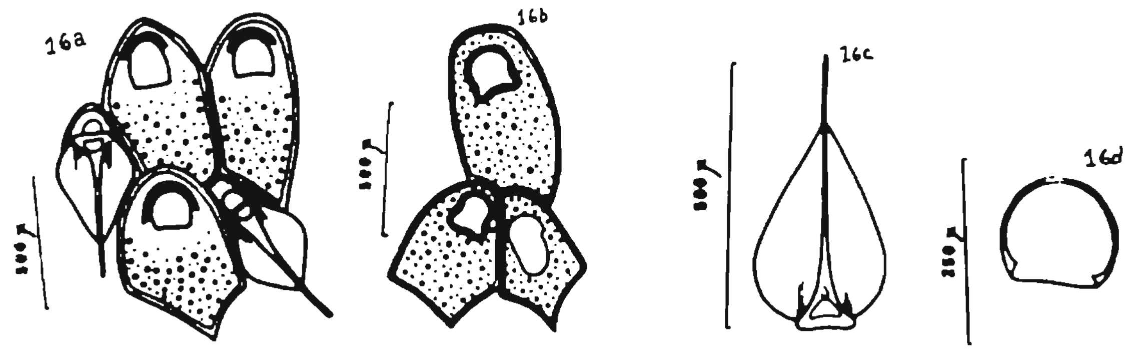


Figure 15a to 15b - *Labioporella sinuosa*. 15a. Portion of a colony. 15b. Operculum

Figure 16a to 16d - *Smittipora abyssicola*. 16a. Portion of a colony. 16b. Two zooecia with the trifoliate opesiules and the avicularian rostrum. 16c. Mandible. 16d. Operculum

DIVISION CELLULARIA Smith, 1867

"The zoarium is erect, flexible or jointed and attached by radicles (loosely encrusting in a few cases); zooecia not heavily calcified, as a rule, and all facing in the same direction (except in Farciminariidae where they form rounded stems); avicularia sessile or pedunculate (both in the Epistomidae); sometimes modified into vibracula; spines occur in most of the species, sometimes modified into frontal scutes above the opesia. Ovicells usually hyperstomial". Osburn (1950).

FAMILY FLUSTRIDAE Smitt, 1867

Erect, free frondose and flexible zoarium (rarely encrusting). Opesia occupy the entire or nearly all of the front. Avicularia inter-zooecial. Ovicell when present endo-zooecial, embedded at the base of the succeeding zooecium or in the avicularian chamber.

GENUS SPIRALARIA Busk, 1861

1861. *Spiralaria* Busk, *Quart. J. micr. Sci.*, 1, p.153.

1942. *Spiralaria* Silen, *Ark. Zool.*, 33A, 12, pp. 56-57.

Lateral walls as a rule provided with a row of spine-like processes, or denticles at a distance within the frontal membrane. The mural rim furnished with spines. Generally beak-shaped avinularia with pointed mandibles. Ovicells often immersed in the avicularia. Uniporous rosette plates on the side walls.

Spiralaria serrata (Mac Gillivray), 1869

(Figs 17a - 17d)

1869. *Membranipora serrata* MacGillivray, *Trans. Proc. Roy. Soc. Vict.*, 9, p. 131.

1952. *Spiralaria serrata* Mawatari, *Publ. Seto Mar. Biol. Lab.*, 2, 2, pp.272-273, fig.7.

Occurrence

Three large colonies encrusting on sponges were collected from Minicoy Is. and Krusadi Is.

Measurements

Zooecium

Length - 500 μ

Breadth - 240 μ

Salient features

Encrusting, unilaminar raised to form frills at certain portions of the colonies. Elongated rectangular, distinct, moderately calcified zooecia arranged in longitudinal rows quincuncially. The definite and clearly serrated mural rims devoid of spines. Two tubercles present, placed at the distal lateral corners of the zooecia. Operculum membraniporine (Fig 17a). Avicularia inter-zooecial with a moderately sized rectangular frontal region. The elongated, disto-laterally directed rostrum extends to the lateral sides of the zooecia (Figs 17a & 17b), mandible elongated, reducing in width distally, with a curved tip (Fig. 17b). Ovicells entozooecial, sub-globular, non-porous and smooth.

Distribution

Japan , Australia (MacGillivray, 1869).

FAMILY SCRUPOCELLARIIDAE Levinsen, 1909

Zoaria erect and unilaminar attached to the substratum by means of root-lets. Zooecia in most species being arranged biserially. Spines usually occur at the distal end of the zooecia, scutum which is a modified spine, present. Dorsal vibracula or avicularia present but may be wanting in Tricellaria.

GENUS TRICELLARIA Fleming, 1828

1828. *Tricellaria* Fleming, " A History of British Animals" p.540

1950. *Tricellaria* Osburn, *Rep. Allan Hancock Pacific Exped.*., 14, 2, p.121.

Jointed zoarium with biserial branches. Elongated zooecia. Branching of types 9 to 12 (Harmer , 1923). Cryptocyst moderately developed proximally. Scutum marginal and frontal avicularia present or wanting .

Tricellaria peachii (Busk), 1851

(Figs 18a - 18c)

1851. Cellularia peachii Busk, *Ann. Mag. Nat. Hist.*, 2, p.82, Pl. 8, figs. 1-4

1923. Tricellaria peachii Harmer, *J. Linn. Soc. (Zool.)*., 35, p.355.

Occurrence

Fragments of a colony epiphytic on Triphyllozoon tubulatum , collected off Mandapam

Measurements

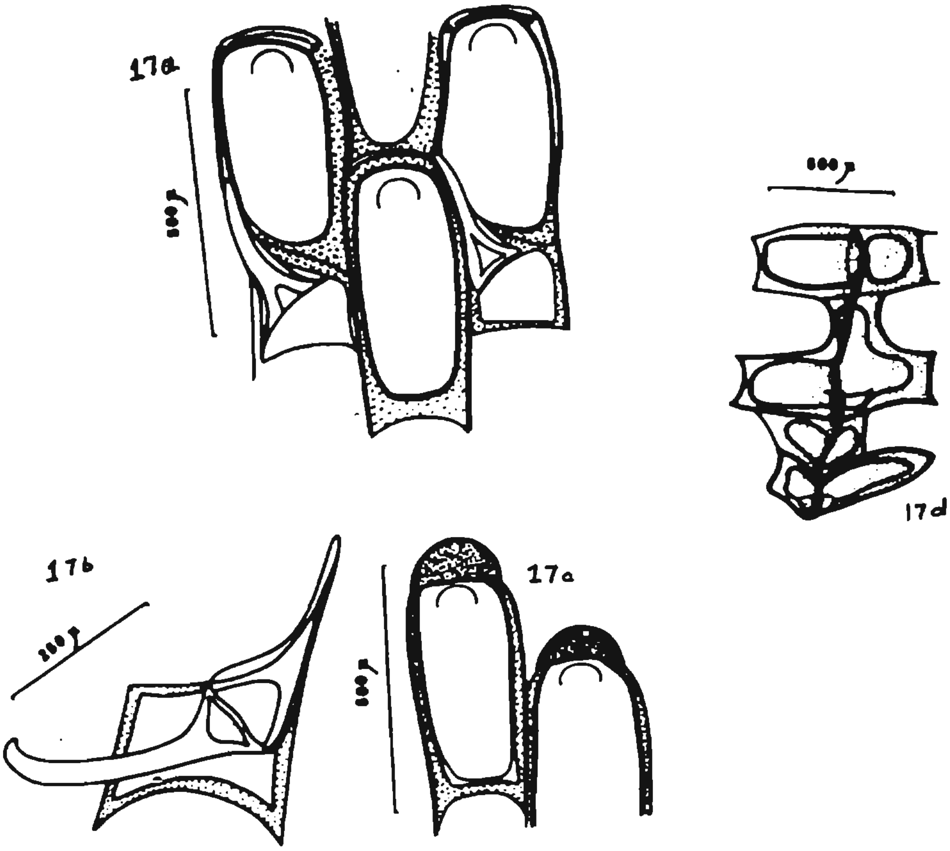
Zooecium

Length :350-500 μ

Breadth :110-130 μ

Salient features

Zoarium whitish in hue. Internodes long with 4 to 6 zooecia. Long zooecium with narrow more or less cylindrical proximal regions. Opesia occupy less than half of the front. The external lateral side of the zooecium produced into a flank. Two external and one internal spines (Figs. 18a & 18b). Scutum, frontal and lateral avicularia wanting.



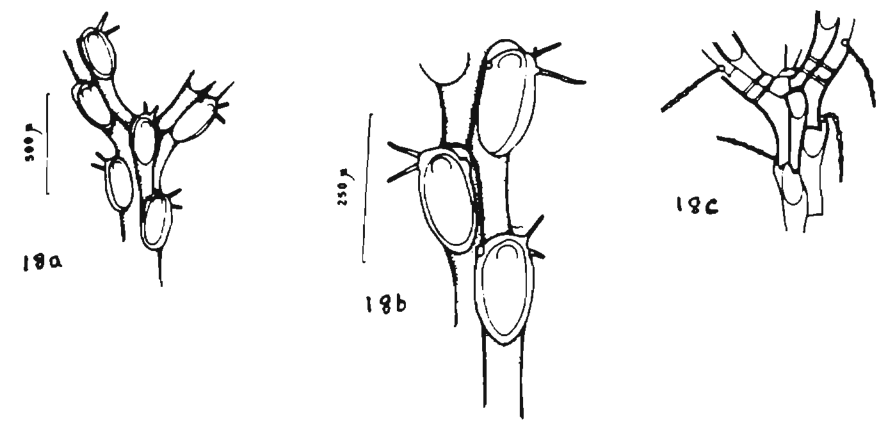


Figure 17a to 17 d - *Spiralaria serrata*. 17a. Portion of a colony. 17b. An avicularium. 17c. Two fertile zooecia. 17d. Distorted zooecia.

Figure 18a to 18c - *Tricellaria peachii*. 18a. Nature of bifurcation. 18b. Portion of a colony. 18c Plan of bifurcation.

Bifurcation of type 11 of Harmer (1923). The joints traverse the opesia of the outer zooecia (Fig. 18c.). Radicles arise from the external aspect of the proximal region of the zooecia.

Distribution

British coast (Busk, 1851)

Scrupocellaria mansueta Waters, 1909

(Figs. 19 a,b,c & d)

1909. *Scrupocellaria mansueta* Waters, J.Linn. Soc. (Zool.)., 31, 5, p.134, Pl. 10, fig.15.

Occurrence

Material collected from Krusadi Islands.

Measurements

Zooecium

Length - 365 μ

Breadth - 195 μ

Salient features

Zoarium bushy, whitish in hue. Zooecia arranged biserially, an internode usually containing eight zooecia. Zooecia oblong , with slightly widened distal end. Opesia occupy three fourth of the front. Frontal avicularia, not represented in all the zooecia, placed on a raised portion on the lateral outer angle of the proximal regions of the zooecia. Mandible directs obliquely distally (Fig. 19a). Lateral avicularia present , rather small and hence do not give the sides a conspicuous serration. Mandibles distinctly bent distally (Fig 19c). Vibracula represented in all zooecia. The furrows of the vibracula slightly arched. Setae long and always longer than the zooecia (Fig.19d). Single axial vibraculum (Fig. 19b). Ovicells large , widely opened and perforated , perforations not placed at the tip of tubercles. Rhizoidal chamber small and point of origin of the rhizoid circular.

Distribution

Suez. (Waters, 1909)

Scrupocellaria spatulata (D'Orbigny), 1851

(Figs. 20a, b, c, d, and e)

1926. *Scrupocellaria spatulata* Harmer, *Siboga Exped.*, 28b, pp.382-384, Pl. 26, figs. 1-10.

1972. *Scrupocellaria spatulata* Menon N R , *Int. Revue ges. Hydrobiol.* 57, 6, 913-931.

Occurrence

Fragments of colonies growing g over a silicious sponge were collected from the Krusadi Is. in the Gulf of Mannar.

Measurements

Zooecium

Length : 320-380μ

Breadth : 115-145μ

Salient features

Zoarium robust, attached to the substratum by radicles. Zooecia long with tubular proximal region, and expanded distal portion (Fig. 20a). Opesia oval, occupy the distal half (Fig.20a). A slight non-serrated erytocyst. Scute small rounded, arise from the median portion of the opesia, cover only the central part of the opesia. Jointed spines typically five, three long external and two comparatively shorter internal ones, (Fig, 20a)

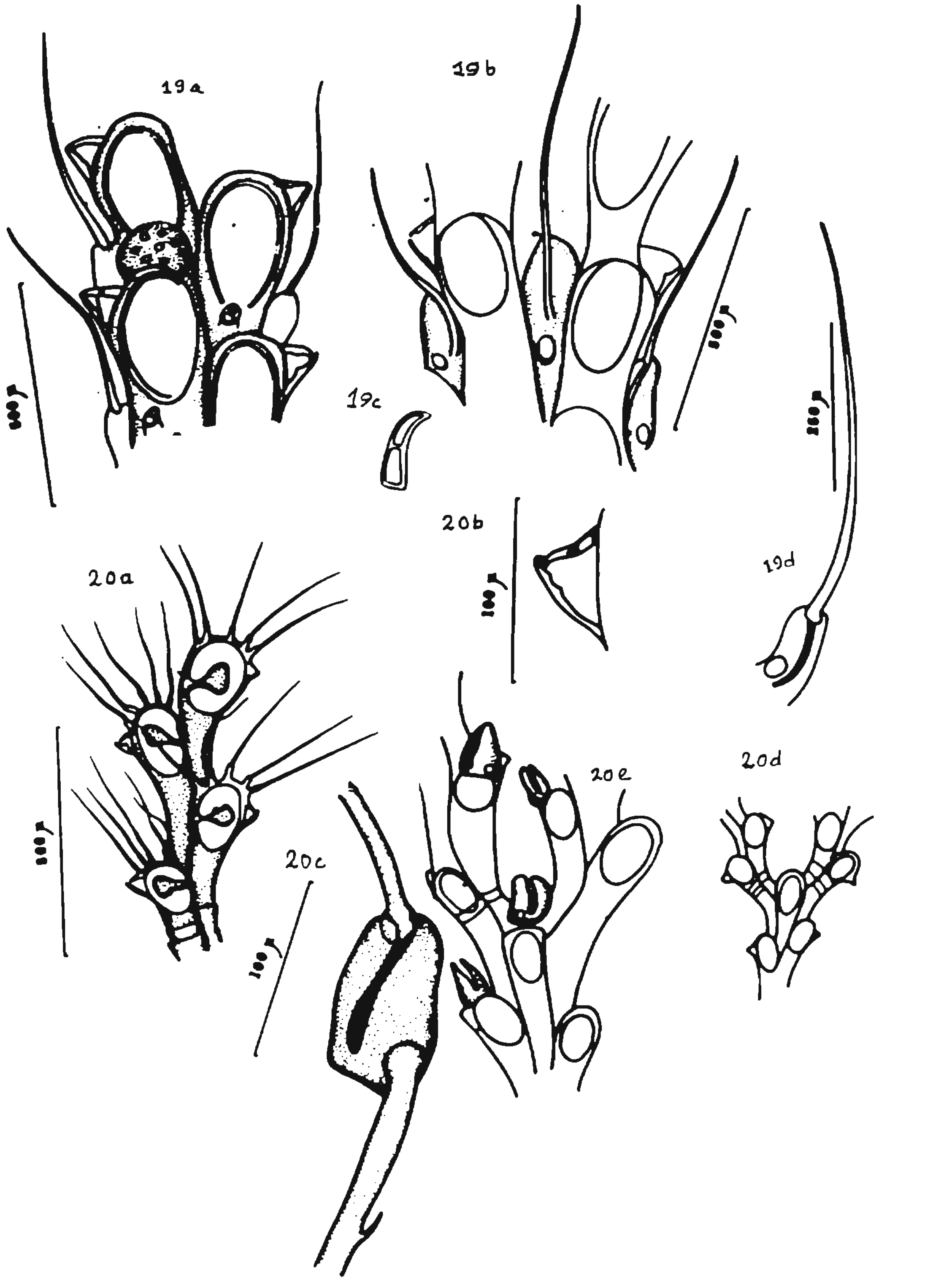


Figure 19a to 19d - *Scrupocellaria mansueta*. 19a. Portion of a colony. 19b. Dorsal view of zooecia at a bifurcation. 19c. Mandible. 19d. Vibraculum

Figure 20a to 20e - *S. spatulata*. 20a. Portion of a colony. 20b. Lateral avicularium. 20c. Vibraculum. 20d -20 e. Bifurcation ventral and dorsal views.

may be even seven when two additional spines occupy the position in between the external and internal sets. No frontal avicularis. Marginal avicularia small (Fig. 20b), placed a little below the distal lateral angle. Vibraculum moderate not seen from the ventral side, vibracular groove extend beyond the vibracular chamber (Fig. 20c). The radicular chamber small, and the place of origin of the radicle rounded. The joints do not traverse the opesia of the outer zooecia. Single axial vibracula (Fig. 20d). Radicles with backwardly directed spinules at the tip (Fig. 20d). No ovicells noticed.

