STUDIES ON THE CORAL REEFS OF LAKSHADWEEP

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By

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KOCHI - 682 031

JULY 1991

DEDICATED TO MY PARENTS

CERTIFICATE

This is to certify that this thesis entitled **Studies on the Coral Reefs of Lakshadweep** embodies the bonafide original research work conducted by Shri **Suresh, V.R.** under my supervision and guidance. I further certify that no part of this thesis has previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles or recognition.

Kochi - 682 031,

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DECLARATION

I hereby declare that this thesis entitled **Studies on the Coral Reefs of Lakshadweep** is a record of original and bonafide research carried out by me under the supervision and guidance of **Dr. K.J. Mathew**, Scientist, Central Marine Fisheries Research Institute, Kochi, and that no part thereof has been presented for the award of any other degree, diploma, associateship, fellowship or other similar recognition.

Kochi - 682 031,

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SURESH, V. R

PREFACE

Popular books and monographs described a romantic image of the coral islands, which if one observes from outside the water is not entirely justified. Once beneath the waves, however, the coral islands show a fantastic and very beautiful world, where the exceptionally diverse organisms involving plants and animals form a complex web of interrelationship. A coral reef is defined (Vaughan, 1991) as "a ridge or mount of limestone, the upper surface of which lies, or lay at the time of its formation, near the level of the sea, and predominantly composed of calcium carbonate secreted by organisms, of which the most important are corals".

Coral reefs of the world cover an estimated area of $6x10^5$ km^2, equivalent to 0.7% of the world ocean area, distributed to seas where temperature never falls below 22°C. Over half of this (54%) lies in the Asiatic Mediterranean and Indian Ocean. Of the remaining, Pacific reefs account for 25%, Atlantic reefs for 6%, Caribbean reefs for 9%, Red Sea reefs for 4%, and Persian Gulf reefs for 2% (Smith, 1978).

Coral reefs are areas of rich living and nonliving resources, and one of the most productive ecosystems known to man, with annual gross production rates in the range of 2,000-5,000 g C/m^2 (Mann, 1982). From time immemorial man has put coral reefs into many uses like fishing, building materials, ornaments, tourism and sports, and more recently for complex organic chemicals (Salm, 1988). Fishing is the most important use of coral reefs to many people and fishes form the major exploited resource on coral reefs. The estimated potential fish yield from world reefs may vary from 6 million (Smith, 1978) to 9 million tonnes per year (Munro, 1985). Reefs are a treasure trove of invertebrate and fish species for the marine aquarist. Export of this is an important industry in many developing countries (Salm, 1988). About 50,000 people are either directly or indirectly involved in the export of aquarium fish from Sri Lanka, where the industry now earns about U.S. $ 1.1 million per annum (Salm , 1988).

Turtles, lobsters, octopus, clams, oysters, ornamental shells, seaweeds and pearls form a major portion of reef fishery. Dead coral rocks are mined from reefs for the production of lime, calcium carbide and building materials (Salm, 1988). Recreation and tourism to reefs are another source of revenue to several countries. SCUBA diving, snorkelling, fish watching and underwater photography in reefs are growing in popularity. Apart from all these, artificial culture of finfish and shellfish to a large degree, is a new reef industry in many world reefs. For example the Marutea lagoon in the French Polynesia is being intensively used for pearl culture (Ward, 1985). Thus a coral reef can be used in a number of ways, and there is no reason why it should not support a certain amount of local industry, if the level of exploitation does not exceed the level of replenishment.

India has a rich resource of coral reefs in the Palk Bay, Gulf of Mannar, Gulf of Kutch, Andaman and Nicobar Islands and Lakshadweep. Lakshadweep is a group of enchanting coral islands, irregularely scattered in the Arabian Sea, between 08° 00' and 12° 30' N. Latitude and between 71° 00' and 74° 00' E. Longitude. The entire Lakshadweep group of islands lie on the northern edge of the 2,500 km long north-south aligned submarine "Lakshadweep Chagos Ridge" rising form a depth of 2,000-4,000 m in the Arabian Sea. The archipelago consists of 27 islands and a number of Sunken banks, open reefs and sand banks. Of these 10 islands are inhabited by man, while others are small and exist as satellites of the inhabited islands (Mannadiar, 1977). Information on the geographical features, land flora and fauna, history etc. are given by Mannadiar (1977).

These islands still remain to be one of the least studied group of coral islands in the Indian Ocean for its reef resources, ecology, biology, and environmental status. They are biologically very significant in view of the isolation from major continental coast line as well as for their rich and varied marine life (Pillai, 1986).

The geographic isolation of the Lakshadweep from the mainland has been a major impediment to maintain status-quo with the progress

and development on the mainland (James, 1989). Of late government of India has assigned top priority for a planned development of its island territories and an emphasis has been made for a conducive growth of the economy and living standards of the islanders. Since the land based resources therein being very limited, future development have to be oriented toward the sea surrounding these tiny islands (Jones, 1986). There is a wide consensus that the living resources around these islands hold immense potential for exploitation (James, 1989) and the vast comparatively shallow, practically calm and protected lagoons of Lakshadweep could provide excellent areas for culture and farming of marine organisms. There have been proposals to initiate mariculture in this area (Alagar swami et al., 1989; Lalmohan et al., 1989) But coral reef ecosystem at Lakshadweep is reported to be deteriorating due to various natural and manmade interferences (Pillai, 1983, 1985, 1986; Wafar, 1986 and James et al., 1989).

Detailed information is required to provide necessary back-stop for a perspective planning and development of these islands. Our knowledge on the marine living resources of these atolls, their environmental conditions (Physical, chemical and biological), their fluctuations and dynamics in the lagoons over a long period of time, the state of growth and maintenance of reefs and the extent of damage occured to the ecosystem are scanty. Fisheries and oceanographic research in this area have recently been reviewed by James (1989). Though there are a number references available from this area, many are results of short term studies carried out at wide intervals. Detailed information on the distribution and availability of living marine resources, dynamics of the important oceanographical and biological parameters in the lagoon, growth and maintenance of corals in the system and environmental damage, are almost lacking from Lakshadweep. A deep knowledge on all these aspects are necessary pre-requisite for planning future utilization of the resources, introduction of culture fisheries in this environment and management and conservation of this ecosystem. It would also provide information to fill up several lacunae with regard to reef biology and oceanography of this area.

With the realization of the need for the above study on Lakshadweep coral reefs, attempts have been made during the present investigation to approach this ecosystem from three different view points; they being (1) Resource point of view, (2) Ecological point of view, and (3) Conservational point of view.

Result of the studies conducted for a period of two years (January, 1988 to 1989, December) are embodied in the present thesis entitled "Studies on the Coral Reefs of Lakshadweep", which consists of four chapters, a short Summary and a Reference section of the literature sited in the text. Chapters 1 to 3 have each an "Introduction" with a brief review of literature relevent to the chapter, "Materials and methods" which explains the methodology involved, "Results" which gives the data obtained and "Discussion", in which the results are discussed in detail. Chapter - 4 has an introduction and a brief description on the state of Lakshadweep coral reef and their management.

The first chapter deals with the faunistic survey conducted at Lakshadweep Atolls, to get an idea about the present status of major living marine resources and their distribution in the lagoons.

Results of an intensive study on the hydrobiological conditions such as hydrography primary productivity, zooplankton distribution and fluctuation and dynamics of these parameters in the selected Kavaratti Atoll form the second chapter.

Environmental factors play a significant role in the growth and survival of corals. For the first time in India, the growth of corals and factors influencing their growth have been studied inorder to provide a base line information on growth and there by assessing the quality of the environment. The above aspect form the content of the third chapter.

Results of the observations made in the islands to assess the state of interference and damage caused to the reefs, need for conservation and possible measures for the management of the system are presented in the fourth chapter.

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Suresh, V.R

CONTENTS

CHAPTER - I

FAUNISTIC SURVEY OF LAKSHADWEEP ATOLLS

INTRODUCTION

The living resources in and around the Lakshadweep Islands hold great potential for exploitation. Ever since human settlement in these islands, a variety of marine living resources available in the lagoons and surrounding oceanic water have been in different state of exploitation. The rich and vast resources available at Lakshadweep have attracted many explorers, and has been a subject of great interest. But from a resource point of view, the Lakshadweep archipelago was not studied seriously. The marine biological and fisheries research in the Lakshadweep Sea and lagoons dates back to the last quarter of the 19th centuary, started with the attempt by British naturalists like A. Alcock during 1891. Next important marine biological event in this region was that of the Cambridge University expedition led by Prof. J. Stanley Gardiner. Results of this expedition were reported in the two volumes of "The Fauna and Geography of the Maldive and Laccadive Archipelagoes" (Gardiner, 1903, 1906). Early information on the marine fauna of Lakshadweep are mostly based on the various articles published in this two volumes.