Harmer (1926) has included the records *S. pilosa* from Indian Ocean by Thornely in 1912 and by Robertson from Ceylon in 1921 under *S. Spatulata*. But he is not definite about the assignment.

Distribution

Mediterranean (Audouin, 1826); Indian Ocean (Thornely, 1912); Ceylon (Robertson, 1921).

Scrupocelllaria bertholettii (Aud.), 1826

(Figs. 21a, b & c)

1930. *Scrupocelllaria bertholettii* Hastings . *Proc. zool,. soc. Lond.* , p. 733.

1965. *Scrupocelllaria bertholettii* Ryland, *Catalogue of Main Marine Fouling Organisms, Polyzoa*, pp. 55-57, figs, 27a, b and c.

Occurrence

Fifteen colonies were collected off Tuticorin. The colonies were found attached to shells and stones.

Measurements

Zooecium

Length : 400µ

Breadth: 210µ

Salient features

Branching zoarium erect, whitish. Somewhat elongate zooecia, with opesia occupying more than half of the front. The number of spines varies greatly. Usually three external and two internal (Fig. 21c). Scutum present, may be a simple spine or a forked one (Fig. 21a). Frontal avicularia present small or very large. In the large ones the rostrum hooked (Fig. 21c).

Vibracular chamber not triangular, a proximolaterally placed rhizoidal chamber. Axial vibracula single (Fig. 21b). Joints traverse the opesia of the outer zooecia. Cryptocyst present not tuberculated. Ovicells large with perforations placed at the tip of tubercles.

Distribution

"Widely distributed species" (Osburn, 1950).

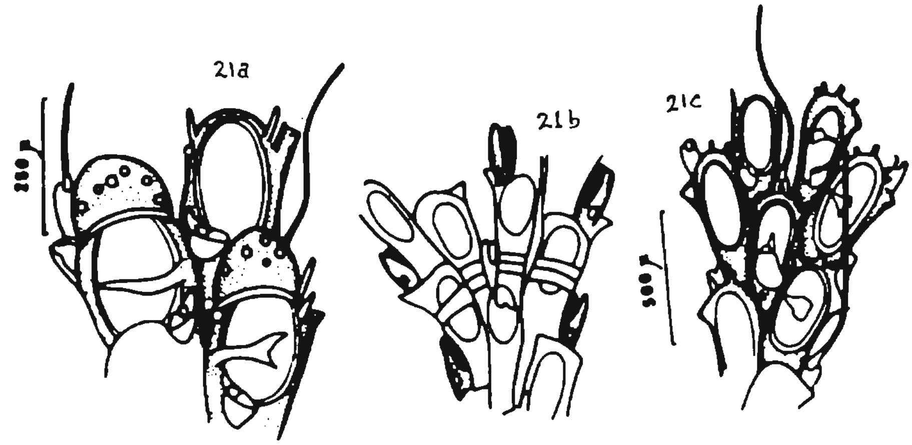
Scrupocellaria talonis Osburn, 1950

(Figs 22 a, b & c)

1950. *Scrupocellaria talonis* Osburn, *Rep. Allan Hancock Pacific Exped.*, 14, 1, pp. 147-148

Occurrence

Fragments of a colony attached to a coral collected from off Mandapam



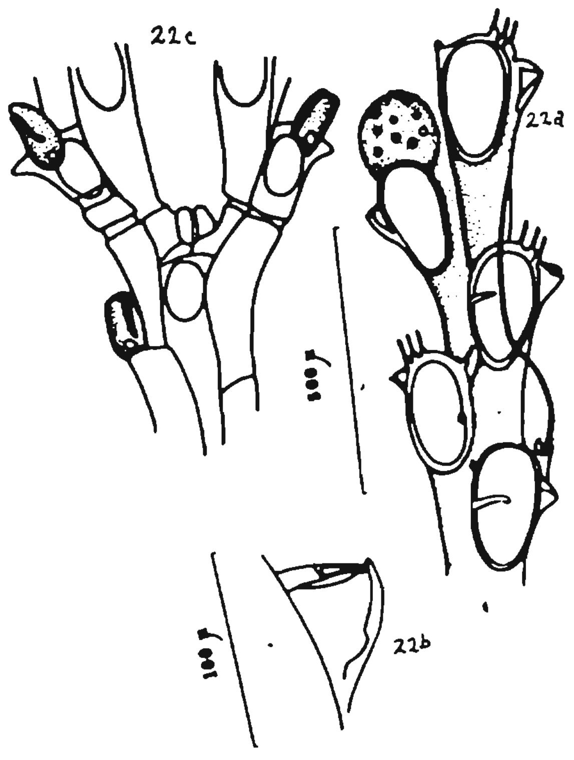


Figure 21a to 21c - *S. bertholetii*. 21a. Portion of a colony. 21b. Plan of bifurcation. 21c. Bifurcation.

Figure 22a to 22c - *S. talonis*. 22a. Portion of a colony. 22b. Lateral avicularium. 22c Plan of bifurcation.

Measurements

Zooecium

Length : 400 μ

Breadth: 190 μ

Salient features

Zooecia long and slender with elliptical opesia. Well developed spines, three external and one internal. Scutum usually absent, may be represented by a small spines. Lateral avicularia present minute with triangular mandibles (Figs. 22 a, c). Large vibracular chamber, visible frontally. Vibracular groove transverse. Long sets nearly twice the length of the zooecium (Fig. 22a). Radicles simple without hooks. Ovicells perforate.

Distribution

Panama (Osburn, 1950)

FAMILY : EPISTOMIDAE Gregory, 1903

GENUS :SYNNOTUM Pieper, 1881

1881. *Mononota* and *Synnota* Pieper, 9 *Jahresb. Westfal. Provinzeal-Ver.Wiss. u. Kunstpro* 1880, p. 43.

1950. *Synnotum* Osburn, *Rep. Allan Hancock Pacific Exped.*, 14, 1, p.150.

Internodes separated by joints. Zooecia arranged back to back in pairs. Each pair connected by tubular prolongations. Sessile lateral avicularia at the distal end, a stalked avicularium occasionally present. Slightly enlarged gonozooecia.

Synnotum aegyptiacum (Aud.), 1826

(Figs. 23a. b, c, d & e)

1826. *Loricaria aegyptiacum* Audouin, Description de l'Egypte, *Hist. Nat.*, 1, 4, p.243.

1950. *Synnotum aegyptiacum* Osburn, *Rep. Allan Hancock Pacific Exped.*, 14, 1 p.151

Occurrence

Several colonies growing on sponge were collected from the sub-tidal levels at Krusadi Is. and Minicoy is.

Measurements

Zooecium

Length : 440 - 500 μ

Breadth: 140 - 150 μ

Salient features

Erect zoarium with prostrate branches at the older parts of the colony, attached by rootlets. Maximum height noticed 20mm. Rootlets absent in most of the internodes. Zooecia paired with obliquely facing front (Figs. 23a &e). A frontal and a basal avicularia present at each internode. Occasionally a pedunculate avicularium takes the place of the frontal one. Enlarged gonozooecium present (Fig. 23d). Spines absent.

Distribution

This species is distributed world widely.

FAMILY : BICELLARIELLIDAE Levinsen, 1909

"The genera included in this family are usually erect, occasionally more or less recumbent or even loosely encrusting, biserial, sometimes uniserial or multiserial. They are usually well chitinized and but little calcified. The zooecia take their origin from the dorsal side of the preceding zooecia in the series, so that the distal ends over-lap more or less the bases of the succeeding zooecia. The opesia are usually large , frequently occupying the whole front, though the gymnocyst may be well developed in many cases. The sides of the zooecia are frequently rolled inward (turbinate). Spines, both terminal and lateral, are usually present and pedunculate avicularia may occasionally be wanting " Osburn, 1950.

GENUS : BUGULA Oken, 1815

1815. Bugula (pars) Oken, Th. 3, Zool. Abth. I, Fleischinsi Thiere., p. 89.

1960. Bugula Ryland, Proc. zool. soc. (Lond.)., 134, 1, p.66.

Unilaminar, erect and branching zoarium. Zooecia alternate, boat-shaped with proximal forking. In frontal view the zooecia usually truncate above and slightly attenuated towards the base. Calcified basal and lateral walls. One or more spines present, a greater number usually occurring at the outer distal angle. Avicularia shaped like a bird's head may be present or absent placed laterally or on the frontal surface. Ovicells hyperstomial the shape of which may range from globular to elliptical.

Bugula crosslandi Hastings, 1939.

(Figs. 24a, b, c, d & e)

1939. *Bugula crosslandi* Hastings, *Novit. Zool.*, 41 pp. 337-338, text figs. 276D, 277A.

1972. *Bugula crosslandi* Menon N R., *Int. Revue ges. Hydrobiol.* 38 B, 5 & 6, p.403-413.

Occurrence

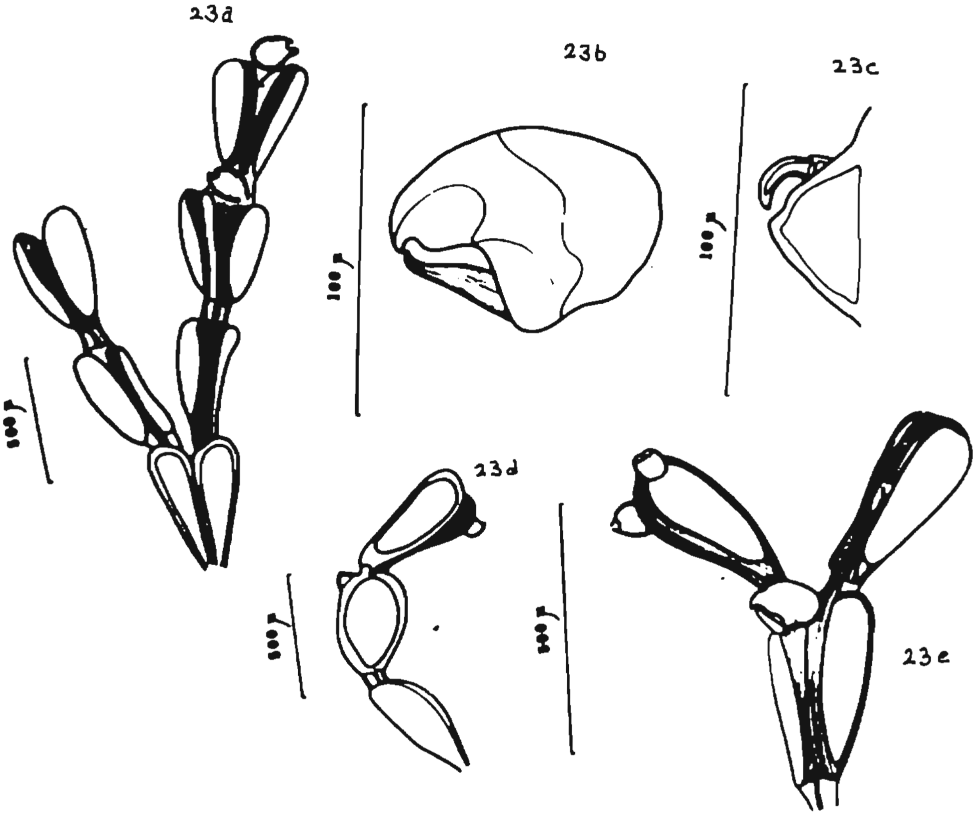
A fragment of zoarium attached to a colony of *Amathia distans* was obtained from the bryozoan collection of the Zoology Department of the Madras Christian College. Locality given is Krusadi Is., Gulf of Mannar.

Measurements

Zooecium

Length : 300 μ

Breadth: 130 μ



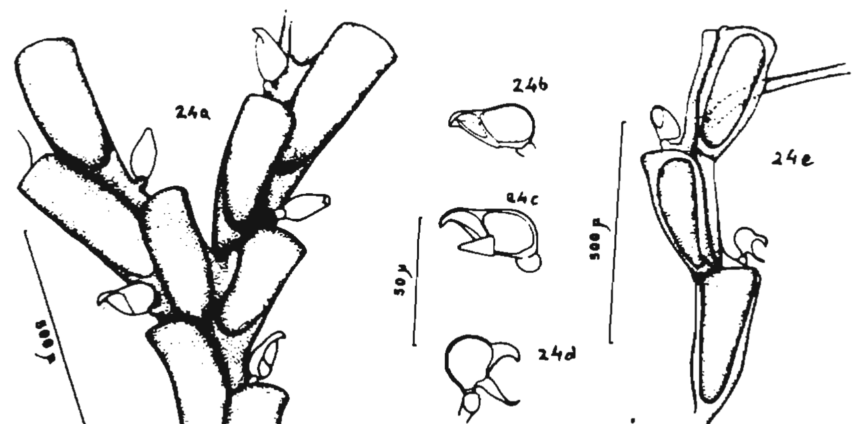


Figure 23a to 23e - *Synnotum aegyptiacum*. 23a. Portion of a colony. 23b. avicularium. 23c. Sessile avicularium. 23d. Portion of a colony with a gonozooecium. 23e.Bifurcation

Figure 24a to 24d - *Bugula crosslandi*. 24a. Portion of a colony. 24b - 24d. Avicularia.

Salient features

Delicate zoarium with biserially arranged zooecia. Branching of type 4 Fig. 14a of Harmer (1923, 1926). Zooecia short, narrow in the proximal region, broadening distally. Opesia occupy the entire front. Spines wanting (Fig. 24a). Avicularia present, placed at the proximal end of the gymnocyst, with rounded head and tubular basis. Rostra long and moderately hooked (Figs 24 b & 24c). No ovicells noticed. Radicles emerge from the median part of the dorsal region (Fig. 24d).

Distribution

Red sea (Waters, 1909), Zanzibar (Hincks collections).

GENUS :BUGULELLA Verril, 1879

1879. Bugulella Verril, Amer. Journ, Sci. Arts., 3, 17, p. 472.

1926. Bugulella Harmer, *Siboga Exped.*, 28b, p. 197.

Single series of zooecia arising from the distal dorsal part of zooecia go to the constitution of the colony. Branching may take place from the sides of the zooecia. Zooecia elongate, clavate, narrow proximally. A large aperture occupies the front. Articulate avicularia present.

Bugulella clavata Hincks, 1887

(Figs. 25 a, b, c & d)

1887. *Bugullella clavata* Hancks, *J. Linn. Soc (Zool,)*, 21, p. 122.

1926. *Bugullella clavata* Harmer, *Siboga Exped.*, 28b, p. 197.

Occurrence

Three fragments were obtained from a sponge collected from Krusadi Is.

Measurements

Zooecium

Length : 950-1000 μ

Breadth: 325 μ

Salient features

Erect Zoarium. Zooecia long and truncate, with an arched distal end, tapering proximally. Aperture long and ovate, occupying more than three fourth of the front. Frontal membrane translucent. Semilunar operculum membraniporine. Cryptocyst wanting . Two avicularia directed laterally and articualted with rounded tubercles, occupy the distal lateral angles (Fig.25a) The shape of the avicularia very much like that of Bugula. Rostrum down curved. Mandible with a bent at the tip. Spine absent. No ovicells noticed.

Distribution

Margui Archipelago (Hincks, 1887)

SUB-ORDER : ASCOPHORA Levinsen, 1909

The frontal area is completely calcified, leaving the aperture. Compenstion sac present which opens into the proximal side of the aperture or into the ascophore situated proximal to the aperture. Operculum compound in the case of forms where the compensation sac opens into the e aperture, simple in the case of those where an ascopore is present.

FAMILY: ARACHNOPODIIDAE Harmer, 1957.

GENUS: TREMOGASTERINA Canu, 1911

1911. *Tremogasterina* Canu , *An. Mus. Nac. Buenos Aires*, 21, p.256.

1957. *Tremogasterina* Harmer, *Siboga Exped.*, 28d, p.659.

"The ovicell is hyperstomial and closed by the operculum. The aperture bears two small cardelles, the poerculum, often chitinised, is attached to the ectocyst, the peristome bears three to five hollow sphines. The frontal is placed above the ectocyst; it is formed of an olocyst surmounted by a rugose or granulated pleurocyst more or less developed; a central area is perforated by reniform pores. The zooecia are separated by interjunctural pores. Large adventitious avicularia appear between the apertures". (Canu and Bassler, 1928).

Tremogasterina granulata Canu and Bassler, 1928

(Figs. 26 a, b & c)

1928. Tremogasterina granulata Canu and Bassler, *Proc. U.s. nat. Mus* . , 72, 14, pp. 45-47..

Occurrence

Three colonies encrusting on coral were collected from off Rameswarm.

Measurements

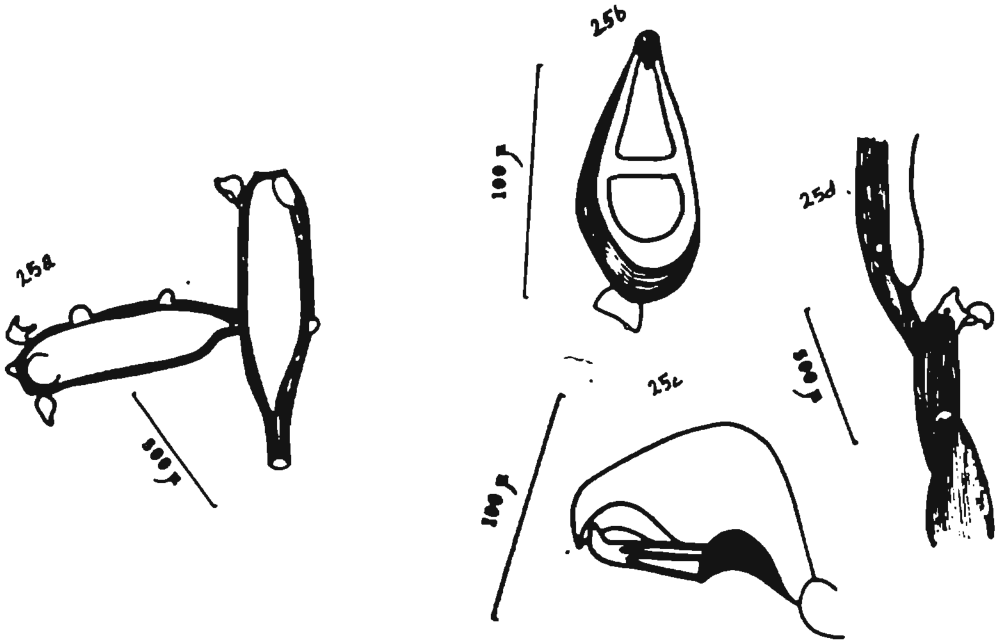
Zooecium

Length : 500 μ

Breadth: 540 μ

Salient features

Encrusting . Distinct, elongate, clave zooecia separated by small pores, which may be inconspicuous. Highly calcified and granulated front with a pore in the middle (Fig. 26a). Elongate and sub-orbicular orifice with a concave border. Two cardeles present. Operculum chitinuous with a continuous sclerite (Fig.26c). Large avicularia placed on



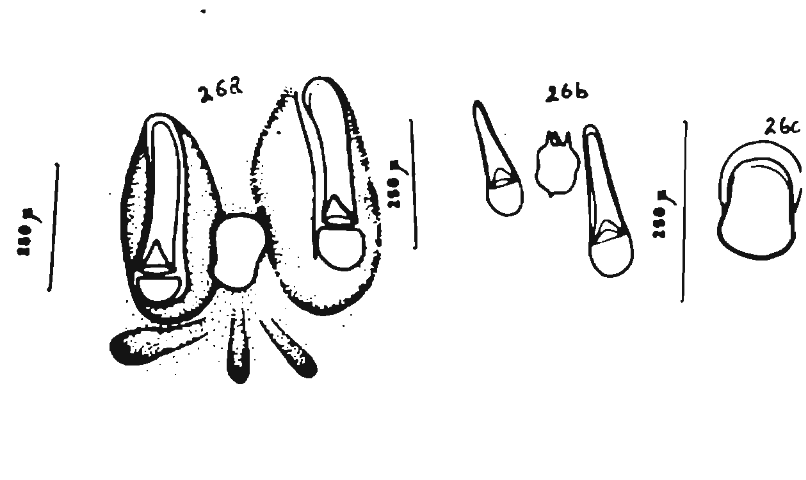


Figure 25a to 25d - *B. clavata*. 25a. Two zooecia. 25a - 25c. Avicularia; basal and lateral views. 25d. Lateral view of zooecia showing branching.

Figure 26a to 26c - *Tremogasterina granulata*. 26a. A zooecia with two avicularia. 26b. Orifice and the lateral avicularia of a young zooecium. 26c. Operculum.

calcareous thickening on either side of the orifice, directed distally (Fig. 26a). Mandibles long with slightly pointed ends. Three small oral spines present in juvenile zooecia.

Distribution

Straits of Florida (Canu and Bassler, 1928)

Tremogasterin lanceolata Canu and Bassler, 1928

(Fig. 27a ,b and c)

1928. *Tremogasterin lanceolata* Canu and Bassler, 1928, *Proc. U.S. Nat. Mus.*, 72, 14, p.48, .

Occurrence

Three colonies encrusting on coral dredged out from off Mandapam.

Measurements

Zooecium

Length : 750 μ

Breadth: 625 μ

Salient features

Zoarium encrusting, multilaminar. Distinct zooecia separated by a line of interjunctural pores. Convex front provided with very small granulations. A median more present. Cardelles small. Large anter and rather small poster. Chitinised elongated oval operculum with a thin marginal sclerite (Fig. 27c). Avicularia large, often paired, usually pointed distally or rarely disto-medianly (Figs. 27a & b). Immersed ovicells tuberculate, often with few large tubercle(Fig. 27a). Ovicells closed by the operculum.

Distribution

North Cuba (Canu and Bassler, 1928).

FAMILY CELLEPORARIIDAE Harmer, 1957

Pleurilaminar zoarium, often forms massive encrustations. Tubular zooecia mainly imperforate with few inconspicuous marginal or submarginal pores. Non-sinuate orifice. Raised peristome. Unilateral sub-oral avicularium, often produced into an ascending rostrum which may be slight or a long spik. Frontal avicularia of various sizes, sometimes gigantic. Hyperstomial and imperforate ovicells.

GENUS CELLEPORARIA Lamouroux, 1821

1821. Celleporaria Lamoroux, Exposition Mithodique des genres ...des Polypiers, p.43.

1957. Celleporaria Harmer, *Siboga Exped.*, 28d, pp. 663-667.

Characters same as that of the family.

Celloporaria pilaefera (Canu and Bassler), 1929

(Figs. 28 a, b, c, d & e)

1929. *Holoporella pilaefera* Canu and Bassler, *Bull. U.S. nat. Mus.*, 9, p. 422, Pl.60, figs. 2-6. text fig. 165.

1957. *Celleporaria pilaefera* Harmer, *Siboga Exped.*, 28d, pp. 679-680, Pl.42, fig.25.

Occurrence

A single colony encrusting on a shell was collected from off Mandapam, Gulf of Manaar

Measurements

Zooecium

Length - 420 μ

Breadth - 290 μ

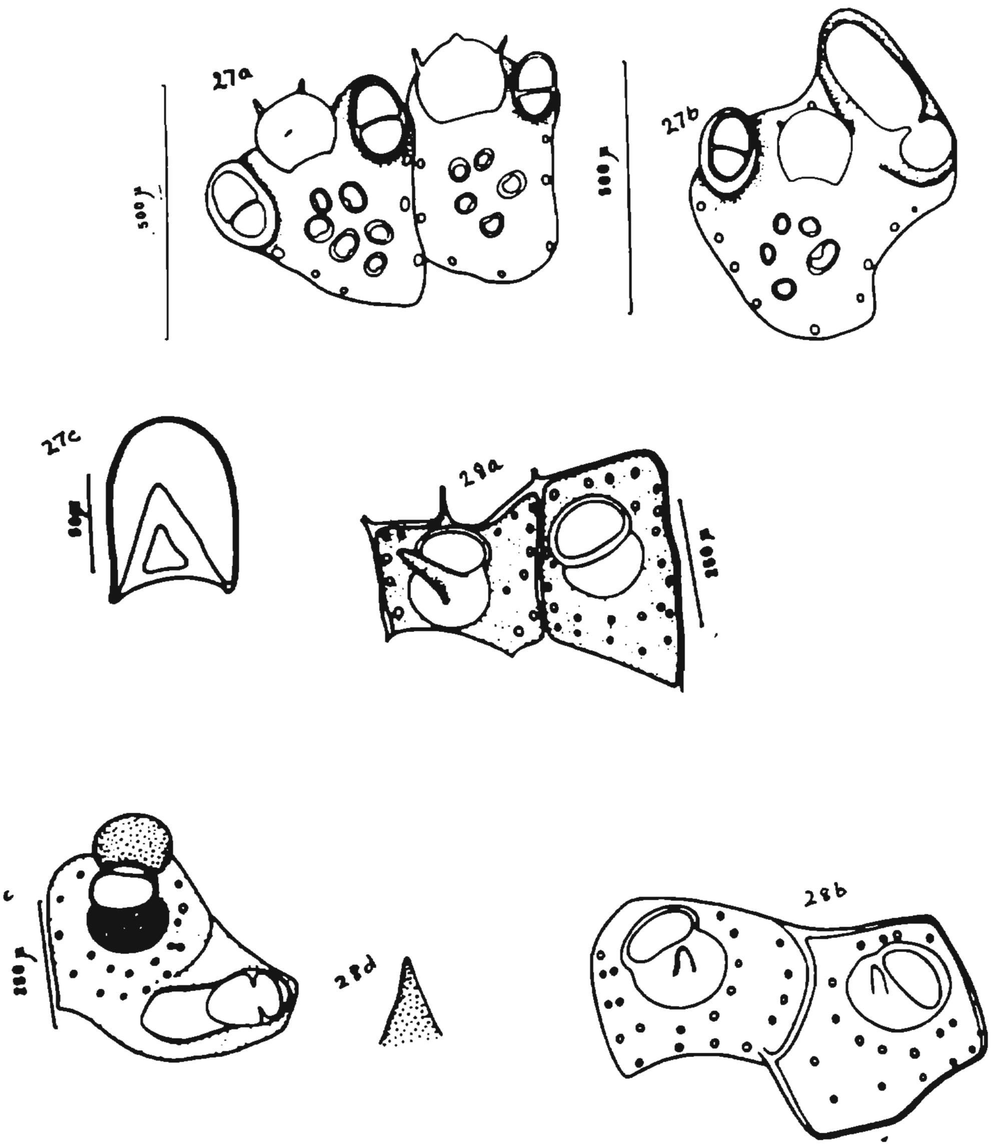


Figure 27a to 27c - *T. lanceolata*. 27a. **Portion of a** colony. 27b. A zooecium with a large vicarious avicularium. 27c. Mandible.

Figure 28a to 28e - *Celloporaria pilaefera*. 28a -28b. Portion of a colony showing the details of zooecia. 28c. A fertile zooecium with a spatulate avicularium. 28d. Rostrum (diagrammatic).

Salient features

Encrusting. Zooecia small. Front with small marginal pores. Semicircular orifice. No oral spines. Condyles wanting. Median sub-oral rostum present often long, arises from an expanded base. Sub-oral avicularium not noticed. Large spatulate vicarious avicularium present with a free raised distal end (Fig.28c). Ovicell imperforate and tuberculated with complete frontal wall, pyriform openings facing proximally (Fig. 28d).

Distribution

Philippines (Canu and Bassler, 1929); Banda Sea and Timur Id. (Harmer, 1957). In addition to these records specimens of this species kept in the B.M. (N.H), collected from Saya de Malha, Indian Ocean (Thornely, 1935) and Ghardaqa, Red Sea (Crossland Collection) are recorded by Harmer (1957).

Celleporaria granulosa (Haswell), 1880

(Figs. 29 a, b, c, d & e)

1880. Celleporaria granulosa Haswell, *Proc. Linn. Soc. N.S.W.*, 5, p. 40.

1957. Celleporaria granulosa Harmer, *Siboga Exped.*, 28d, pp. 688-690.

Occurrence

Two colonies encrusting on a coral were collected from off Mandapam south-east coast of India.

Measurements

Zooecium

Length - 425 μ

Breadth - 280 μ

Salient features

Encrusting, zoarium multilaminar. Distinct calcareous lines present in between young zooecia. Marginal pores present. Orifice orbicular, surrounded by a calcareous border, which sub-orally bears a rounded avicularium (Fig.29a) placed on a large rounded thickening. The spike-like projection absent. Large vicarious avicularium expanded distally with a columella rare (Fig.29c). Operculum large and with slightly curved proximal border. No ovicells noticed.

Distribution

Queensland (Haswell, 1880); Torres Strait (Krikpatrick, 1890); Mauritius (Thornely, 1912).

FAMILY PETRALIELLIDAE Harmer, 1957

Colonies encrusting or hemescharan. Usually zooecia large and reticulopunctate. Large orifice, variable in form and in the presence or absence of lateral denticles or articular condyles. Sub-oral mucro often present. Different kinds of avicularia, like lateral oral, sub-oral and frontal. Rounded or acute mandible. Large mandibles sometimes with a median sclerite and frequently with denticulate margins. Small avicularia and others commonly with a distal semicircular, denticulate vertical flange. Globose and porous ovicells. Smooth basal sclerite usually with one or more pore-chambers capable of giving rise to membraneous root-lets. Rarely reticulo-punctate, uniformly porous.