Coelenterates studied from Lakshadweep were mainly corals by Gardiner in his studies during the expedition. Information on corals, their taxonomy and distribution in this area have been elaborated by Pillai (1971, 1971a, 1972, 1986a, 1987). Despite these works, the coral fauna of Lakshadweep, except that of Minicoy, remained virtually unknown to the scientific community. Pillai (1987) presented a resume of corals and coral reef of this area and reported a total of 78 species of corals divided among 31 genera, based on the studies at Minicoy and Kiltan Islands. Pillai and Jasmine (1989) in a recent report, increased the number of species to 104, which they divided among 37 genera, through a survey extended to other islands of Lakshadweep.

Information on the crustacean resources of Lakshadweep is limited to only a few faunistic reports on crabs, lobsters, prawns, and stomatopods. Early studies on the brachyuran crabs and lobsters of this area are those of Borradaile, published in the two volumes of "Fauna and Geography of the Maldive and Laccadive Archipelagoes". Stomatopods from Lakshadweep have been studied by Lanchester (1903) and Shanbhogue (1986). Sankaran Kutty (1961) recorded 27 species of crabs from Minicoy and 9 species from Kavaratti, Amini, and Bitra islands. Meiyappan and Kathiravel (1978) published new records of brachyuran crabs like Grapsus albolineatus, Cardiosoma carnifex, lobsters like Panulirus homarus and Parribacus antarticus from Minicoy Island. Pillai et al. (1984) recorded Panulirus versicolor from Minicoy and also reported its seasonality in distribution.

Early records of echinoderms from Lakshadweep is that of Bell (1902). He reported 4 species of starfishes from Minicoy. Three species of holothurians have been reported by Kochler and Vaney (1908), and 40 species of echinoderms from various islands of Lakshadweep by James (1969). Nagabhushan and Rao (1972) reported 49 species of echinoderms from Minicoy Island. James (1973) described a new species of starfish. Daniel and Haldar (1974) have listed 23 species of echinoderms from Lakshadweep including deep sea forms. Sivadas (1977) and Murty, et al. (1979) have reported the occurrence of "Crown of Thorns" starfish Acanthaster planci at Lakshadweep. Twleve species of shallow water holothurians from Androth, Kalpeni, and Minicoy were noted by Mukhopaday and Samanta (1983). Recently James (1989) published a list of echinoderms of Lakshadweep and their zoogeography, in which 78 species are recorded.

A scrutiny of the literature on the fauna of Lakshadweep reveals that there are only scanty reports on molluscs from these islands. Early studies on the molluscan fauna are those of Eliot (1906), Hoyle (1906), Smith (1906), and Burton (1940). Appukuttan (1973) observed 9 species of coral boring bivalves. Rao et al. (1974) reported three rare dorideferan nudibranch molluscs and Panicker (1978) studied the marine gastropod shells

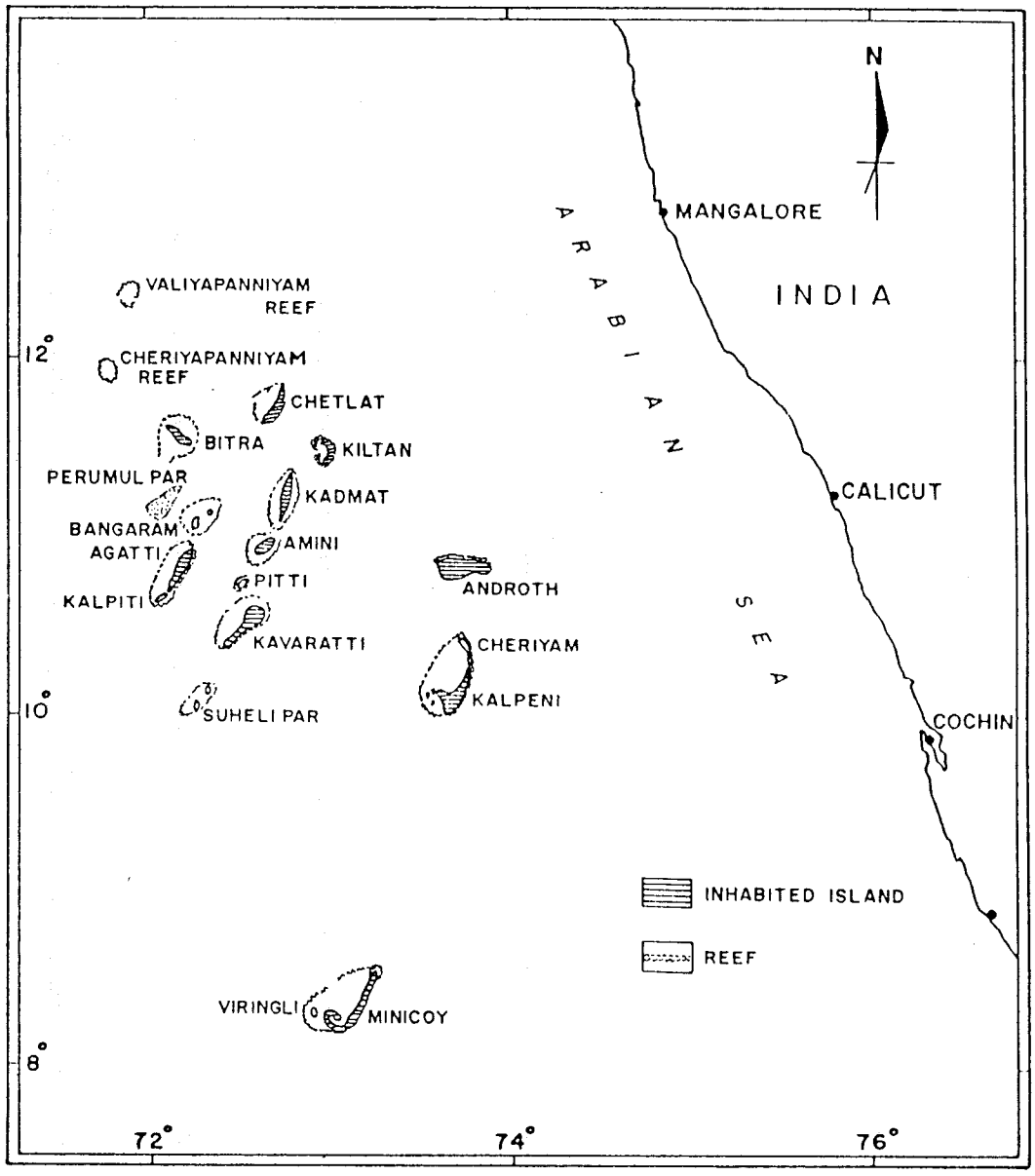
of this area. Zonation of molluscan assemblage at Kavaratti atoll has been studied by Namboodiri and Sivadas (1979).

Ichthyofauna of Lakshadweep attained special interest from very long since. Some of the early accounts on this are that of Alcock in his survey during 1891. On a visit to Lakshadweep Balan (1958) documented 80 species of fishes belonging to 65 genera. Jones (1960, 1969), Jones and Kumaran (1967, 1967a, 1971) and Jones et al. (1969, 1970) have elaborated the list of ichthyofauna. "Fishes of Lakshadweep Archipelago" by Jones and Kumaran (1980) is the most comprehensive account of the fish fauna of Lakshadweep, which documented 603 species of fishes. Kumaran et al. (1989) gave an accont of live bait resources and its development. Suggestions for exploitation on commercial basis and export of ornamental fishes from Lakshadweep were made by Tomey (1985), James (1987). Murty et al. (1989) surveyed the resources of ornamental fishes and presented an account of their distribution in Lakshadweep.

MATERIALS AND METHODS

During the study period, 10 islands of Lakshadweep namely Kavaratti Agatti , Bangaram, Amini, Kadmat , Kalpeni, Chetlat, Suheli, and Minicoy were visited. Out of these, all except Suheli and Minicoy, were surveyed. All the surveys were made between January and May 1988 and 1989. Location of these and other islands of Lakshadweep in Arabian Sea is shown in Figure 1.

Detailed survey methods prescribed for coral reefs which involve extensive diving and personnel support, could not be undertaken at Lakshadeep, because of the remoteness of the place and personal and infrastructural constraints. Therefore a combination of general "limited-time survey"(DeSilva, 1984) and random quadret survey method were used to study the major faunistic components such as corals, crustaceans, molluscs, echinoderms and fishes. Details of the methods employed for each group are given below.



Figur· Geographic location of Lakshadweep group of islands in Arabian Sea (Islands are not in scale).

Corals

For the survey of corals, the lagoon area was broadly grouped into different ecological zones such as lagoon flat, reef flat, reef crust, and leeward reef of the island (UNESCO, 1984). In all these zones, four quadrets of 10 x 10 m each were selected randomly and each quadret was intensively surveyed for its coral fauna in a limited time period of 2 hours during low tides. Small samples were detached from coral colonies using hammer and chisel and covered in numbered polythene bags. Care was taken not to damage any colonies. In deeper areas, snorkel diving (Plate 1a) was adopted upto a depth of four metres. Small samples were cleaned off all the tissues by keeping them in a solution of equal parts by weight of sodium hypochlorate and sodium carbonate (Veron and Pichon, 1976) and then washed in freshwater. Larger samples were kept in freshwater for two days and washed with a jet of freshwater. The washed samples were dried in sunlight, labelled and stored in polythene bags.

Crustaceans, Molluscs and Echinoderms

Crustaceans, molluscs and echinoderms were collected in separate surveys from different quadrets of 10 x 10 m - the ideal method for macro-invertebrates (Birkeland, 1984) - in all the above mentioned zones, and also from same type of quardrets in the intertidal beach zone and the seagrass beds in a limited time of 2 hours each. Long forceps, scoopnets and small beach seines were used for the collection. Swimming with face mask and snorkel was found to be very effective for locating specimens. Handpicking was found to be the most effective method for collection of molluscs. Dead coral heads and undersides of boulders provided good collecting sites for molluscs and echinoderms. Care was taken to replace the boulders in position after collection of specimens from underneath.

Fishes

Fish fauna was surveyed only in Kavaratti, Kalpeni, Amini and Kadmat islands. Reef associated fishes were collected by means of a small encircling nylon net of 1 cm mesh, having 5 m length, and 3 m breadth .

Top portion of the net was provided with floats, and bottom with sinkers. The net was operated by three or four persons, wearing face masks and snorkels (Plate 1b). Fishes moving around coral formations were encircled by the net, or scared into the net, and the net was brought close. Fishes trapped in the net were caught by hand or by using a small scoop net. Using this method, fishes were collected from randomly selected 10 quadrets of 20 x 20 m each at different areas of the lagoon for a limited time of 2 hours for each quadret. Small scoop nets and spears were also used for collection. Collections were made upto a maximum depth of 2.5 m.

Identification

On-the-spot identification was made for all common and easily identifiable forms and released them back into the environment. Others were preserved and later identified in the field lab and also after consultation with specialists in the field. Literature and monographs used for the identification were Clark and Rowe (1971), Devid and George (1979), Eisenberg (1971), FAO (1984), Gardiner (1903, 1906), James (1969, 1973, 1986), Jones and Kumaran (1980) Meiyappan and Kathiravel (1978), Peter Dance (1977), Pillai (1986, 1987), Pillai and Scheer (1974, 1976), Sankarankutty (1961), Scheer and Pillai (1974, 1983) Smith and Philip (1986), Tadashige Hab (1968), Tetsuki Kira (1965), Veron and Wallace (1984), Veron et al. (1977), Veron and Pichon (1976, 1979, 1982), Walls (1982) and Wood (1983). Specimens are deposited in the museum of Directorate of Fisheries (Lakshadweep) and C.M.F.R.I. Kochi.

Total number of species from each island was noted and presented in the results as tables in alphabetical order. Separate tables are given for each faunal group with names of species against each island, and their density of population arbitrarily indicated by terms: Abundant (A), Common (C), Rare (R) and Not Observed (-). Economically important species, their fishery and future prospects are also discussed briefly in the discussion part.

RESULTS

Results of the faunistic survey for corals, crustaceans, echinoderms, molluscs, and fishes, conducted at Lakshadweep Islands are presented with their level of abundance. Total number of family, genera and species recorded from Lakshadweep, and from each island surveyed is shown in Table 1. Tables 2 to 6 show the alphabetically arranged families, genera and species from each island with their density of population. Newly recorded forms in the present survey are indicated with an asterisk.

Corals

Table 2 shows the species of corals collected from different islands of Lakshadweep. A total of 110 species divided among 40 genera and 15 families were recorded in this survey. Of this, 105 species were scleractinians, and 5 non-scleractinians. The non-scleractinians belonged to 3 genera and 3 families. Out of the 110 species noted in this survey, 22 species were new records to Lakshadweep. Genera like Herpolitha, Leptoseris, Oulophyllia, and Pachyseris have not been previously noted from this area. Kavaratti Island ranked first with 86 species and Kalpeni followed it with 79 species. Seventy seven species have been recorded from Bangaram, 63 species from Agatti, 52 species from Chetlat, 49 species from Amini and 39 species from Kadmat. Highest number of families (14) and genera (35) were observed in Kalpeni, while lowest from Kadmat with 11 families and 23 genera. Acropora dominated in Lakshadweep with 25 species. Acropora austera (Dana) - Kalpeni and Agathi; Acropora capillaris (Klunzinger) Kavaratti; Acropora divaricata (Dana) - Kavaratti; Acropora florida (Dana) - Kalpeni and Bangaram; Acropora monticulosa (?)Brugg - Kavaratti, Kalpeni, Agatti, Bangaram, Amini and Chetlat; Acropora pharaonis (Milne Edwards & Haime) - Kavaratti and Kalpeni; Acropora selago (Studder) - Kalpeni and Bangaram; Acropora valenciennesi (Edwards & Haime) - Kavaratti, Kalpeni, Agatti and Bangaram; Astreopora gracilis (Bernard) - Kavaratti and Aggathi); Montipora hispida (Dana) - Kavaratti;Leptoseris scabra Vaughan-Kadamat ; Pachyseris rugosa (Lamarck) - Kalpeni, Pavona minuta Wells - Kavaratti, Agatti and Bangaram; Tubastraea micranthus (Ehrenberg) -

Agatti; Turbinaria stelullata (Lamarck) Kadamat and Agatti; Cyphastraea chalcidium (Forskal) - Kavaratti; Hydnophora exesa (Pallas) - Kavaratti, Kalpeni, Agatti, Bangaram and Chetlat; Oulophyllia crispa (Lamarck) - Kavaratti, Kalpeni and Bangaram; Cycloceris cyclolites (Lamarck) - Kavaratti and Kalpeni; Herpolitha limax (Houttayn) - Bangaram; Lobophyllia hemprichii (Ehrenberg) - Kavaratti; and Porites murrayensis Vaughan - Kavaratti and Bangaram are the newly recorded species from this area (Plates 2 to 5). As inferred from Table 2, the distribution and degree of abundance of each species vary from island to island. There are very few species which are 'Abundant' in these islands, many are 'Common' and majority of the species recorded occur in 'Rare' proportion. There are 22 species which were found to be common to all the seven islands surveyed.

Crustaceans

Distribution and abundance of crustaceans in Lakshadweep islands are shown in Table 3. More attention was given to crabs, lobsters and prawns in the survey. Altogether 50 species divided among 32 genera and 18 families were recorded. Out of these 41 species divided among 24 genera and 12 families were crabs, 2 species, one genera and one family were lobsters and 7 species, divided among 7 genera and 5 families were prawns. As evident from Table 1, Kavaratti ranked first in maximum number of species (37) and Amini stood last with 20 species. Kavaratti has 37 species divided among 27 genera and 15 families. Thirty species, 24 genera and 15 families were recorded from Kalpeni; 29 species in 22 genera and 13 families from Agatti, 22 species in 18 genera and 11 families from Bangaram, 20 species in 14 genera and 10 families from Amini, 24 species 19 genera and 13 families from Kadmat and 22 species divided among 15 genera and 11 families from Chetlat. Eight species (6 species of crabs and 1 species each of lobster and Prawn) were found to be common to all the islands studied. In general the central islands showed maximum number of species.

PLATE 2. Species of corals recorded for the first time from from Lakshadweep.

a. Acropora austera (Dana)

b. Acropora capillaris (Klunzinger)

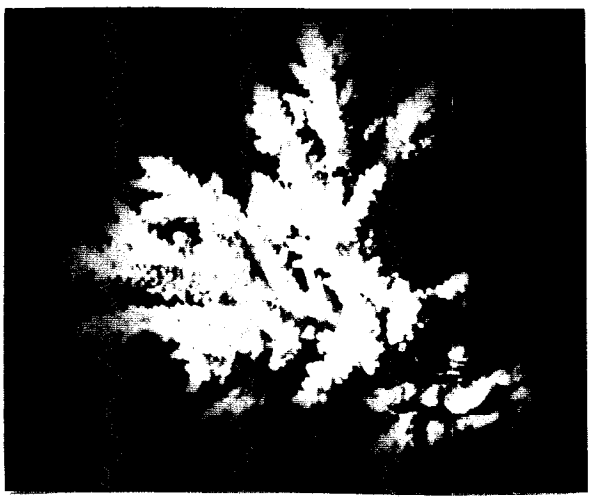
c. Acropora divaricata (Dana)

d. Acropora florida (Dana)

e. Acropora monticulosa (?) Brugg

f. Acropora pharaonis (Milne Edwards & Haime)

PLATE 2



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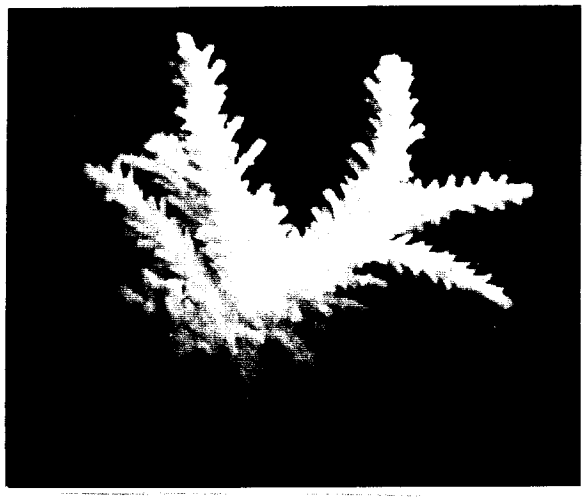