GENUS MUCROPETRALIELLA Stach, 1936

1936. Mucropetraliella Stach, *Rec. Aust. Mus.*, 19, 6, pp. 363, 372.

1957. Mucropetraliella Harmer, *Siboga Exped.*, 28d, pp. 709-710.

"Lyrula and lateral denticles usually present. A sub-oral avicularium, generally associated with a mucro is the most important feature of the genus". Harmer (1957).

Mucropetraliella philippinensis (Canu and Bassler), 1929

(Figs.30 a, b, c & d)

1929. Petraliella philippinensis Canu and Bassler, *Bull. U.S. nat. Mus.*, 9, p. 261.

1957. Mucropetraliella philippinensis Harmer, *Siboga Exped.*, 28d, pp. 710-711.

Occurrence

A part of a hemescharan colony was collected from the dredging conducted in the Gulf of Manaar.

Measurements

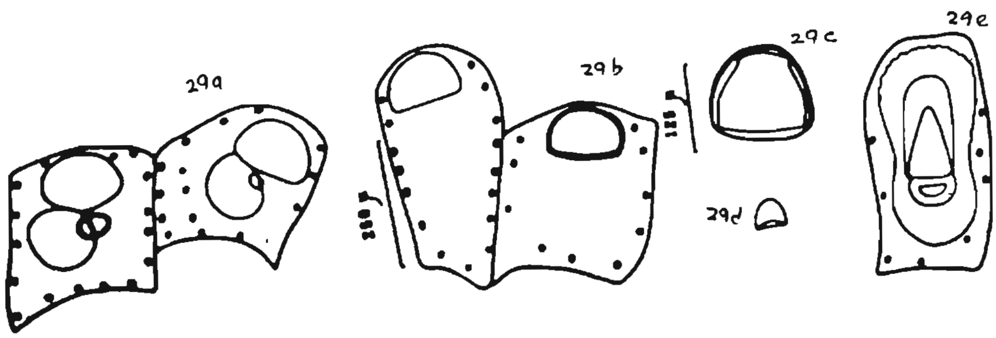
Zooecium

Length - 510 μ

Breadth - 380 μ

Salient features

Colony hamescharan. Large and flat zooecia with inconspicuous septal lines. Front with small pores (Fig. 30a). Distal walls of the peristome thin. Orifices wider than long (Fig.30d). Lyrula short and wide with pointed lateral corners. Denticles present, pointed (Fig.30d). Sinuses not closed. Majority of avicularia small and rounded. Large lateral avicularia usually present placed slightly away from the lateral sides of the orifice. Sub-oral and lateral frontal avicularia large (Fig. 30a). Mandibles of small avicularia with denticles. A well developed mucro present, often branched and overarch the secondary orifice. No ovicells noticed.



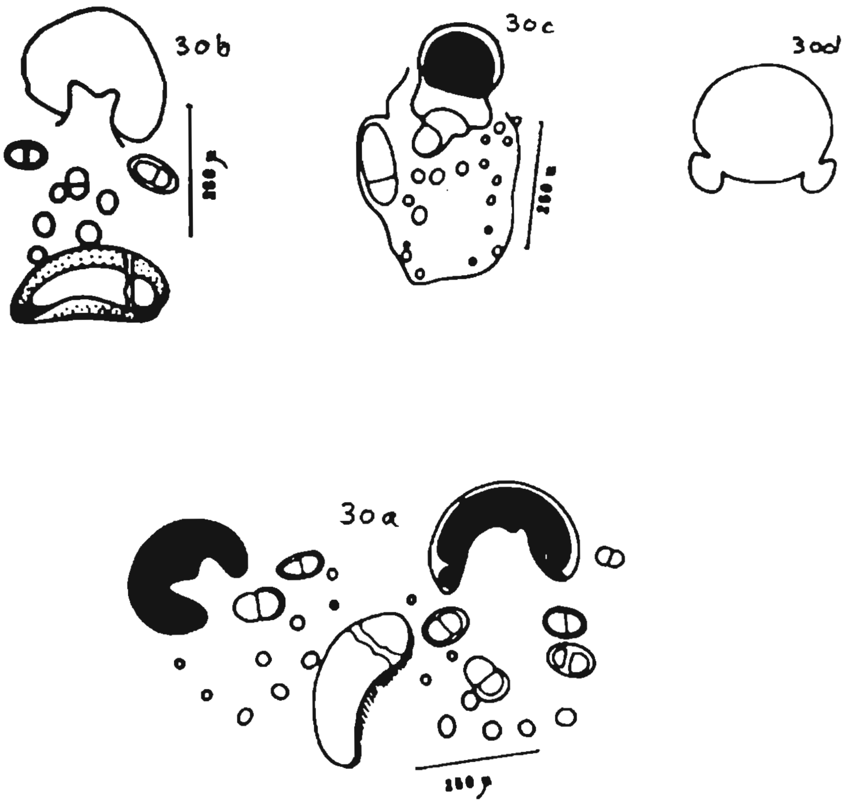


Figure 29a to 29e - *C. granulosa*. 29a. Two zooecia with the details. 29b. Two marginal zooecia. 29c. Operculum 29d. Mandible. 29e. Vicarious avicularium.

Figure 30a to 30d - *Mucropetraliella philippinensis*. 30a. Portion of a colony. 30b. A zooecium. 30c. Zooecium with secondary orifice and operculum. 30d. Primary orifice.

Distribution

Philippines (Canu and Bassler, 1929); Paternostu Is. and Talaut Is. (Harmer, 1957).

FAMILY SMITTINIDAE Levinsen, 1909

Front an olocyst, pleurocyst or temocyst. Semicircular primary orifice, usually with cardelles and a lyrula. Oral spines common. Sub-oral or frontal avicularia present. Ovicells hyperstomial.

GENUS PARASMITTINA Osburn, 1952

1952. *Parasmittina* Osburn, *Rep. Allan Hancock Pacific Exped.*, 14, 2, p. 411.

1963. *Parasmittina* Lagaaij, *Publ. Institute of Marine Science*, 9, p. 197.

"Avicularia variously distributed on the frontal, but never median, suboral and bilaterally symmetrically developed around the proximal border of the aperture; they take their origin from areolar pores on one side". (Osburn, 1952). Pleurocyst, with a row of areolar pores. Lyrula and cardelles usually well developed. Variously developed ovicells present.

Since all species treated here possess a pleurocystal front and variously placed avicularia without a bilateral chamber, they are placed under *Parasmiitina* Osburn. Hence few species described by Harmer (1957) and others under Smittina are synonymised under Parasmittina. Harmer's work though completed in 1939, was published only in 1957. So naturally Osburn was not able to consult this work before completing his report on Pacific coast Bryozoa published in 1950-1953. Osburn (1952) assigned species belonging to Smittina, with a pleurocystal front and variously placed avicularia without a bilateral chamber, under Parasmittina the new genus proposed by him.

Parasmittina tubula (Kirkpatrick), 1888

(Photo micrograph 3a and 3b)

1957. *Smittina tubula* Harmer, *Siboga Exped.*, 28d, pp. 940-941, Pl. 65, fig.4.

1972. *Parasmittina tubula* Menon N R. *Mar.Biol.* 14, l, pp.73.

Occurrence

A fragment of a colony was obtained from a coral collected from Kavarathi Island and also from the Krusadi Island.

Measurements

Zooecium

Length - 434.7 μ

Breadth - 260.8 μ

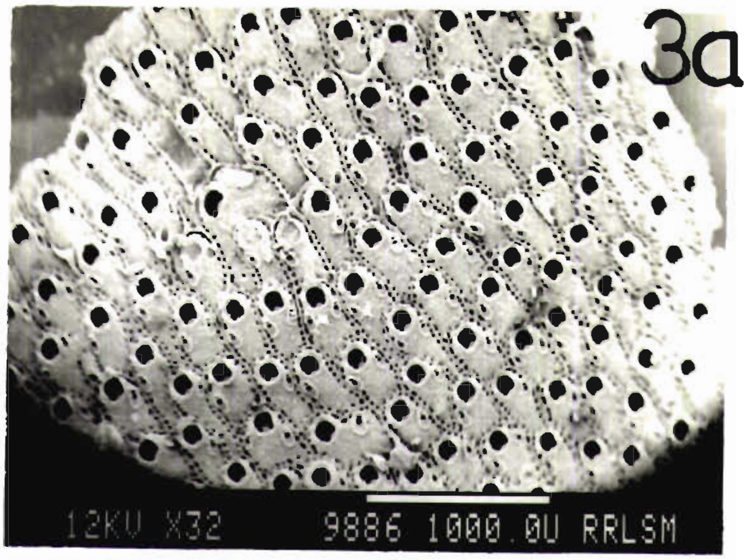
Salient features

Zoarium encrusting. Small zooecia separated by vague calcareous lines. Marginal pores very small. Front coarse and highly tuberculated. A highly raised peristome, proximally with a sinus. Spines present-two to three in number on the distal region of the peristome. A broad lyrule present. Unilateral avicularia, with triangular or rounded tip directing proximally. Ovicell not noticed.

This is recorded from Lakshadweep first time.

Distribution

Madagaskar, Ceylon (Thornely, 1905 & 1912); Mauritius (Kirkpatrick, 1888).



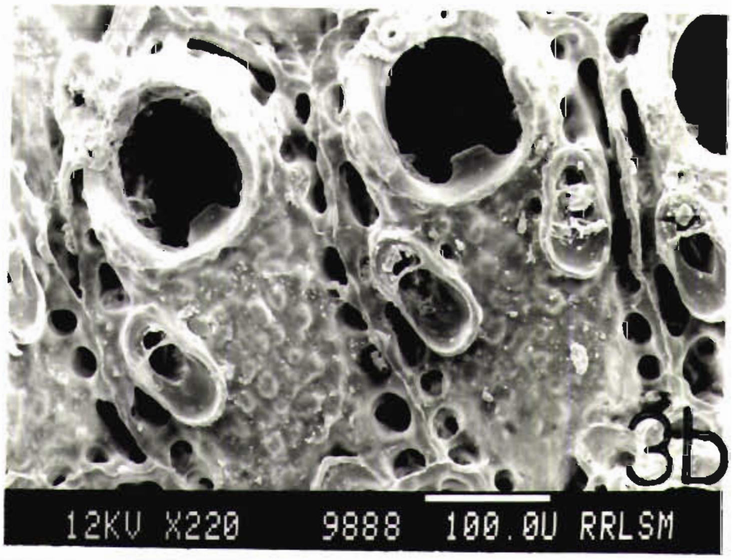


Photo micrograph 3a - *Parasmittina tubula*. The encrusting portion of a colony.

Photo micrograph 3b - *Parasmittina tubula*. Enlarged view of a zooecium.

Parasmittina elongata (Okada and Mawatari), 1936

(Figs. 31 a and 31b)

1936. *Smittina elongata* Okada & Mawatari, Science Reports of the Tokyo Burnika Daigaku, B, 49, p. 69.

1972. *Parasmittina elongata* Menon N R. *Mar.Biol.* 14, l, pp.74.

Occurrence

A single colony on a *Triphyllozoon sp.* was dredged out from the Gulf of Manaar.

Measurements

Zooecium

Length - 300 μ

Breadth - 245 μ

Salient features

Zoarium encrusting. Whitish in hue. Flat zooecia arranged in longitudinal rows alternately. Front with numerous small tubercles. Moderately sized marginal areolae. Thin peristome nearly circular and tubular, with six spines or spine bases. Sunk primary orifice. A descending sinus. Lyrula absent. Unilateral avicularia narrow and long, raised from the frontal surface, proximo-lateral to the peristome, directing proximally (Fig.31a). No spatulate avicularia. Operculum semicircular with a tongue prolonging into the sinus. The avicularian mandible narrow and long slightly rounded at the tip. (Fig 31b)

Distribution

Japan (Okada & Mawatari, 1936).

Parasmittina californica (Robertson), 1908

(Photo micrograph 4a and 4b)

1952. *Parasmittina californica* Osburn, *Rep.Allan Hancock Pacific Exped.*, 14, 2, pp.415-416

1971. *Parasmittina californica* Menon N R , *Mar. Biol.* 14, 1, pp-80

Occurrence

The colonies encrusting on inner side of coconut shell collected from Kavarathi coral lagoon at a depth of 25 m.

Measurements

Zooecium

Length - 500-571.4 μ

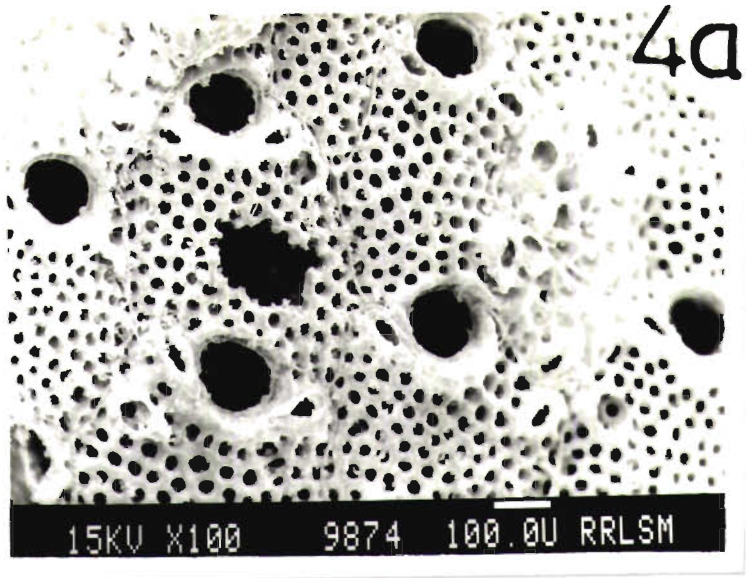
Breadth - 285.7-385.71μ

Salient features

Zoarium encrusting. Colonies with coarse zooecia having more or less quadrangular shape. Zooecia separated by grooves, and their mural rims obscured when secondary calcification takes place. Calcified front a pleurocyst but irregularly arranged pores often present. Thin and low peristome. Primary orifice rounded with a moderately developed lyrula and two small condyles. Laterally directed oval, pointed, spatulate avicualria placed on various parts of the front. A large spatulate proximo-laterally directed avicularium occasionally present. No oral spines. Heavily calcified ovicells perforated. Their proximal region usually invaded by the peristome.

Distribution

California, Arabian sea.



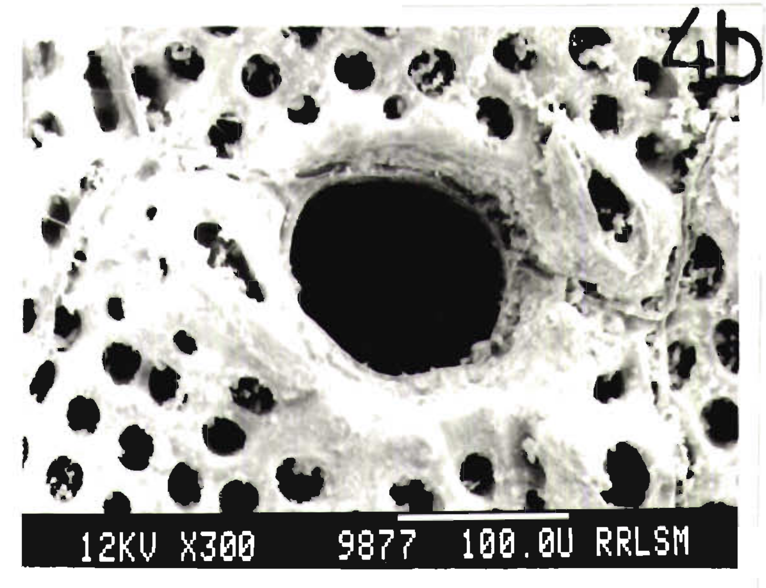


Photo micrograph 4a - *Parasmittina californica*. The encrusting portion of a colony.