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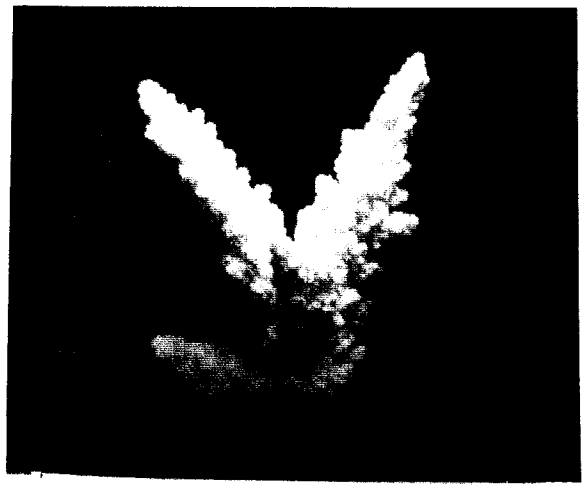

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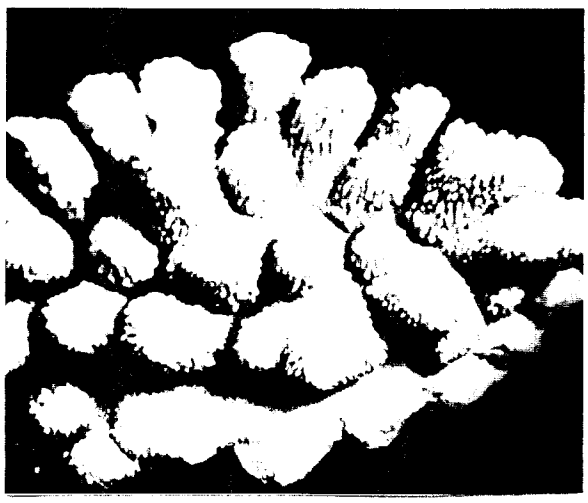

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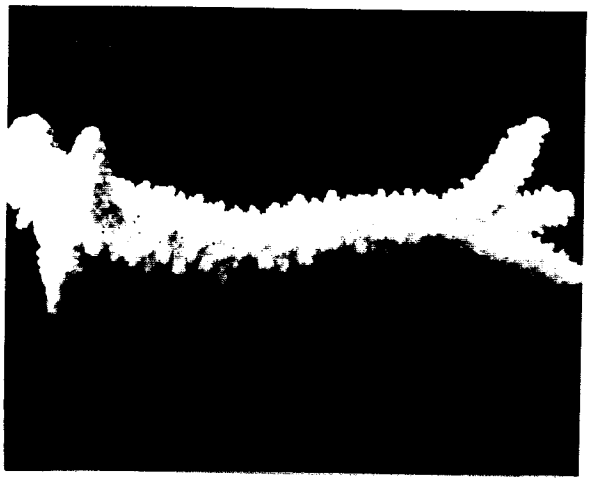

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Echinoderms

Distribution and abundance of echinoderms in Lakshadweep islands are shown in Table 4. The present survey revealed 46 species of echinoderms divided among 31 genera and 19 families. Out of these one species is a new record to Lakshadweep. There were 11 species belonging to Asteroides, divided in 9 genera and 6 families; 15 species belonging to Echinoidea, divided in 13 genera and 9 families; 16 species belonging to Holothuriodea, dispersed in 8 genera and 3 families, and 4 species belonging to Ophiuroidea (under a single genera and family). The family Mithrodiae with a species Mithrodia clavigera (Lamarck) is reported here for the first time from Lakshadweep waters (Plate 6a). Echinoidea showed highest number of genera (13) in Lakshadweep, while Holothurioidea showed domination with 16 species, Kavaratti Island showed highest degree of species abundance (42 species) and Bangaram the lowest number of species (18). A total of 19 families, 28 genera and 42 species were recorded from Kavaratti Island; 15 families, 24 genera and 38 species from Kalpeni; 12 families, 18 genera and 27 species from Agatti ; 8 families, 12 genera and 18 species from Bangaram;11 families, 16 genera and 26 species from Amini; 11 families, 15 genera and 24 species from Kadmat and 33 species divided among 21 genera and 14 families from Chetlat Island (Table 1). Thirteen species were found to be common to all the islands surveyed.

Molluscs

Table 5 depicts the abundance and distribution of molluscs in Lakshadweep Islands. A total of 230 species divided among 87 genera and 60 families were recorded in the present survey. Of this, 37 species 22 genera and 19 families came under bivalves, 5 species, 3 genera and 3 families came under cephalopods and 188 species, 62 genera and 38 families under gastropods. The family Conidae dominated in number with 40 species and Cypraeidae family followed it with 29 species. Total number of families, genera, and species were highest in Kavaratti with 16, 3 and 37 families; 21, 3 and 55 genera; and 28, 5 and 157 species of bivalves, cephalopods and gastropods. The survey revealed 139 spcies divided among 59 genera and 44 families from Kalpeni; 140 species, 58 genera and 42 families from

Agatti; 113 species, 51 genera and 37 families from Bangaram; 70 species, 33 genera and 26 families from Amini; 85 species, 42 genera and 31 families from Kadmat and 124 species divided among 54 genera and 40 families from Chetlat Island. Thirty five species were found to be common to all the islands surveyed.

Fishes

Results of the survey conducted for fishes in four islands are given in Table 6. There were 120 species of fishes divided among 67 genera and 35 families. The species Forcipiger flavissimus Jordan and Mc Gregor (Plate 6b) and Pygoplites diacanthus (Boddaert) (Plate 6c) have not previously been recorded from Lakshadweep. The family Labridae with 13 species dominated in this survey, followed by Pomacentridae (12 species) and Acanthuridae (10 species). Species abundance was highest in Kalpeni with 105 species divided among 57 genera in 28 families, whereas maximum number of families were observed in Kavaratti (32 families). There were 89 species distributed in 54 genera and 32 families in Kavaratti; 57 species divided among 36 genera and 19 families in Amini and 62 species divided among 35 genera and 18 families in Kadmat Island. Fourty two species were found to be common in the islands surveyed.

DISCUSSION

The updated check list of corals (Pillai, 1983a) indicated that altogether 199 species divided among 71 genera have been hitherto documented from India, including Lakshadweep, Gulf of Kutch, Gulf of Mannar, Palk Bay and Andaman & Nicobar Islands. Out of this, 155 species belonging to 50 genera are scleractinians and 44 species divided among 21 genera are non-scleractinians. A total of 24 genera and 37 species were recorded from Gulf of Kutch, 94 species divided among 37 genera from Palk Bay and Gulf of Mannar, 59 genera and 135 species from Andaman & Nicobar islands and 78 species divided among 31 genera from Lakshadweep. Pillai and Jasmine (1989) recorded 104 species divided among 37 genera from Lakshadweep, and opined that 40 to 45 genera should occur in this area.

Table 1. Number of Family, Genera and Species of corals, crustaceans, echinoderms molluscs and fishes from each island and total for Lakshadweep

	KAVARATTI			KALPENI			AGATTI			BANGARAM			AMINI			KADMAT			CHETLAT			TOTAL FOR LAKSHADWEEP		
	F	G	S	F	G	S	F	G	S	F	G	S	F	G	S	F	G	S	F	G	S	F	G	S
CORALS																								
Scleractinians	10	30	82	12	33	75	10	25	59	10	29	73	10	24	45	9	21	37	11	24	48	12	37	105
Non-scleratictinians	2	2	4	2	2	4	3	3	4	3	3	4	2	2	4	2	2	2	2	2	4	3	3	5
TOTAL	12	32	86	14	35	79	13	28	63	12	32	77	12	26	49	11	23	39	13	26	52	15	40	110
CRUSTACEANS																								
Crabs	10	20	29	9	16	22	9	16	22	9	16	19	7	11	16	9	14	18	8	12	18	12	24	41
Lobsters	1	1	2	1	1	1	1	1	2	1	1	2	1	1	2	1	1	2	1	1	2	1	1	2
Prawns	4	6	6	5	7	7	3	5	5	1	1	1	2	2	2	3	4	4	2	2	2	5	7	7
TOTAL	15	27	37	15	24	30	13	22	29	11	18	22	10	14	20	13	19	24	11	15	22	18	32	50
ECHINODERMS																								
Asteroidea	6	8	10	4	6	7	3	5	7	2	2	3	2	3	4	2	3	4	3	4	5	6	9	11
Echinoidea	9	11	12	7	11	13	5	7	7	2	2	2	5	6	6	5	6	6	7	10	11	9	13	15
Holothurioidea	3	8	16	3	6	14	3	5	12	3	7	12	3	6	13	3	5	12	3	6	14	3	8	16
Ophiuroidea	1	1	4	1	1	4	1	1	1	1	1	1	1	1	3	1	1	2	1	1	3	1	1	4
TOTAL	19	28	42	15	24	38	12	18	27	8	12	18	11	16	26	11	15	24	14	21	33	19	31	46
MOLLUSCS																								
Bivalves	16	21	28	14	14	18	12	14	19	10	11	14	6	6	7	7	7	10	12	13	15	19	22	37
Ceaphalopods	3	3	5	1	1	3	3	3	4	1	1	2	1	1	2	1	1	2	2	2	3	3	3	5
Gastropods	37	55	157	29	44	118	27	41	117	26	39	97	19	26	61	23	34	73	26	39	106	38	62	188
TOTAL	56	79	190	44	59	139	42	58	140	37	51	113	26	33	70	31	42	85	40	54	124	60	87	230
FISHES	32	54	89	28	59	105							19	36	57	18	35	62				35	67	120

F. Family, G. Genera, S. Species

Table 2. Distribution of corals in seven islands of Lakshadweep

(New records are indicated with asterisk)

Family Genus Species	Kavaratti 1	Kalpeni 2	Agatti 3	Bangaram 4	Amini 5	Kadmat 6	Chetlat 7
SCLERACTINIAN CORALS							
Family : Acroporidae							
Genus: *Acropora*							
A. abrotanoides (Lamarck)	R	-	R	-	R	R	R
A. aspera (Dana)	R	A	R	R	-	C	-
* *A. austera* (Dana)	-	C	C	-	-	-	-
* *A. capillaris* (Klunzinger)	R	-	-	-	-	-	-
A. corymbosa (Lamarck)	R	C	R	C	R	R	R
A. cythera (Dana)	R	C	-	C	-	-	-
A. danai (Edwards & Haime)	R	-	-	-	-	-	-
* *A. divaricata* (Dana)	R	-	-	-	-	-	-
A. echinata (Dana)	R	C	R	R	-	-	-
* *A. florida* (Dana)	-	C	-	C	-	-	-
A. formosa (Dana)	A	A	A	A	C	C	A
A. forskali (Ehrenberg)	-	R	-	-	R	R	-
A. humilis (Dana)	C	A	C	A	-	R	C
A. hyacinthus (Dana)	R	C	R	R	R	-	R
A. indica (Brook)	R	-	-	-	-	-	R
* *A. monticulosa* (?) Brugg	C	R	R	R	R	-	R
A. nasuta (Dana)	-	R	-	R	-	-	-
A. palifera (Lamarck)	R	C	C	C	R	R	C
* *A. pharaonis* (Milne Edwards & Haime)	R	C	-	-	-	-	-
A. pulchra (Brook)	-	R	-	R	-	-	-
A. robusta (Dana)	R	R	-	-	-	-	-
* *A. selago* (Studer)	-	R	-	R	-	-	-
A. teres (Verrill)	-	A	R	R	-	-	-
* *A. valenciennesi* (Edwards & Haime)	R	C	R	R	-	-	-
A. valida (Dana)	-	R	-	C	-	-	-
Genus : *Astreopora*							
* *A. gracilis* (Bernard)	R	-	C	-	-	-	-
A. listeri (Bernard)	R	R	-	R	-	R	R
A. myriophthalma (Lamarck)	R	C	C	R	R	-	C
Genus : *Montipora*							
* *M. hispida* (Dana)	R	-	-	-	-	-	-
M. millipora (Crossland)	R	-	-	-	-	-	-
M. tuberculosa (Lamarck)	C	C	C	C	C	C	C
Family : Agariciidae							
Genus : *Gardineroseris*							
G. planulata (Dana)	R	R	R	R	R	R	R
Genus : *Leptoseris*							
* *L. scabra* Vaughan	-	-	-	-	-	-R	-
Genus : *Pachyseris*							
* *P. rugosa* (Lamarck)	-	R	-	-	-	-	-

	1	2	3	4	5	6	7
Genus : *Pavona*							
P. maladivensis (Gardiner)	R	-	R	R	--	-	-
* *P. minuta* (Wells)	R	-	R	C	-	-	-
Family : Caryophylliidae							
Genus: *Euphyllia*							
. *glabrescens* (Chamisso & Eysenhardt)	-	R	-	-	-	-	R
Family : Dendrophyllidae							
Genus: *Tubastraea*							
T. aurea (Quoy & Gaimard)	R	R	R	R	R	R	R
* *T. micranthus* (Ehreberg)	-	R	-	-	-	-	-
Genus: *Turbinaria*							
T. mesenterina (Lamarck)	R	C	C	C	R	-	-
* *T. stelullata* (Lamarck)	R	-	C	-	-	-	-
Family : Faviidae							
Genus: *Caulastrea*							
C. tumida Matthai	R	-	-	R	-	-	-
Genus: *Cyphastrea*							
* *C. chalcidium* (Forskal)	R	-	-	-	-	-	-
C. microphthalma (Lamarck)	R	-	-	-	-	-	-
C. serailia (Forkal)	C	R	A	R	R	-	R
Genus: *Diploastrea*							
D. heliopora (Lamarck)	R	-	-	R	-	-	-
Genus: *Echinopora*							
E. lamellosa (Esper)	R	C	R	C	-	-	-
Genus: *Favia*							
F. favus (Forskal)	R	R	-	R	-	R	R
F. matthaii (?) Vaughan	-	-	-	R	R	-	-
F. specosa (Dana)	R	C	R	R	R	R	R
F. stelligera (Dana)	R	R	R	R	R	-	R
F. pallida (Dana)	R	R	R	C	R	-	R
F. valenciennesi Milne-Edwards & Haime	R	-	R	-	-	-	-
Genus: *Favites*							
F. abdita (Ellis & Solander)	R	-	-	R	-	-	-
F. flexosa (Dana)	R	C	R	C	-	-	-
F. halicora (Ehrenberg)	-	R	R	C	-	-	-
F. melicerum (Ehrenberg)	R	R	R	-	-	-	-
F. pentagona (Epser)	-	R	R	-	-	R	-
F. russelli (Wells)	R	-	-	-	-	-	-
Genus: *Goniastrea*							
G. pectinata (Ehrenberg)	C	C	C	A	R	R	C
G. retiformis (Lamarck)	R	C	C	C	R	-	R
Genus: *Hydnophora*							
* *H. exesa* (Pallas)	R	C	R	R	-	-	R
H. microconos (Lamarck)	C	C	C	C	R	R	C
Genus: *Leptastrea*							
L. bottae (Milna Edwards & Haime)	-	R	-	-	-	-	-
L. purpurea (Dana)	C	A	A	R	R	R	R
L. transversa Klunzinger	C	C	C	C	C	R	C

	1	2	3	4	5	6	7
Genus: *Leptoria*							
L. phrygia (Ellis & Solander)	-	R	C	C	-	R	R
Genus: *Oulophyllia*							
**O. crispa* (Lamarck)	R	R	-	R	-	-	-
Genus: *Platygyra*							
P. daedalea (Ellis & Solander)	R	R	-	R	-	R	-
P. sinensis (Edwards & Haime)	R	-	C	C	R	-	R
Family : Fungiidae							
Genus: *Cycloseris*							
**C. cyclolites* (Lamarck)	R	R	-	-	-	-	-
Genus: *Fungia*							
F. fugites Linnaeus	R	C	C	C	R	R	R
F. moluccensis Vander Horst	-	-	-	R	-	-	-
F. scutaria (Lamarck)	C	A	A	C	C	R	C
Genus: *Herpolitha*							
**H. limax* (Houttuyn)	-	-	-	R	-	-	-
Genus: *Polyphyllia*							
P. talpina (Lamarck)	-	-	-	R	-	R	-
Family : Merulinidae							
Genus: *Merulina*							
M. ampliata (Ellis & Solander)	-	R	-	-	-	-	-
Family : Mussidae							
Genus: *Acanthastrea*							
A. echinata (Dana)	R	R	R	-	R	-	-
Genus: *Lobophyllia*							
L. corymbosa (Forskal)	R	R	R	R	-	-	-
**L. hemprichii* (Ehrenberg)	R	-	-	-	-	-	-
Genus: *Symphyllia*							
S. nobilis (Dana)	-	R	R	R	R	-	R
S. radians (Edwards & Haime)	R	R	R	R	-	-	-
Family : Oculinidae							
Genus: *Galaxea*							
G. fascicularis (Linnaeus)	C	C	C	C	C	R	C
Family : Pocilloporidae							
Genus: *Pocillopora*							
P. damicornis (Linnaeus)	C	A	A	A	R	C	C
P. eydouxi (Edwards & Haime)	R	R	-	R	-	-	-
P. molokensis	R	-	-	-	-	-	-
P. verrucosa (Ellis & Solander)	C	C	R	C	R	R	R
Genus: *Stylophora*							
S. pistillata Esper	R	C	-	-	R	R	R
Family : Poritidae							
Genus: *Alveopora*							
A. superficialis (?)	R	R	-	-	-	-	R
Alveopora Sp.	-	-	-	-	R	-	-
Genus: *Goniopora*							
G. minor (Crossland)	R	R	R	R	R	-	C
G. stokesi (Edwards & Haime)	C	C	R	R	R	-	R
Genus : Porites							
P. (Cynarea) Convexa (Verrill)	R	R	-	-	-	R	R