Photo micrograph 4b - *Parasmittina californica*. Enlarged view of a zooecium.

GENUS : SMITTINA Norman, 1903

The frontal is a tremocyst with numerous pores; a suboral median avicularium similar in origin to that of Porella; lyrula well developed and varying in length and breadth; ovicell hyperstomial, usually with numerous perforations similar to the frontal pores.

The suboral avicularium is usually included in the peristomial fold of the 'sinus', but may be quite prominal to it; the front wall is usually thick and the pores are sometimes much enlarged and infundibulate; frontal avicularia are sometimes present in addition to the constant suboral type; the peristome often overhangs the primary aperture and obscures its characters; the ovicell pores are usually numerous and well distributed, but in a few cases they are limited to 1 or 2 central pores and even these may be occluded in final calcification.

Smittina sp.

(Photo micrograph 5a abd 5b)

Occurrence

Colonies encrusting on a damaged boat's hull collected from lagoon of Kadmat atoll.

Measurements

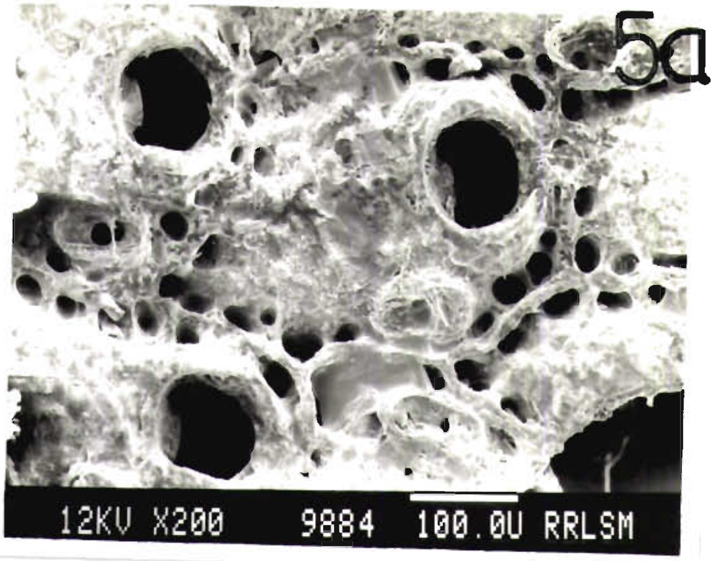
Zooecium

Length - 366.66 μ

Breadth - 280 μ

Salient features

Zooecia more broad than long. The front provided with numerous whitish tubercles giving a rugged appearance. Elevated peristome. The secondary orifice



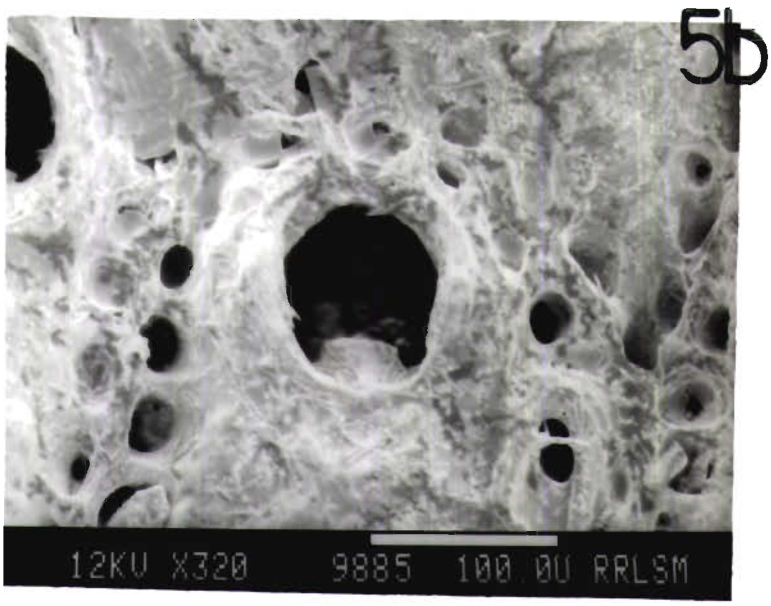


Photo micrograph 5a - *Smittina sp*. The encrusting portion of a colony.

Photo micrograph 5b - *Smittina sp*. Enlarged view of a zooecium laterally flared. A very prominent lyrula. The operculum calcareous with well developed condyles. Vicarious avicularia laterally placed directing proximally. Avicularian mandible blunt. The septum separating mandibles well developed. The colony whitish in hue. The tremopores numerous and present marginally.

FAMILY RETEPORIDAE Smitt, 1867

"Zooecia heavily calcified, with few pores, spines present or wanting; a well developed vestibular arch which is usually beaded; dependent avicularia of varying size and form (usually sub-oral or not in the midline); ovicell at first prominent but becoming immersed, often with a median fissure, above the orifice a labellum or prolongation. In the erect forms the zooecia are all on the frontal side and the dorsal side is covered by a layer of kenozooecia, which may or may not have pores and avicularia. Erect species are usually fenestrate, sometimes forming a close network (retepores), but a few are mere branching or have occasional fusions". (Osburn, 1952).

GENUS TRIPHYLLOZOON Canu and Bassler, 1917

1917. Triphyllozoon Can and Bassler, *Bull. U.S.nat.Mus.*, 96, p.56

1935. Triphyllozoon Harmer, *Siboga Exped.*, 28c, pp.590-591.

Zoarium fenestrate. Ovicells with a trifoliate stigma. Peristome may be with a closed labial pore or an open sinus. Generally the operculum with an indefinite border. Large bicuspid avicular commonly present. Small round and oval avicularia present. Basal vibices few.

Triphyllozoon tubulatum (Busk), 1884

(Figs. 32 a, b, c, d, e, f, g and h)

1884. Retepora tubulata (Pars) Busk, *Zool.Challeng.Rep.*, p.121.text fig.32.

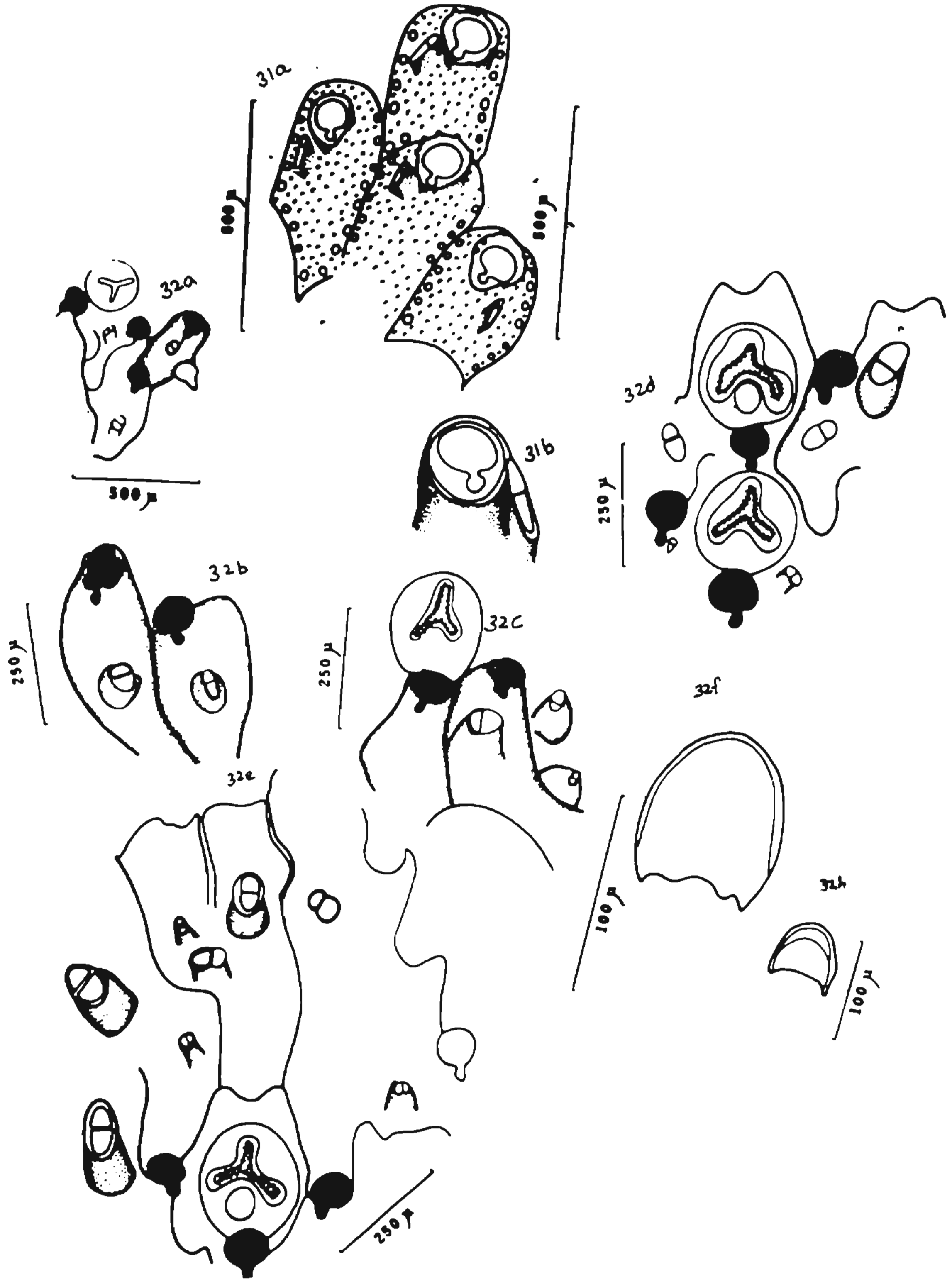


Figure 31a to 31b - *Parasmittina elongata*. 31a. Portion of a colony. 31b. Orifice and lateral avicularium.

Figure 32a to 32h - *Triphyllozoon tabulatum*. 32a. Portion of a colony. 32b. Two enlarged zooecia. 32b -32d. Fertile zooecia and avicularia. 32e. Rim of a funnel. 32f. Operculum. 32g and 32h. Mandibles.

1935. Triphyllozoon tubulatum Harmer, *Siboga Exped.*, 28c, pp.600-603.

Occurrence

A single colony measuring 60mm. in height was collected off Mandapam from the Palk Bay.

Measurements

Zooecium

Length - 385 μ

Breadth - 200 μ

Salient features

Tubular zoarium, with delicate tubes and funnels, usually with orifices arranged in the interior phase of the funnel. Fenestrae oval. Peristome with a distinct sinus (Figs. 32 a&d). Labial avicularia present but rare. Numerous sub-median or lateral avicularia invariably present (Fig. 32 a &d). Infra-fenestral avicularia rare may be facing the fenestrae or in an oblique manner frontally with two to four cusps. Large frontal avicularia with rounded rostrum, mandible rounded (Figs32 d & g). Operculum with a marginal sclerite. Delicate ovicells with trifoliate stigma (Figs.32 a, c, d & e).

Distribution

Torres Strait (Busk, 1884; Hastings, 1932); Many Siboga Stations in the Indo-Australian Archipelago (Harmer. 1935); Gulf of Manaar (Thornely, 1905).

Rhynchozoon larreyi (Audouin), 1826

(Figs. 33a, b, c and d)

1826. *Cellepora larreyi* Audouin, Description de l'Egypte, *Hist. Nat.*, 1, 4, p. 239.

1957. *Rhynchozoon larreyi* Harmer, *Siboga Exped.*, 28d, pp. 1074-1076.

Occurrence

Several colonies encrusting on stone were collected from the sub-tidal region at Mandapam from the Gulf of Manaar.

Measurements

Zooecium

Length - 380-400 μ

Breadth - 190-200 μ

Salient features

Zoaria encrusting and multilaminar. Zooecia distinct at the margin of the colony (Fig.33 a) and irregular at the centre. Marginal pores present. Front highly tuberculated, and the tubercles give the colony a very irregular appearance (Fig. 33c). Peristome bilabiate, one of the processes aviculiferous (Fig.33a). In the older zooecia small tooth-like processes present at the proximal region of the peristome. Small sub-oral avicularia placed obliquely. Frontal avicularia present, placed near the distal region proximal to the peristome, triangular and acute (Fig. 33 b & 33c). Primary orifice with a distinct sinus, distal portion denticulate. Operculum with a wide circular anter and a distinct poster (Fig. 33d). Ovicells non-porous and tuberculated.

Distribution

Egypt, Ceylon (Thornely, 1905); Indo-Australian Archipelago (Harmer, 1957).

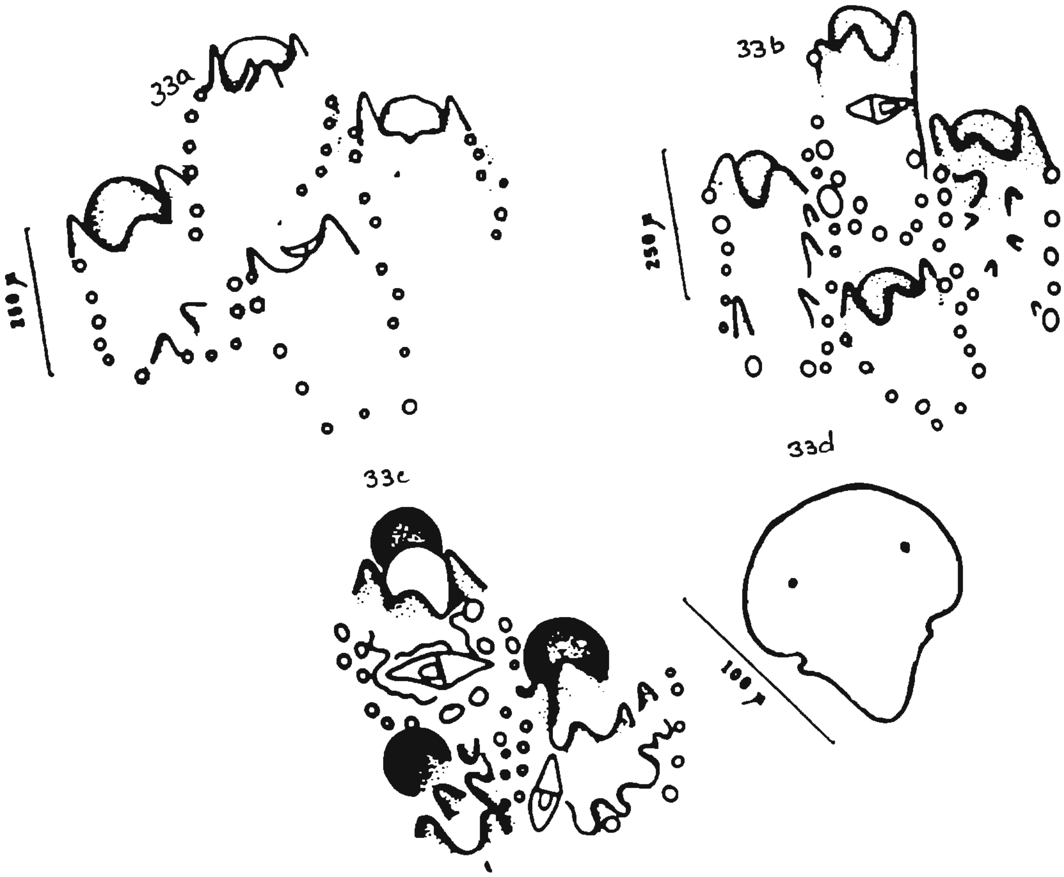
Rhynchozoon globosum Harmer, 1957

(Figs. 34 a, b and c)

1957. *Rhynchozoon globosum* Harmer, *Siboga Exped.*, 28d, pp. 072-1073..