	1	2	3	4	5	6	7
P. cylindraica (Dana)	A	C	C	C	A	R	-
P. lichen (Dana)	R	C	-	C	R	-	C
P. lutea (Edwards & Haime)	A	A	A	A	A	A	A
* *P. murrayensis* Vaughan	R	-	-	R	-	-	-
P. rus (Forskal)	C	R	C	R	C	R	R
P. solida (Forskal)	C	A	A	A	C	C	C
Family : Thamnasteriidae							
Genus: *Psammocora*							
P. contigua (Esper)	C	C	A	C	C	C	A
P. digitata (Edwards & Haime)	R	R	R	R	R	-	R
P. haimeana (Edwards & Haime)	R	-	-	-	R	-	-
P. nierstranzi Vander Horst	R	-	-	-	R	-	-
P. profundacella Gardiner	R	R	R	R	-	R	R
NON-SCLERACTINIAN CORALS							
Family : Helioporidae							
Genus: *Heliopora*							
H. coerulea (Pallas)	A	R	R	C	R	R	A
Family : Milleporidae							
Genus: *Millepora*							
M. dichotoma (Forskal)	R	R	-	-	R	-	R
M. exesa (Forskal)	R	R	-	-	R	-	R
M. platyphyllia (Ehremberg)	R	C	R	R	C	-	R
Family : Tubiporidae							
Genus: *Tubipora*							
T. musica	-	-	R	R	-	-	-

A = Abundant, C = Common, R = Rare, - = Not observed.
* = New records for Lakshadweep.

Table 3. Distribution of crustaceans in seven islands of Lakshadweep

Family Genus Species	Kavaratti 1	Kalpeni 2	Agatti 3	Bangaram 4	Amini 5	Kadmat 6	Chetlat 7
CRABS							
Family : Calappidae							
Genus : *Calappa*							
C. calappa (Linnaeus)	C	C	C	C	C	C	C
C. hepatica (Linnaeus)	R	C	R	-	-	-	R
Genus : *Matuta*							
M. banksi Leach	-	-	-	R	-	-	-
Family : Diogenidae							
Genus : *Dardanus*							
D. lagopodes (Forskal)	R	-	-	-	R	-	-
D. megistos (Herbst)	-	R	-	-	-	-	-
Genus : *Coenobita*							
C. clypeatus (Herbst)	A	A	A	C	C	C	C
C. jousseaumei (Bouvier)	R	-	C	-	R	R	R
Family : Dorippidae							
Genus : *Ethusa*							
E. indica Alcock	R	-	-	-	-	-	R
Family : Dynomenidae							
Genus : *Dynomene*							
D. pilumnoides Alcock	-	-	-	-	-	R	-
Family : Grapsidae							
Genus : *Geograpsus*							
G. crinipes (Dana)	R	R	-	-	-	-	-
G. grayi (Dana)	-	-	R	-	-	-	-
Genus : *Grapsus* (Dana)							
G. tenuicrustatus (Herbst)	C	C	R	-	-	C	-
Family : Lucosiidae							
Genus : *Nucia*							
N. speciosa Dana	R	R	R	R	R	R	R
Family : Majidae							
Genus : *Huenia*							
H. brevifrons Ward	R	-	-	R	-	-	-
H. proteus DeHann	R	-	R	-	-	R	-
Genus : *Hyastenus*							
H. diacanthus (DeHann)	-	R	-	-	-	-	-
H. elongatus Ortmann	R	R	R	-	R	R	-
Family : Ocypodidae							
Genus : *Ocypoda*							
O. ceratophthalmus (Pallas)	C	C	C	C	C	C	C
O. cordimana Desmarest	C	R	C	-	-	R	R
Family : Paguridae							
Genus : *Paugitta*							
P. harmsi (Gordon)							

	1	2	3	4	5	6	7
Family : Parthenopidae							
Genus : *Actaeomorpha*							
A. erosa Miers	-	C	R	C	-	-	R
Family : Portunidae							
Genus : *Portunus*							
P. orbicularis Crosnier	-	R	-	-	-	-	-
Genus : *Tualamita*							
T. admeta (Herbst)	R	-	R	-	-	-	R
T. picta Simpson	-	R	-	-	R	-	-
T. pilumnoides Borradaile	-	C	R	R	R	R	R
Family : Xanthidae							
Genus : *Atergatis*							
A. singnatus (Adams & White)	R	R	-	C	C	C	C
A. subdentats DeHann	C	C	R	C	C	R	C
Genus : *Carpilius*							
C. convexus (Forskal)	R	-	-	-	R	R	R
C. coralinus	R	C	C	-	R	R	R
C. maculatus (Linnaeus)	R	R	R	-	R	-	-
Genus : *Eriphia*							
E. Sebana Sebana (Shawe & Nodder)	A	A	C	A	C	C	C
Genus : *Liomera*							
L. bella (Dana)	R	-	-	R	-	-	-
L. caeleta (Odhner)	C	C	-	R	R	C	C
L. margarita Milne Edhards	-	-	-	R	-	-	-
Genus : *Pilodius*							
P. pilumnoides White	C	R	C	C	-	-	R
Genus : *Pilumnus*							
P. longicornis Hilgendrof	R	-	R	R	-	-	-
P. orbitosyinis Rathbun	-	-	R	-	-	R	-
P. vespertilio (Fabricius)	R	-	-	-	-	-	-
Genus : *Trapezia*							
T. ferruginea Latreille	-	-	-	R	-	-	-
T. guttata Ruppell	R	-	R	-	-	-	-
Genus : *Xanthias*							
X. lamarcki (H. Milne-Edwards)	R	-	-	R	-	-	-
LOBSTERS							
Family : Palinuridae							
Genus : *Panulirus*							
P. homarus (Linnaeus)	R	-	R	R	C	R	C
P. versicolor (Latreille)	C	C	C	A	C	R	R
PRAWNS							
Family : Gnathophyllidae							
Genus : *Hymenocera*							
H. picta	R	R	-	-	C	-	-
Family : Palaemonidae							
Genus : *Periclimenes*							
P. saggittifer (Norman)	R	R	-	-	-	R	-

	1	2	3	4	5	6	7
Family : Penaeidae							
Genus : *Metapenaeopsis*							
M. borradailei (De Man)	R	R	R	-	-	R	R
Genus : *Penaeus*							
P. latisulcatus Kishinouye	C	C	R	-	-	-	-
Genus : *Trachypenaeopsis*							
T. minicoyensis Thomas	R	C	R	-	-	-	-
Family : Sergestidae							
Genus : *Sergestes*							
S. armatus Kroyer	-	R	R	-	-	-	-
Family : Stenopodidae							
Genus : *Stenopus*							
S. hispidus (Oliver)	C	C	C	C	R	C	R

A = Abundant, C = Common, R = Rare, - = Not observed.

Table 4. Distribution of echinoderms in seven Islands of Lakshadweep

(New records are indicated with asterisk mark)

Family Genus Species	Kavaratti	Kalpeni	Agatti	Bangaram	Amini	Kadmat	Chetlat
	1	2	3	4	5	6	7
ASTEROIDEA							
Family : Acanthasteridae							
Genus : *Acanthaster*							
A. planci (Linnaeus)	R	R	-	-	-	-	-
Family : Asterinidae							
Genus : *Tegulaster*							
T. ceylanicus (Doderlein)	R	R	R	-	-	-	-
Family : Asteropidae							
Genus : *Asteropsis*							
A. carinifera (Linnaeus)	R	-	-	-	-	-	R
Family : Mithrodiae							
Genus : *Mithrodia*							
* *M. clavigera* (Lamarck)	R	-	-	-	-	-	-
Family : Ophidiasteridae							
Genus : *Dactylosaster*							
D. cylindricus (Lamarck)	C	R	R	-	R	R	R
Genus : *Formia*							
F. indica (Perrier)	R	-	R	-	-	-	-

	1	2	3	4	5	6	7
Genus : *Leiaster*							
L. leachi (Gray)	-	R	-	-	-	-	-
Genus : *Linckia*							
L. laevigata (Linnaeus)	C	C	R	C	R	C	C
L. multifora (Lamarck)	R	C	R	C	R	C	R
Family : Oreasteridae							
Genus : *Culcita*							
C. novaeguineae (Muller & Troschel)	R	R	R	R	-	-	R
C. schmidetiana (Retzius)	R	-	R	-	R	R	-
ECHINOIDEA							
Family : Arbaciidae							
Genus : *Arbacia*							
A. lixula (Linnaeus)	C	R	-	-	R	-	R
Family : Brissidae							
Genus: *Brissus*							
B. latearinatus (Leske)	R	-	R	-	-	-	-
Family : Cidaridae							
Genus : *Prionocidaris*							
P. verticellata (Lamarck)	C	C	R	-	-	R	C
Family : Diadematidae							
Genus : *Diadema*							
D. savignyi Michelin	-	C	-	-	-	-	R
D. setosum (Leske)	-	R	-	R	-	-	-
Genus : *Echinothrix*							
E. calamaris Pallas	R	C	-	-	-	-	R
Family : Echinolapadidae							
Genus : *Echinolampas*							
E. ovata (Leske)	R	R	-	-	R	-	R
Family : Echinometridae							
Genus : *Echinometra*							
E. mathaei							
Genus : *Echinostrephus*							
E. molaris (Blainville)	R	R	C	-	-	R	-
Genus : *Heterocentrotus*							
H. mammillatus (Linnaeus)	R	R	R	-	-	-	R
Family : Echinoneidae							
Genus : *Echinoneus*							
E. cyclostomus Leske	C	C	R	R	-	R	R
Family : Parasaleniidae							
Genus : *Parasaleina*							
P. boninensis (?)	R	-	-	-	-	-	-
Family : Toxopneustidae							
Genus : *Toxopneustes*							
T. pileolus (Lamarck)	-	C	-	-	R	-	R
Genus : *Tripneustes*							
T. gratilla (Linnaeus)	R	A	-	-	C	C	A
HOLOTHURIOIDEA							
Family : Holothuriidae							
Genus : *Actinopyga*							
A. mauritiana (Quoy & Gaimard)	C	A	R	R	A	C	A

	1	2	3	4	5	6	7
Genus : *Bohadschia*							
B. argus Jaeger	R	A	R	-	A	A	C
B. marmorata Jaeger	A	A	R	C	R	R	C
Genus : *Holothuria*							
H. atra Jaeger	C	C	C	A	C	C	A
H. arenicola Semper	R	R	-	-	-	-	R
H. hilla lesson	C	C	C	A	C	C	A
H. impatiens (Forskal)	C	C	R	R	R	R	C
H. leucospilota (Brandt)	A	A	A	C	A	C	A
H. nobilis (Selenka)	C	A	A	C	C	R	C
H. parda Selenka	C	C	R	R	c	C	C
Family : Stichopodidae							
Genus : *Stichopus*							
S. chloronotus Brandt,	R	C	R	-	R	R	C
S. variegatus Semper	R	C	R	R	R	R	R
Genus : *Thelenota*							
T. ananas (Jaeger)	R	-	-	R	-	-	R
Family : Synaptidae							
Genus : *Euapta*							
E. godeffroyi (Semper)	R	R	-	-	R	-	-
Genus : *Ophiodesma*							
O. grisea (Semper)	R	-	-	R	-	-	-
Genus : *Synapta*							
S. maculata (Chamisso & Eysenhardt)	C	C	R	R	C	R	C
OPHIUROIDEA							
Family : Ophiocomidae							
Genus : *Ophiocoma*							
O. dentata Muller & Trosehel	R	R	-	-	-	-	-
O. erinaceus Muller & Trosehel	R	C	R	-	C	R	R
O. pica Muller & Tros ehel	R	R	-	-	R	R	C
O. scolopendrina (Lamarck)	R	R	-	R	R	-	R

A = Abundant C = Common, R = Rare, - = Not observed * = New records for Lakshadweep

Table 5. Distribution of molluscs in seven Islands of Lakshadweep

Family Genus Species	Kavaratti 1	Kalpeni 2	Agatti 3	Bangaram 4	Amini 5	Kadmat 6	Chetlat 7
BIVALVES							
Family : Arcidae							
Genus : *Arca*							
A. complanata	-	R	C	-	R	-	R
Family : Cardiidae							
Genus : *Fragum*							
F. fragum Linnaeus	R	-	-	-	-	-	-
Family : Carditidae							
Genus : *Cardita*							
C. variegata (Burg)	R	R	-	R	-	-	R
Family : Chamidae							
Genus *Chama*							
C. (Pseudochona) retroversa	R	-	-	R	-	-	R
Family : Donacidae							
Genus : *Donax*							
D. faba	-	R	R	-	-	-	-
Family : Lucinidae							
Genus : *Codakia*							
C. orbicularis (Linnaeus)	C	R	R	R	-	R	R
C. orbiculata (Montagu)	R	-	C	-	-	R	R
Family : Mactridae							
Genus : *Mactra*							
M. cuneata	R	-	-	R	-	-	-
Mactra sp.	-	R	-	-	-	-	-
Family : Mytilidae							
Genus : *Brachiodontes*							
B. modiolus	-	-	R	-	C	C	R
Genus : *Lithopaga*							
L. gracilis	-	R	R	-	-	-	-
L. nigra Dorbigny	R	-	-	R	-	R	R
Genus : *Modiolus*							
M. metgaigi	R	-	-	R	-	R	-
M. tulipa	-	R	C	C	R	-	-
Modiolus sp.	R	-	-	-	-	-	-
Family : Ostreidae							
Genus : *Ostrea*							
O. (Lopha) cristagalli (Linnaeus)	R	R	-	-	-	-	-
Genus : *Saccostrea*							
S. cucullata	C	C	C	C	C	R	C
Family : Pectinidae							
Genus : *Pectin*							
Pectin sp.	-	C	R	-	-	-	-
Family : Pteriidae							
Genus : *Pinctada*							
P. fucata	R	R	-	-	-	-	-
P. sugillata	-	R	C	C	R	R	R

	1	2	3	4	5	6	7
Family : Psammobiidae							
Genus : *Asaphis*							
A. deflorata Jinnaues	A	A	C	R	R	-	R
Family : Semelidae							
Genus : *Leptomya*							
L. cuspidariaeformis	R	-	-	-	-	-	-
Family : Spondylidae							
Genus : *Spondylus*							
S. layardi	-	R	R	-	-	-	-
S. nicobaricus	R	-	R	-	-	-	-
Spondylus sp.	R	-	-	-	-	-	-
Family : Tellinidae							
Genus : *Tellina*							
T. listeri Roding	R	-	R	-	-	-	-
T. rugosa Born	C	-	R	R	-	-	R
T. scobinata (Linnaeus)	C	-	-	R	-	R	R
Family : Tridacnidae							
Genus : *Tridacna*							
T. maxima (Roding)	C	C	C	A	R	R	C
T. squamosa (Lamarck)	R	R	R	R	-	-	-
Family : Veneridae							
Genus : *Grafarium*							
G. pectinatum (Linnaeus)	R	R	R	-	-	R	R
Genus : *Lioconcha*							
L. castrensis (Linnaeus)	R	-	-	-	-	-	-
Genus : *Venus*							
V. listeri Gray	R	-	R	-	-	-	-
CEPHALOPODS							
Family : Nautilidae							
Genus : *Nautilus*							
N. pompilius (Linnaeus)	R	-	R	-	-	-	-
Family : Octopodidae							
Genus : *Octopus*							
O. cyaneus	R	R	R	R	R	C	R
O. macropus	R	R	-	-	-	-	-
O. vulgaris	C	A	A	c	C	A	C
Family : Spirulidae							
Genus : *Spirula*							
S. spirula (Linnaeus)	R	-	R	-	-	--	R
GASTROPODS							
Family : Architectionicidae							
Genus : *Architectionica*							
A. trochlearis Hinds	R	-	-	R	-	-	-
Family : Atyidae							
Genus : *Atys*							
A. cylindricus (Hebling)	R	-	-	-	-	R	R
A. naucum	R	C	-	-	-	-	-

	1	2	3	4	5	6	7
Family : Buccinidae							
Genus : *Cantharus*							
C. undosus (Linnaeus)	R	R	C	C	R	R	C
Genus : *Engina*							
E. mendicaria (Linnaeus)	R	C	A	C	C	R	A
Genus : *Pisania*							
P. ignea (Gmelin)	-	R	R	-	-	-	-
Genus : *Pusiostoma*							
P. lineatum	A	A	C	A	C	C	A
Family : Bullidae							
Genus : *Bulla*							
B. ampulla (Linnaeus)	C	C	R	R	-	-	R
B. vernicosa (Linnaeus)	C	C	C	C	R	R	C
Family : Bursidae)							
Genus : *Bursa*							
B. bubo (Linnaeus)	R	-	R	R	-	R	-
B. granularis Roding	R	R	R	-	-	R	R
Family : Cassididae							
Genus : *Casmaria*							
C. cornuta	-	R	-	-	-	-	-
C. ponderosa (Gmelin)	R	R	R	-	-	-	-
Genus : *Cypraecassis*							
C. rufa (Linnaeus)	R	R	R	-	-	-	-
Family : Cerithiidae							
Genus : *Cerithium*							
C. articulatum (Adams & Reeve)	R	R	-	-	-	-	R
C. asper (Linnaeus)	C	C	C	C	-	R	C
C. nodulosum (Bruguiere)	C	C	C	R	-	-	C
C. sinensis (Gmelin)	R	R	-	R	-	-	R
Cerithium sp.	R	-	-	-	-	-	-
Cerithium sp.	-	R	-	-	-	-	-
Cerithium sp.	-	-	R	-	-	-	-
Family : Colubrariidae							
Genus : *Colubraria*							
C. maculosa (Gamelin)	R	-	-	R	-	R	R
C. testacea (Morch)	R	R	-	-	-	-	-
Family : Conidae							
Genus : *Conus*							
C. abbreviatus Reeve	-	R	-	R	-	-	-
C. arenatus Hwass	R	-	R	R	-	-	-
C. aulicus Linnaeus	R	-	R	R	-	-	R
C. betulinus Linnaeus	R	R	R	C	-	-	-
C. capitaneus Linnaeus	R	-	R	-	A	C	C
C. catus Hwass	C	C	C	R	C	C	C
C. chaldeus (Roding)	C	C	R	C	R	R	R
C. coronatus Gmelin	R	-	R	-	-	-	R
C. cylindraceus (Broderip & sow)	-	R	-	-	-	-	-
C. dalli Stearns	R	-	R	-	-	-	-
C. distans Hwass	-	-	R	-	-	-	-
C. ebraeus Linnaeus	R	R	R	-	R	R	R
C. eburneus Hwass	R	-	R	-	-	R	R