Occurrence

Three colonies encrusting on sponges were collected from the Gulf of Manaar.



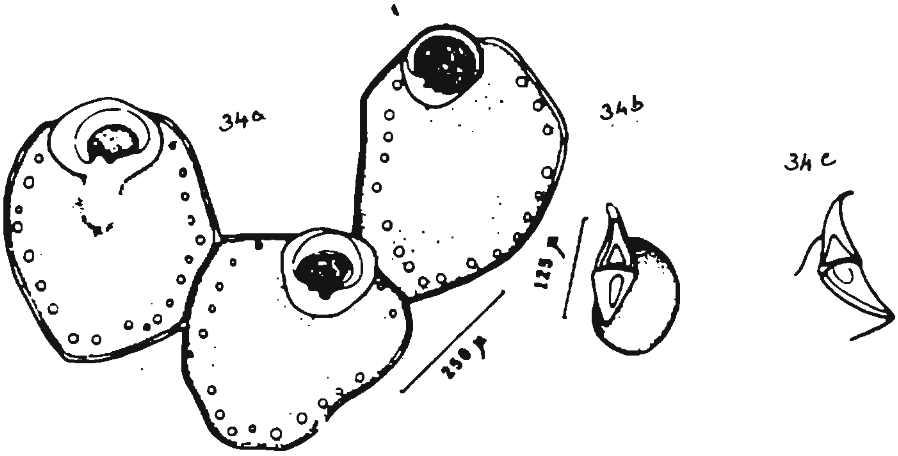


Figure 33a to 33d. *Rhynchozoon larreyi*. 33a. Rim of a colony with less calcified zooecia. 33b. Portion of a colony with highly calcified zooecia. 33c. Three fertile zooecia. 33d. Operculum.

Figure 34a to 34c. *R. globosum*. 34a. Portion of a colony. 34b. Frontal avicularium. 34c. Sub-oral avicularium.

Measurements

Zooecium

Length - 470 μ

Breadth - 370 μ

Salient features

Encrusting. Front finely tuberculated. Peristome with two to three mucros, one of which may be aviculiferous. Sub-oral avicularia present, placed on globular thickenings. Rostrum without uncinate process. Frontal avicularia placed on calcareous thickenings in young zooecia. Mandibles hooked at the tips (Figs 34a & 34b). Orifice with small sinus. No ovicells noticed.

Distribution

Timor (Harmer, 1957). In addition to this record Harmer (1957) has also reported this species from the Cambridge Museum collection obtained from Torres Strait and Japan, donated by Haddon and Owston respectively.

SUB-ORDER : CTENOSTOMATA Busk

Chitinous zoaria encrusting, erect, stolonate or burrowing. Aperture simple, closed by inversion of tentacle sheath, or retraction of polypide specialised apertures present in some genera, where they may be bilabiate produced or operculate. No avicularia or true external ovicell. Kenozooecia in the form of stolons in stolonifera and as spines in carnosa.

ORDER : CYCLOSTOMATA Busk, 1852

DIVISION : ARTICULATA Busk, 1859

FAMILY : CRISIIDAE Johnston, 1838

Erect and jointed zoarium, with zooecia arranged in single series or alternating in two series. Ovicell a gonozooid, with an ooeciostome.

GENUS: CRISIA

1953. Crisia Osburn, *Rep. Allan Hancock Pacific Exped.*, 14, 3, pp. 678-679.

Long internodes, zooecia arranged symmetrically in two alternating series, the peristome giving the edges a serrated appearance. Gonozooides usually place in median line between the zooid rows.

Crisia elongata Milne Edwards, 1838

(Photo micrograph 6a and 6b)

1963. *Crisia elongata* Osburn, Rep. Allan Hancock Pacific Exped., 14, 3, pp.684.

Occurrence

Colony were collected from coral lagoon of Kalpeni atoll at a depth of 3m.

Measurements

Zooecium

Height - 688.85 μ

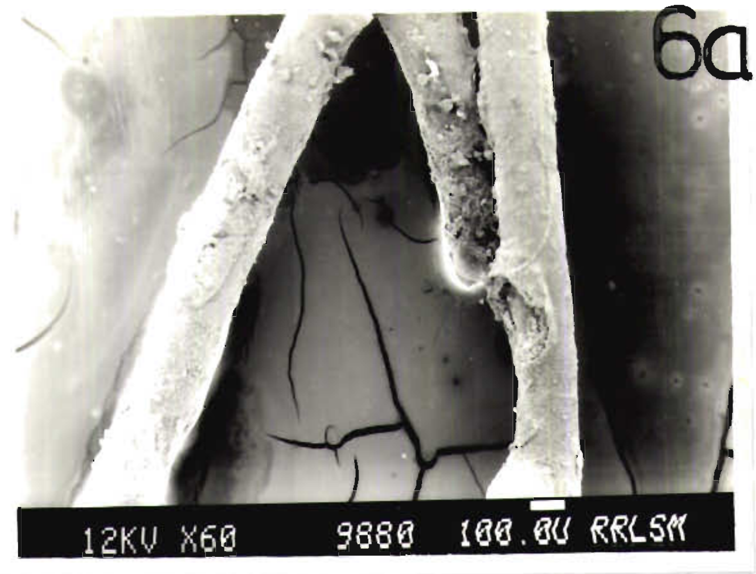
Salient features

Delicate zoarium. Projecting peristome gives the branches a serrated appearance. Zooecia long and adnate, the peristome placed obliquely directing forwards. No ovicell noticed.

This is the first record from Lakshadweep.

Distribution

Ceylon, Gulf of californica.



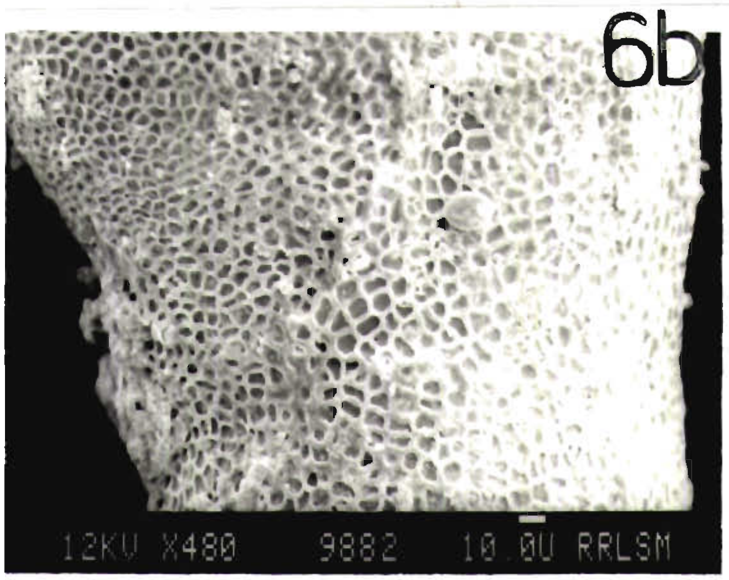


Photo micrograph 6a - *Crisia elongata*. The erected portion of a colony.

Photo micrograph 6b - *Crisia elongata*. Enlarged view of a portion of colony.

4.4.2. Remarks on the fauna

Coral associated bryozoan fauna is a very diverse one, probably consisting of several species. However, the Indian bryozoan fauna of coral reefs is poorly understood. No specific work has been done on fauna existed in the Laccadive islands, south-east coast of India and the Andamans. Around 30 species belonging to 20 genera have been recorded from the Indian waters. However, many species belonging to the common genera such as, Stylopoma, Parasmittina, Antropora, Crassimarginatella, Micropora, Puellina, Hippothoa, Celloporaria etc. have not been recorded from Indian waters. It is quite possible that these genera were also represented in Indian coral reefs. In an excellent review on Bryozoa of coral reefs in Great Barrier Reef (GBR), Ryland and Hayward (1992) have described around 81 species of bryozoans. Curiously enough, 14 species have been described as new and 25 species have been identified to be widely distributed in the Indo-Pacific area. Among the species recorded in the present study majority are having a world wide distribution along the shallow waters of the tropical and temperate seas. Majority of the species described by the various authors are taxonomically simple and widely distributed. Temperature regime of these species normally ranges between 20-30 °C. The habitat and the substratum which help in successful settlement of larva and development of ancestrula normally should have macroscopic crevices, enundations and profuse water exchange. These characters accompanied by the existence of endemic populations of bryozoans provide with a haven to the bryozoan fauna.

CHAPTER 5

ASPECTS OF CONSERVATION OF CORAL REEFS

5.1 Introduction

Coral reefs serve as feeding, breeding and nursery grounds for indigenous and transient marine populations. In addition, organisms inhabiting the reef benefit from physical protection from the destructive forces of the sea. Coral reefs are, however, extremely vulnerable to unnatural changes in environmental parameters.

In order to maintain the high productivity characteristic of reefs, as well as to ensure continuity of the ecological processes, to preserve genetic diversity and to allow for the development of relevant sustained economic potential, there is now an urgent need for rational management of resources associated with coral reef. Any effective management scheme, however, must begin with a sound knowledge of the extent of the resources. In order to accumulate such knowledge, sufficient information must be obtained on the distribution, type structure and species composition of reefs throughout the Lakshadweep archipelago.

The need for conservational management of coral reefs and their associated organisms is urgent and has been recognised by the International Union of Conservation of Nature and Natural Resources (IUCN) as a global priority (Kenchington and Hudson, 1984). Lakshadweep coral reefs, the only atolls in Indian territorial waters and a rich marine biodiversity reservoir, is a national heritage and must be conserved.

5.2 Conservation of coral reefs of Lakshadweep archipelago

Conservation of coral atoll reefs of Lakshadweep is very important as rapid economic development is taking place in the atolls. The islanders have been living for many years in a delicate ecological balance, that sustains the islands, within these atoll environment.

The direct human interference by means of dredging of the lagoons, blasting of the lagoon reefs, coral mining, excessive fishing etc. causes environmental stress to coral reefs. Some of these activities cause excessive siltation which is far above the sediment removing capacity of the coral polyps and puts them under an enormous environmental stress. This excessive siltation is world wide and is one of the master factors which causes massive coral reef mortality. Coralline boulders (mainly *Porites spp.)* have been used, as a cheap substitute, for construction of houses and for the extraction of lime (photographs 3a,b and c). Fortunately, a ban on coral picking exists but is not strictly enforced

The increase in domestic tourism has resulted in a demand for souvenir collections of reef animals, including corals. Industrial development i.e. construction of wharves, jetties etc. certainly caused damage to the reefs.

Indirect impacts of human activities are erosion from the land caused by inadequate land use, like deforestation, inputs of excessive nutrients by means of sewage, garbage or fertilizers, oil and pesticide pollution. These environmental impacts may change competition pattern on the reefs, which might result in the over growth of the reef by algae or the occurrence of epidemics, like the population increase of the coral predator *Acanthaster planci* (the real cause of the population explosion of this species is not known, but it is thought to be related to human disturbances like predator removal).

The coral reefs are extremely sensitive to eutrophication, because the coral reef itself is an oligotrophic ecosystem which is extremely sensitive to extra nutrient inputs from outside the system. On densely populated islands like the Lakshadweep, construction activities will result in increased sediment loads and nutrient input. Corals are especially very sensitive to extra nitrogen inputs in the form of ammonia or nitrates. Nitrogen is considered to be the limiting nutrient in coral reef ecosystems (this is in contrast to freshwater ecosystems where phosphorus is in general the limiting factor). Results obtained from the line intercept transect survey from the Lakshadweep atoll reefs especially from Kavarathi indicate that the coral reefs and probably also the lagoon ecosystems are under a strong environmental stress (photograph 5g). The new developmental activities in Lakshadweep such as introduction of inter-island ferries and related engineering and constructional activities are the major environmental impact at present. The widening of the entrance channels by blasting and dredging in order to make the new ferries accessible and the dredging of the lagoons seems to result in extensive coral mortality near the channel entrance and in the lagoon. The dead coral reef will be unprotected from erosion by wave action. The health of the reef near the entrance of Kavarathi is already in very poor condition. In order to protect the coral reef ecosystem of the Lakshadweep archipelago more effectively, it would be necessary to give the atolls the status of a Marine Biosphere Reserve. Recently the problem of reef degradation has been recognised by the administration and the concerned departments are taking steps to regulate human impact upon the coral reef. A proposal was prepared to establish marine park at Agathi.

5.3 Management approach for conservation of coral reefs.

Better management plans require a proper survey of the physical structure of the reefs, their species composition, and the response of the ecosystem as a whole to external stress.

Natural phenomena rarely cause extensive and irreversible damage to reef. But human activities do, and these come in a number of forms such as collection of corals, shells and ornamental fishes, intensive fishing, sewage disposal and eutrophication, oil pollution, dredging, construction activities and recreation and tourism. Each one of these can result in the damage of reefs.

Excessive and indiscriminate mining of corals, dredging and blasting resulting in the accumulation of coral debris was the main cause of damage in Kavarathi lagoon. The poor percentage of living corals in the north west of the lagoon reef clearly depicts this fact. Since this is the capital of the union territory, this activity commenced much earlier and continues even today. The destruction of live coral up to 95% in the localised sites is assumed to be due to dredging, collection of shells and corals, live-bait and octopus fishing, coral walking , oil pollution etc.

From a temporal stand point sea level rise can pose a threat to the existence of the islands associated with the atolls; reefs may not be affected directly, but if their growth rate does not match the rate of sea level rise , then the protection afforded by the reefs to the island will be lost.

A rational policy on management of coral resources is very much required because of the present degraded state of many atolls in Lakshadweep and the possibility of increased human intervention.

This can be done by declaring the reef where damage has been excessive, as protected environment thus banning all human activities. For instance the Gulf of Kutch Marine Park and Wandoor National Marine park at Andamans were declared as protected area. A distinct recovery of the reefs in the recent years in the marine park of Gulf of Kutch was noted through satellite photographs combined with ground survey.

The management approaches for the conservation of coral reefs are diverse and can be grouped into: 1. Management of space 2. Management of species and 3. Extension service-for instilling a sense of awareness about the importance of coral reefs among local population and tourist (Wafer, 1986). The management of reef can best be achieved by establishing a marine park. The motivation behind this is conservation, promotion of tourism and recreation and cultural uses. This include control and regulation of commercial fisheries and collection of corals and other reef organisms, particularly molluscs. In the inhabited islands of Lakshadweep collection of corals is banned, but it is to be enforced strictly. Management measures would undoubtedly be effective at least partially if not wholly in conserving reefs, but it is important to create public awareness regarding the fragility of the coral reef ecosystem. This can be done by extension programs.

The present status of our reefs can best be summarised with reference to the following sequence of human impact on marine sources: Discovery, exploitation, over exploitation and irreparable damage. Recognition of the need for conservation and management cause only after the environmental conditions deteriorated.

Human induced damage to coral reefs comes in many forms, ranging from the widespread destruction caused by mining of corals for building purposes, chemical pollution, or localised damages caused by fishermen's anchors, tourism and scientific collections.

5.4 Measures to protect/conserve atoll environment.

1. Dredging of navigational channel for the maintenance of depth. Further deepening of channel or development of new jetties or harbour should not be allowed.

2. The more distroyed atolls of Kavarathi should be allowed to recover the coral resources by providing suitable conditions for the continued settlement of planula larvae.

3. The atolls where moderate healthy reefs exist should not be subjected to any ecological disturbance.

4. The importance of the healthy existence should be made aware to the locals.

5. Uncontrolled collection of coral products as souvenirs by tourists, sale of corals to tourist etc. should be prevented.

6. Disposal of sewage and human waste, solid waste and garbage to surrounding environment or lagoon should be avoided. Recently department of science, technology and environment has taken some steps in this regard (see photograph 6).

7. The islands where reefs are under threat should not be subjected to tourism development activity until the reef regain healthy condition.

8. Coral reef walking for various purposes such as oyster fishing , collection of shells etc. during low tide was noticed in many of the atoll lagoons (photograph 7). This should be prevented.

10. It is necessary to demarcate zones as multi-purpose marine parks and /or sanctuaries in order to further strengthen conservation.

It might be more judicious to make a beginning by stopping the degradation of the most undisturbed of all coral reef areas, rather than attempting to manage all the coral resources as a whole. Simultaneous efforts should also be made to formulate general legislation that would prevent or stop activities that cause degradation of the reefs as a whole, and to develop an appropriate machinery for their enforcement. Very essential or unavoidable development activities should be allowed in all inhabited atolls.

5.5 Recommendations

The coral reefs of the Lakshadweep islands are the lifeline for the continued existence of the islands. They protect the islands against sea erosion by means of breaking the sustained wave action. For this reason coral mining or collection of dead coral heads for the construction purpose, has to be strictly controlled. The only means to control this is the supply of alternative construction materials from the main land. Major human interference like large scale dredging and blasting which has been done in the past should not be allowed . Only maintenance dredging and controlled blasting should be allowed. The dredged sand and coral debris have to be discarded on

Photograph 6.: One of the steps taken by department of Science, Technology and Environment, U.T. of Lakshadweep to protect the environment.

Photograph 7.: Coral reef walking - An activity which destroy live corals.

the islands themselves and might be used to protect beaches. For example the lagoon beach at Kavarathi might be yearly heightened with the sand from the maintenance dredging. This will avoid a negative sand budget of the islands and avoid the loss of excessive sand from the island ecosystem.

Negative impacts of tourism development on the life of corals have to be checked. These include excessive anchoring of boats, breaking of coral heads, pollution by sewage facilities etc. It seems that international tourism can be of considerable economic importance for the Lakshadweep islands. Therefore, care has to taken to avoid the negative side effects of this type of tourism development. The water quality of Kavarathi atoll has to be checked on a regular basis in order to detect pollution by oil or sewage. The Kavarathi lagoon already shows some signs of eutrophication, probably caused by leaching of polluted ground water into the lagoon. Septic tank system on the islands have to be improved to such an extent that fresh ground water pollution by inadequately treated sewage does not occur.

Islanders use the traditional pole and line fishing method for catching tuna. This method requires live bait collected from coral colonies, resulting in reef damage. Thus, an increase in fishing activities will adversely effect the reefs. Modern methods need to be adopted to increase the tuna yield. Rodrigues (1996) recommended a fisheries co-operative society to be set up in collaboration with main-landers to adopt modern fishing techniques and float factories with bases at Kochi, Calicut and Mangalore. This will divert the pressure to mainland ports.

Extreme care has to be taken to avoid chronic oil spillage in the lagoon. At present small scale oil pollution occurs on all the islands where 200 liter oil drums

Table 18

SOURCES AND LOCATIONS OF CORAL DAMAGE IN INHABITED ATOLLS OF LAKSHADWEEP

Activity	Consequences	Location	Possible remedies
1. Dredging of channels	Coral mortality, erosion	From entrance to jetty	Ban/regulate
2.Collection of corals for construction of houses, white washing	Coral mortality, reef damage	Mainly eastern side of inhabited atolls	Ban/ provide subsidies for transport of materials from mainland
3.Collection of live corals and shells and reef walking	Coral mortality, reef damage	Western reef during low tide.	Ban/discourage
4. Tourism	Collection of corals, shells, reef damage Damage to corals due to anchor operations of tourist boats	Lagoon and reef	Ban coral picking , Ban/discourage/regulate collection of shells Provide mooring buoys
5. Collection of live bait for fishing	Reef damage	Lagoon and reef	Culture of live bait, introduction of modern fishing techniques
6. Octopus hunting	Reef walking, Reef damage	Western reef	Ban
7. Domestic waste disposal		Two sides of the inhabited area of land	Regulate
8. Pollution by oil hydrocarbons	Reef damage	Lagoon	Regulate

are unloaded by local vessels. The estimation of the PHC concentration in lagoon waters of Kavarathi and Kadmat done during the present investigation shows a maximum of 1 ppb at Kavarathi and 0.4 ppb at Kadmat. Eventhough these values are not significant, care has to be taken to avoid oil spill caused by pumping a water/oil mixture from the engine hold of fishing vessels into the lagoon, discharge of diesel oil from the Suheli and the Odams (the marine vessels carrying diesel oil from main land) (see table 18).

SUMMARY

1. The main of the work centres around a survey of the coral lagoons of the Lakshadweep with a view to understand the general distribution of orgasmic assemblage especially corals based on general morphology. Therefore, Line Intercept Transect (LIT) technique has been utilized to conduct the investigation.

2. The topic of study is explained in the chapter general introduction.

3. The second chapter deals with the surveys of the lagoon employing the LIT technique. The literature associated with similar studies is reviewed. The material and methods are described and the results of the investigation of four islands are explained with suitable figures and tables. The findings are discussed with the help of available literature and the practical experience and knowledge gained during the numerous field trips conducted to these islands.

4. Chapter on hydrological study is devoted only to estimate and record the most common hydrographical parameters as it was not the intention of this study for a thorough investigation of the hydrography of the coral islands. From the results it has become apparent that the seasonal variations are normally available.

5. A detailed examination of various groups of lower marine invertebrates co-habiting with corals has indicated that `byrozoans' form the most important and diverse group of lophophores inhabiting the coral islands. Lack of specific knowledge of species and their diversity resulted in looking into the species composition of bryozoans associated coral reefs of Indian waters. A total of 30 species have been described here and the lesser known one have been described with suitable electron micrographs. The aspects

connected with distribution of this diverse tropical invertebrates has been attempted in this chapter.

6. Some thoughts have been expressed with refer to conservation of coral reefs as it was felt that this would help the planners and policy makers to understand the significance of conservation of coral reefs.

7. All important and relevant papers dealing with the subject matter of study have listed under reference.

REFERENCES CITED

Anonymous, 1984. *The coral paradise*. (Lakshadweep Secretariat) p.51.

*Audouin, J.V., 1826. *Explication sommaire des Planchesde Polypes de l'Egypte et de la Syrie. In, Description de l'Egypte, Hist. Nat. 1, Pt.4*

Benayahu Y and Y. Loya, 1977. Space partitioning by stony corals, soft corals and benthic algae on the coral reefs of the northern Gulf of Eilat (Red Sea). *Helgolander wiss. Meeresunters*, **30**: 362-382.

Benayahu Y and Y. Loya, 1981. Competition for space among coral reef sessile organisms at Eilat, Red sea. *Bull. Mar. Sci.*, **31**: 514-522.

Bouchan, C, 1981. Quantitative study of the Scleractinian coral communities of a fringing reef of Reunion Island (Indian Ocean). *Mar. Ecol. Prog. Ser.*, **4**: 273-288.

Brabdury, R.H., Y.Loya, R.E.Reichelt and W.T.Williams, 1986. Pattern in the structural typology of benthic communities on two coral reefs of the central Great Barrier Reef. *Coral Reefs*, **4**: 161-167.

*Busk, G, 1852a. An account of the Polyzoa and Sertularian Zoophytes, collected in thevoyage of the "Rattlesnake" on the coast of Australia and the Louisade Archipelago, etc. Appendix no. IV. 343-402. In Mac Gillivray, J., *'Narrative of the voyage of H.M..S. Rattlesnake'. (T & W. Boone: London)*. **1**: 402.

*Busk, G, 1861. Zoophytology. Descriptions of new or imperfectly known polyzoa. No.1. *Quarterly Journal of Microscopical Science (n.s)* **1**: 153-156, Pls 34,35.

*Busk, G, 1884. Report on the polyzoa collected by H.M.S. Challenger during the year 1873-76. Part 1, The Cheilostomata. *Report on the scientific results of the voyage of H.M.S. "challenger", Zoology 10* **(30)**: 1-216.

*Canu, F, 1911. *Iconographie des Bryozoaires fossils de l'Argentine. Anale del Museo Nacional de Buenos Aires 21*: 215-291.

*Canu, F and Bassler, R.S, 1917. A synopsis of American Early Tertiary Cheilostome Bryozoa. *Bulletin of the U.S. National Museum* **96**: 1-87.

Canu, F and Bassler, R.S, 1928. Fossil and Recent Bryozoa of the Gulf of Mexico region. *Proc. U.S. natn. Mus.* **72 (14)**: 1-99.

Canu, F and Bassler, R.S, 1929. Bryozoa of the Phillippine Region. *Bull. U.S. natu. Mus.* **100 (9)**: 1-685.

Connel, J.H., 1978. Diversity in tropical rainforest and coral reefs. *Science*. **199**: 1302-1310.

Cook, P.L, 1968. Polyzoa from west Africa. The Malacostega. Part1. *Bull. Br. Mus. Nat. Hist. (Zool.)* **16**: 115-160.

Cuffey, R.J., 1973. Bryozoa distribution in the modern reefs of Eniwetok Atoll and the Bermuda platform. *Pacific Geology*, **6**: 25-30.

FAO, 1975. Manuel of methods in aquatic environment research. *FAO Fish. Tech. Paper*, 137: 1-238.

FAO, 1984. FAO species identification sheets for fishing purposes. Western Indian ocean (Fishing Area 51) Fischer, W and G Bianchi (Eds.). Vol. 1-6 (DANIDA), FAO, Rome.

*Fleming, J, 1828. Zoophyta. *History of British animals*. Edinburgh, London. pp.505-554.

Gardiner, J.S, (Ed.), 1903, 1906. *The Fauna and Geography of the Maldive and Laccadive Archipelagoes*. **1** & **2**: 470 & 1079 pp

Gardiner, J.S, 1904. Madreporaria pt.2. Asteidae. *Fauna and geography of the Maldive and Laccadive Archipelagoes*. **2**: 758-790. Pl. 59-64.

Gardiner, J.S, 1905. Madreporaria pt.3. Fungida. *Ibid.*, 2: 933-957, pls, 89-93.

Gates, C.E, 1979. Line transect and related issues. In: Cormack, R. M., Patil, G.P. and D.S.Robson (eds). *Sampling Biological Populations*. Inter. Co-op. Publishing House, Fairland, Maryland.

Girijavallabhan, K.G., .Davidraj, I and Alavandi, S.V, 1989. Hydrobiology of Lagoons. In: *Marine Living Resources of the Union Territory of Lakshadweep. CMFRI bulletin* **43**: 200-211.

Goswamy, S.C, 1973. Observations on some planktonic groups of Kavarathy Atoll (Laccadive). *Indian nat. sci. Acad.*, **391 (6)**: 676-686.

Goswamy, S.C, 1979. Zooplankton studies in the Laccadive sea (Lakshadweep). *NIO Tech. Rept.*, pp.180.

Gray, J.E, 1848. List of specimens of British animals in the collection of the British Museum. Part 1, Centroniae or radiated animals. *Polyzoa*, pp. 91-151.

*Greig-smith, P, 1964. Quantitative plant ecology, Butterworths, London.

Hall, D.N, 1984. Cheilostome Bryozoa from Townsville Harbour and Picnic Bay, North Queensland. *Proceedings of the Royal Society of Queensland*. **95**:

57-70.

*Harmer, S.F, 1923. On cellularine and other Polyzoa. *Journal of the Linnean Society of London, Zoology.* **35**: 5-41.

*Harmer, S.F, 1926. The Polyzoa of the Siboga Expedition. Part 2, Cheilostomata Anasca. *Siboga Expedition Reports* **28** B: 183-501.

*Harmer, S.F, 1957. The Polyzoa of the Siboga Expedition. Part 4, Cheilostomata Ascophora II. *Ibid.*

Hasting, A.B, 1930. Cheilostomatous Polyzoa from the vicinity of the Panama Canal collected by Dr. C. Crossland on the cruise of the S.Y. 'St.George', *Proc. Zool.Soc.Lond.* 1929. 697-740.

Hasting, A.B, 1939. Notes on some Cellularine Polyzoa (Bryozoa). *Novit. Zool. Tring.* **41**: 321-344.

*Haswell, W.A, 1881. *Ibid.* Pls 1-3.

*Haswell, W.A,. 1880. On some Polyzoa from the Queensland coast. *Proc. Linn. Soc. N.S.W.* **5:** 33-44.

Hincks, T, 1887. Critical notes on the Polyzoa. 1. Madeiran Polyzoa. *Annals and Magazine of Natural History* (5) **19**: 150-164.

Hughes, T.P. and Jackson, J.B.C, 1985. Population dynamics and life histories of foliaceous corals. *Ecol. Monogr.*, **55**: 141-166.

Hydrographic office, 1961. West coast of India Pilot. 10th Edition, Admiralty London.

IOC/UNESCO, 1984, Manuel for Monitoring oil and Dissolved/Dispersed Petroleum Hydrocabons in Marine water and on Beaches. *Manuels and Guides* **13**: 35

IUCN/UNEP/WWF, 1980. World coservation strategy. Coral Reefs. Ecosystem of the world. Ed. Z. Dubinsky (Elsevier science publishers B.V. 1990). **25**: 458.

Jackson, J.B.C., and Winston, J.E, 1982. Ecology of cryptic coral reef communities. 1.Distribution and abundance of major groups. *Jour. Exp. Mar. Biol. Ecol.* **57**: 135-147.

James, P.S.R.B., Pillai, C.S.G., Thomas, P.A., James, D.B and Said Koya, 1989. Environmental damage and consequences., In: CMFRI Bulletin .*Marine living resources of the Union Territory of Lakshadweep,* **43:** 212-227.

Jayaraman, R.,. Ramamirtham, C.P., Sundadaraman, K.V., and. Aravindakshan Nair, C.P, 1960. Hydrography of the Laccadive offshore waters. *J. mar. biol. Ass. India*, **2**(1): 24-35.

*Jullien, J, 1882. *Note sur une nouvelle Division des Bryozoaires Cheilostomes. Bull. Soc. zool. Fr.*, **6**: 271-285.

Kenchigton R.A and Hudson B.E.T, 1984. Coral Reef Management Hand book. UNESCO, Jakarta Indonesia, 281pp.

Kirkpatrick, R.I, 1890a. Report upon the Hydrozoa and Polyzoa collected in the China sea. *Ann. Mag. nat. Hist., 6,* **5:** 11-24.

*La gaaiji, R, 1963a. Cupuladria canariensis (Busk)- portrait of a bryozoan. *Palaeontology 6,* **1**: 172-217. Pls. 25-26.

*Lamouroux, J.V.F, 1816. *Historic des polypiers coralligens flexibles caen.*

*Lamouroux, J.V.F, 1821. *Exposition methodique des genus des polypiers,* Paris.

Laxton, J.H., Stablum, W.J, 1974. Sample design for quantitative estimation of sedentary organisms of coral reefs. *Biol. J. Linn. Soc.*, **6**: 1-18.

Loya, Y, 1972. Community structure and species diversity of hermatypic corals at Eilat, Red sea. *Mar. Biol.* **13**: 100-123.

Loya, Y, 1975. Possible effects of water pollution on the community structure of Red sea corals. *Mar. Biol.*, **29**: 177-185.

Loya, Y, 1976. Effects of water turbidity and sedimentation on the community structure of Puerto Rican corals. *Bull. mar. Sci.*, **26**: 450-466.

Loya, Y and Slobodkin, L. B., 1971. The coral reefs of Eilat (Gulf of Eilat, Red sea). *Symb. Zool. Soc., Lond.*, **28**, 117-139. In: D.R. Stoddart and C.M. Yonge, (eds.). *Regional variation in Indian Ocean coral reefs.* London and New York, Academic press (pp 584).

Lyndon M. De Vantier, 1986. Studies in the assessment of coral reef ecosystem. In: *Human induced damage to coral reefs,* UNESCO reports in marine sciences, **40**: 99-111.

*Mac Gillivray, P.H, 1869. Descriptions of some new genera and species of Australian Polyzoa. *Trans. Proc. roy. soc. vict.*, **9**: 126-148.

Mannadir, N.S.(ED), 1977. *Lakshadweep.* Gazetteer of India, Administration of Union Territory of Lakshadweep, Kavarathi, pp.375.

Mapstone, B.D., Choat, J.H, Cumming, R.L, and Oxley, W.G, 1989. The fringing reefs of Magnetic Island: benthic biota and sedimentation. A baseline study. A report to the Great Barrier Reef Marine Park Authority, pp.88.

Marsh, L.M., Bradbury, R.H and Reichelt, R.E, 1984. Determination of the physical parameters of coral distributions using line transect data. *Coral Reefs*, **2**:

173-180.

*Mayor, A.G, 1918. Ecology of the Murray Island coral reef. *Papers Dept. Mar.Biol. Carnegie. Inst.* **9**: 1-48.

*Mayor, A.G, 1924. Structure and ecology of Samoan reefs. *Ibid*. **19**: 1-25.

Menon, N.R, 1971. Vertical and horizontal distribution of fouling bryozoans in Cochin Backwaters, south-west coast of India. *International Bryozoology Association, 2nd International Conference (England)*, 153-164.

Menon, N.R, 1972. Species of the genera *Parasmittina* (Bryozoa, Ascophora) from Indian waters. *Mar. Biol.* **14** (1): 72-84.

Menon, N.R., Nair, N.B, 1975. Indian Species of Malacostega (Polyzoa, Ectoprocta), *J. mar. biol. Ass. India.* **17** (3): 553-579.

Moran, P.J., R.H. Bradbury and R.E. Reichelt, 1986. Mesoscale studies of the crown-of-thorns/coral interaction: a case history from the Great Barrier Reef. In: *Proceedings of the Fifth International Coral Reef Symposium*, Tahiti, **5**: 321-326.

Nair, P.V.R, Murty, A.V.S, Ramamirtham C.P., Rao, D.S and Pillai, V.K, 1986. Environmental features of the sea around Lakshadweep. *Mar. Fish. Infor. Serv. T & E. Ser.* **68**: 10-13.

Nandini Menon, N, 1997. Investigation on the effects of petroleum hydrocarbons on the marine bivalve, Perna viridis and Sunetta scripta, Ph.D thesis, Cochin University of Science and Technology, 172 pp.

Navas, K.A, 1993. Present status of coral erosion in Lakshadweep with special reference to Minicoy. Ph.D thesis, Cochin University of Science and Technology, 182pp.

Odum, H.T. and Odum, E.P, 1955. Trophic structure and productivity of a windward coral reef community on Eniwetok Atoll. *Ecol. Monog.*, **25**: 291-320.

Okada, Y and Mawatari, S, 1936. Bryozoa fauna collected the 'Misago' during the zoological survey around Izu Peninsula (II). *Sci. Rep. Tokyo. Burnika Daigaku.*, *3*, **49**: 53-73, pls.9-10.

*Oken, 1815. *Lehrebuch der Naturgeschichte, 3, Theil. Zoologie, I Abth., Fleischlose Thiere Leipzip.*

Osburn, R.C, 1950. Bryozoa of the Pacific coast of America. Part 1, Cheilostomata-Anasca, *Rep. Allan. Hancock Pacific Exped. 14*, **1**: 1-269, pls. 1-29.

Osburn, R.C, 1952. Bryozoa of the Pacific coast of America. Part 2, Cheilostomat-

Ascophora, *Ibid.*, *14*, **2**: 271-611, pls. 30-64.

Osburn, R.C, 1953. Bryozoa of the Pacific coast of America. Part 3. Cyclostomata-ctenostomata, Entoprocta and Addenda, *Ibid.*, *14*, **3**: 613-841, pls.65-82.

Ott, B, 1975. Quantitative analysis of community pattern and structure on a coral reef bank in Barbados, West Indies. Ph.D thesis, Mc Gill University, pp.156.

Patil, M.R and Ramamirtham, C.P, 1963. Hydrography of Laccadive offshore waters. A study of the winter conditions. *J.mar.biol.Ass.India.* **5** (2): 159

Peres J.M and Picard J, 1969. *Reflexions sur la structure trophique des edifices recifauz. Mar. Biol.* **3**: 227-232.

*Pielon, E.C, 1977. "Mathematical ecology". Wiley, New York.

*Pieper 1881. *Eine neue Bryozoe der Adria: Gemellaria(?) avicularis. Jahresbericht des Westfalischen Provinzialvereins fur Wissenschaft und Kunst* **9**: 43-48

Pillai, C.S.G, 1971. Distribution of shallow-water stony corals at Minicoy Atoll in the Indian Ocean. *Atoll Res. Bull. Wash.* **141**: 1-12.

Pillai, C.S.G, 1971a. Composition of the coral fauna of the south-eastern coast of India and the Laccadives. In: *Regional Variation in Indian Ocean Coral reefs. Symp. Zool. Soc.Lond.*,**28**: 301-327.

Pillai, C.S.G, 1975. An assessment of the effects of environment and human interference on the coral reefs of Palk Bay and Gulf of Mannar along the Indian coast. *Seafood Export J.*, **7(12):** 1-13.

Pillai, C.S.G, 1983a. The endangered marine and terrestrial habitats of Minicoy Atoll in Lakshadweep. *Proc. Seminar. World. Conservation. Developing countries,* Bombay, *nat. Hist. Soc,* (in press).

Pillai, C.S.G, 1985. Ecological crisis in coastal and marine habitats. In: *India's Environment- Crisis and Responses.* Nataraj publication, Dehradun: 120-130.

Pillai, C.S.G, 1986. Status of coral reefs in Lakshadweep. *Mar. Fish. Infor. Serv. T & E Ser.*, **68**: 38-41.

Pillai, C.S.G, 1987. Structure and generic diversity of recent Scleractina of India. *J. Mar. Biol.Ass. India* **25** (1&2): 78-90.

Pillai, C.S.G, 1989. Environmental Damage and Consequences. In: CMFRI bulletin-**43** *Marine Living Resources of the Union Territorry of Lakshadweep.* 212-227.

Pillai, C.S.G and Madan Mohan ,1986a. Ecological stress in Minicoy lagoon and its impact on tuna-baits. *Mar. Fish. Infor. Serv. T & E Ser.*, **68**: 33-37.

Pillai, C.S.G and Scheer, G, 1976. Report on the stony corals from the Maldive Archipelago. *Zoologica* (stuff) **126**: 1-83pls, 1-32.

*Porter J.W, 1972a. Ecology and species diversity of coral reefs on opposite sides of the Isthmus of Panama. In: M.L. Jones, (ed.), The Panama Biota- A symposium prior to the sea level canal. *Bull. Biol. Soc. Wash.* **2** : 89-116.

Porter J.W, 1972b. Patterns of species diversity in Caribean reef corals, *Ecology*, **53**: 745-748.

Qasim, S.Z, Bhattathiri, P.M.A and Reddy, C.V.G, 1972. Primary production of an atoll in the Laccadives. *Int. Reves. Ges. Hydrobiol.*, **57**(2): 207-225.

Qasim, S.Z., Nair, P.N.R and Sivadas, P, 1974. Oil spill in the Laccadives from the oil tanker `Transhuroon'. *Mahasagar*, 7: (1&2): 83-91.

Rao Panakala, D, Sarme, R.V.S, Sastry, J.S and Premachand K, 1976. On the lowering of the surface temperature in Arabian sea with the advance of south west mosoon season. *Proc. 11th Symp. on. Tropical Monsoons*, Pune, India.

Rasheed, K and Balchand A.N, 1997. Dredging impact assessment (DIA) at Cochin Port. Iind Indian National Conference on Harbour and Ocean Engineering (Inchoe-97), Thiruvananthapuram, 586-594.

*Reichelt , R.E, Loya, Y and Bradbury, R.H. (in Press). The use of space by the major benthic groups on Davies and Myrmidon Reefs, Great Barrier Reef. *Marine Ecology*, P.S.N.Z.I.

Rodrigues C.L, 1996. Taxonomic and ecological survey of the Lakshadweep for Perumal Marine Park. Project completion Report, Dept. of Marine Sciences and Marine Biotechnology, Goa University, 47pp.

Rogers, C.S, 1990. Response of coral reefs and reef oraganisms to sedimentation. *Mar.Ecol.Pros.Ser.*, **62**: 185-202.

Ryland, J.S and Hayward, P.J. 1992. Bryozoa from Heron Island, Great Barrier Reef. *Memoirs of the Queensland Museum* **32(1):** 223-301.

Ryland, J.S, 1960. The British species of *Bugula* (polyzoa). *Proc. Zool. Soc. London.*, **134**: 65-105.

Ryland, J.S, 1965. "Catalogue of Main Marine Fouling Organisms (found on ships coming to European waters). Vol. 2: Polyzoa". Organisation for Economic Co-operation and Development, Paris. pp.83.

Ryland, J.S, 1970. *Bryozoans*. Hutchinson University Library, London. pp.1.75

Ryland, J.S, 1974. Bryozoa in the Great Barrier Reef Province. Proceedings of the 2nd International Coral Reef Symposium. **1**: 341-348.

Ryland, J.S, 1984. Phylum Bryozoa. In: A Coral Reef Handbook, 2nd ed. (The Australian Coral Reef Society : Brisbone) Eds. Mather, P and Bennett, I. 68-75.

Sankaranarayan ,V.N,1973. Chemical characteristics of waters around Kavarathi Atoll (Laccadives), *Indian J. Mar. Sci.*, **2**: 23-26.

Scheer, G and Pillai C.S.G, 1974. Report on the scleractinia from the Nicobar Islands. *Zoologica Stutt* **122**: 1-75.

Scheer, G and Pillai C.S.G, 1983. Report on the stony corals from Red sea. *Zoologica* (Stuff), **133**: 1-198pls, 41.

Sen Gupta, R, Caroline Moraes, Kureishy T.N, Sankaranarayanan V.N, Jana T.K, Naqvi S.W.A and Rajagopal M.D, 1979. Chemical oceanography of Arabian sea. Part IV- Laccadive sea. *Indian J.Mar.Sci.*, **8**: 215-221.

Silen, L, 1942. Cheilostomata Anasca (Bryozoa) collected by Prof.Dr. Sixten Bock's expeditionto Japan and the Bonin Islands 1914. *Ark. Zool.* **33 A (12):** 1-130. 9 pls.

Sivadas, P, 1987. Possible threats to the marine environment and ecology of Lakshadweep (Laccadive islands). *Environmental conservation* **14**(4): 361-363.

*Smith, S.V, 1978. Coral reefs aren and contributions of reefs to processes and resources of the world oceans. *Nature, Lond.*, **273**: 225-226.

Southwood, T.R, 1966. *Ecological methods*. Methuen, London.

Stach, L.W, 1936. Studies on Recent Petraliidae (Bryozoa). *Rec. Australian. Mus.*, **19**: 355-379.

Stoddart, D.R, 1969. Ecology and morphology of recent coral reefs. *Biol. Rev. Camb. Philos. Soc.*, **44**: 433-98.

Stoddart, D.R, 1972. Field methods in the study of coral reefs. In: Proc. Symp. Corals and Coral reefs. *Mar.Biol.Assoc. India*. 71-80.

Stoddart, D.R, Davies, P.S, Keith, A.C. 1966. Geomorphology of Addu Atoll. *Atoll. Res. Bull.*, **116**: 13-41.

Strickland, J.D.H and Parson, T.R, 1968. A practical Hand-Book of seawater

Analysis. *Fish. Res. Board. Can. Bull.*, ***167:*** 311pp

Suresh, 1991. Studies on the coral reefs of Lakshadweep, Ph. D., Thesis. CUSAT

*Thorney, L.R, 1905. Report on the polyzoan collected by Prof. Herdmann, at Ceylon, in 1902. Report to the Government of Ceylon on the pearl oyster fisheries of the Gulf of Mannar **4** (supplementary report 26): 107-130.

*Thorney, L.R, 1907. Report on the marine polyzoa in the collection of the Indian Museum. *Rec. Indian. Mus.* **1**: 179-196.

*Thorney, L.R, 1912. The marine polyzoa of the Indian ocean, from H.M.S. sealark. *Trans. Linn. Soc. Lond. (Zool.)* **15**: 137-157.

Tranter, D.J and Jacob George, 1972. Zooplankton abundance at Kavarathi and Kalpeni atolls in the Laccadive sea. In: *Proc. Symp. Corals and coral reefs*: Mar. Biol. Ass. India, 239-256.

UNEP, Regional Seas, 1993. Monitoring coral reefs for global change. *Reference Methods for Marine Pollution studies* **61**: 1-72.

UNESCO, 1984. Manuel for monitoring oil and dissolved/dispersed petroleum hydrocarbons in marine waters and on beaches, 35 pp.

Varkey, M.J, Kesava Das and Rama Raja D.V, 1979. Physical characteristics of the Laccadive sea (Lakshadweep). *Indian. J. Mar. Sci.*, **8**: 203-210.

*Vaughan, T.W, 1911. Physical conditions under which paleozoic coral reefs were formed. *Geol. Soc. Am. Bull.*, **22**: 238-252.

Victor, A.C.C, Chellam A and Ramdoss, K, 1989. Underwater obsevation in the lagoons. In: CMFRI Bulletin . *Marine living resources of the Union Territory of Lakshadweep*, **43:** 212-227 .

Wafer, M.V.M, 1986. Corals and coral reefs of India. *Proc. Indian Acad. Sci. (Anim. Sci.) suppl.*, 19-43.

Wallace, C, 1974. Distribution patterns of the coral genus *Acropora* on the reef slope: A preliminary report. Paper presented at the 2nd Crown of Thorns Symposium, Brisbane, pp.18.

*Waters , A.W, 1909. Reports on the marine biology of the Sudanese Red Sea, from collections made by Cyril crossland, together with collection made in the Red Sea by Hartmeyer. Xii. The Bryozoa. Part 1. Cheilostoma. *J. Linn. Soc. (Zool)* **31**: 123-181.

Webb, L.J., Tracy J.G, Williams, W.T and Lance, G.N, 1970. Studies in the numerical analysis of complex rainforest communities. V. A comparison of the properties of floristic and physiognomic- structural dat. *Journal of*

Ecology, **58**: 203-232.

*Wilkinson, C.R, 1993. Proceeding 7th International Coral Reef Symposium, University of Guam, Mangilao, in press.

Winston, J.E and Heimberg, B.F, 1986. Bryozoans from Bali, Lombok and Komodo. *Lbid.*, **2847**: 1-49.

Winston, J.E and Jackson, J.B.C, 1984. Ecology of cryptic coral reef communities. IV. Life histories of encrusting cheilostomes. *Jour. Exp. Mar. Biol. Ecol.* **76**: 1-21.

Winston, J.E, 1986. An annotated check list of coral associated bryozoans. *Am.Mus.Novit*, **2359**: 1-39.

* Not referred in original