	1	2	3	4	5	6	7
C. episcopus Hwass	R	-	-	-	R	-	-
C. flavidus Lamarck	R	R	C	R	C	R	R
C. generalis Linnaeus	R	-	R	R	R	-	R
C. geographus Linnaeus	R	R	R	-	R	-	R
C. granulatus Linnaeus	R	-	-	-	-	-	-
C. leopardus (Roding)	C	R	C	R	C	R	R
C. litoglyphus Hwass	R	-	C	-	-	-	C
C. lividus Hwass	-	R	R	R	-	R	R
C. miles Linnaeus	R	-	-	R	-	-	R
C. mustelinus Hwass	R	-	R	-	-	-	R
C. mutabilis	R	R	R	-	R	R	R
C. nigropunctatus Sowerby	R	-	R	-	-	-	R
C. nussatella Linnaeus	R	R	-	R	R	-	R
C. omaria Hwass	R	-	R	R	-	-	-
C. pennaceus	R	R	R	-	R	R	R
C. rattus Hwass	R	-	R	R	-	-	R
C. retifer	R	-	-	-	-	-	-
C. scabriusculus Dillwyn	R	-	R	-	-	-	R
C. striatus Linnaeus	R	-	R	R	-	-	-
C. tessulatus Born	R	-	R	-	-	-	R
C. textile Linnaeus	-	R	R	-	-	-	-
C. trigonus Reeve	-	-	R	R	-	-	-
C. tulipa Linnaeus	R	R	R	-	R	R	R
C. vexillum Gmelin	R	R	R	R	-	-	-
C. violaceus Gmelin	R	R	C	-	R	-	C
C. virgo Linnaeus	R	R	R	R	R	-	-
C. zonatus Hass	C	C	R	-	R	-	C
Family : Coralliophillidae							
Genus : *Coralliophila*							
C. violacea	-	-	R	-	-	-	-
Genus : *Magilus*							
M. antiquus Montfort	C	R	C	R	R	R	C
Genus : *Quoyula*							
Q. madreporarium	R	C	-	-	R	-	-
Family : Cymatiidae							
Genus : *Charonia*							
C. tritonis Linnaeus	-	R	R	-	R	-	R
Genus : *Cyamatium*							
C. muricinum Roding	R	C	-	C	R	R	A
C. nicobaricum	R	-	R	-	-	-	-
Genus : *Distorsio*							
D. anus Linnaeus	R	R	-	R	-	R	R
Family : Cypraeidae							
Genus : *Cypraea*							
C. annulus Linnaeus	R	R	R	-	R	R	-
C. arabica Linnaeus	R	R	-	R	-	R	R
C. arugus Linnaeus	R	-	-	R	-	-	-
C. asellus Linnaeus	R	R	-	R	-	R	R
C. caputdraconis Melvill	R	C	-	-	-	-	R
C. caputserpentis Linnaeus	C	A	A	A	C	C	A

	1	2	3	4	5	6	7
C. carneola Linnaeus	-	R	-	R	-	-	R
C. coffea	-	R	-	-	R	-	-
C. cribraria Linnaeus	-	R	-	-	-	-	-
C. depressa Gray	R	R	R	R	-	R	-
C. diluculum Reeve	R	R	-	R	-	-	R
C. erosa Linnaeus	R	R	R	R	R	R	R
C. globulus Linnaeus	R	R	R	-	R	R	R
C. helvola Linnaeus	R	-	R	-	R	-	-
C. histrio Gmelin	R	C	-	-	-	-	C
C. isabella Linnaeus	C	C	C	C	R	R	C
C. lynx Linnaeus	R	R	R	-	R	-	R
C. maculifera Schilder	R	R	R	-	-	R	R
C. marginalis	R	R	-	-	-	-	-
C. moneta Linnaeus	R	R	A	A	C	C	A
C. nucleus Linnaeus	-	R	R	-	-	R	-
C. ocellata Linnaeus	R	R	-	R	-	-	-
C. pantherina Lightfoot	R	R	-	R	-	-	-
C. scurra Gmelin	R	R	R	-	-	-	-
C. talpa Linnaeus	R	R	R	R	-	R	R
C. testudinaria Linnaeus	-	-	-	R	-	-	-
C. tigris Linnaeus	C	C	C	C	-	R	R
C. urscllus Gmelin	R	-	-	-	-	-	-
C. vitellus Linnaeus	R	C	R	C	R	R	C
Family : Epitoniidae							
Genus : *Epitonium*							
Epitonium sp.	R	-	-	-	-	-	-
Family : Fasciolariidae							
Genus : *Latiro*							
L. lagena	R	-	-	R	-	-	R
Genus : *Latrius*							
L. craticulatus Linnaeus	R	-	-	-	-	-	-
L. polygonus Gmelin	R	-	R	R	-	R	-
Genus : *Peristernia*							
P. nassatula Lamarck	R	-	-	R	-	-	R
Genus : *Pleuroploca*							
P. filamentosa Roding	R	-	-	-	-	-	-
P. gigantea Kiener	-	R	-	-	-	-	-
Family : Fissurellidae							
Genus : *Diodora*							
Diodora sp.	R	-	-	-	-	-	-
Family : Haliotidae							
Genus : *Haliotis*							
H. ovina Gmelin	R	R	-	-	-	-	R
Family : Harpidae							
Genus : *Harpa*							
H. amouretta Roding	-	R	-	-	-	-	-
H. major Roding	-	-	-	R	-	-	-
Family : Janthinidae							
Genus : *Janthina*							
J. janthina Linnaeus	R	R	-	R	-	-	-

	1	2	3	4	5	6	7
Family : Littorinidae							
Genus : *Littorina*							
L. fasciata Philippi	A	R	C	-	R	R	C
L. undulata Gray	C	R	C	C	R	-	C
Family : Melampidae							
Genus : *Melampus*							
M. castaneus	R	-	-	-	C	R	C
M. fasciatus	R	R	-	R	C	R	C
Family : Mitridae							
Genus : *Mitra*							
M. ambigua Swainson	R	-	R	R	-	R	-
M. clathrus Gmelin	-	-	-	R	-	-	-
M. coronata Lamarck	-	R	-	-	-	R	-
M. cucumerina Lamarck	C	C	C	C	R	-	R
M. ferruginea Lamarck	R	R	R	R	-	R	R
M. mitra Linnaeus	R	R	R	-	-	-	-
M. stictica Link	-	R	-	-	-	-	-
Genus : *Pterygia*							
P. crenulata Gmelin	R	-	-	-	-	-	R
Genus : *Strigatella*							
S. litterata Lamarck	R	-	R	-	-	-	C
S. paupercula Linnaeus	R	C	C	R	R	R	R
S. restusa Lamarck	R	-	-	R	-	-	-
Genus : *Vexillum*							
V . exasperatum Gmelin	-	-	R	-	-	R	-
Family : Muricidae							
Genus : *Drupa*							
D. lobata (Blainville)	R	R	R	-	-	-	R
D. morum Roding	C	C	C	R	C	R	R
D. ricinus (Linnaeus)	R	C	C	R	R	-	-
D. rubusidaeus Roding	R	-	R	-	-	R	-
Genus : *Morula*							
M. fusca Roding	R	-	-	R	-	-	-
M. granulata (Duclos)	R	R	R	-	R	R	R
Genus : *Murex*							
M. ramosus Linnaeus	R	-	R	-	-	-	-
M. sauliisowbery	E	-	-	-	R	-	-
Genus : *Nassa*							
N. serta Bruguiera	R	R	-	-	-	-	-
Genus : *Purpura*							
P. rodolphi Lamarck	R	R	R	R	R	R	R
Genus : *Thais*							
T. siro	R	-	R	R	-	-	-
T. tuberosa Roding	R	-	-	R	-	R	R
Family : Nassariidae							
Genus : *Nassarius*							
N. distortus Adams	C	R	R	C	-	-	C
N. papillosus Linnaeus	R	R	R	-	-	-	-
N. pullus	R	-	-	R	-	-	-

	1	2	3	4	5	6	7
Family : Naticidae							
Genus : *Natica*							
N. (Notocochlis) lineata	-	-	-	R	-	-	-
N. vitellus Linnaeus	-	R	-	R	-	-	-
N. zebra	-	-	-	R	-	-	-
Genus : *Sinum*							
S. perspectivum Say	C	R	R	R	R	R	C
Genus : *Polinices*							
P. flemingiana Recluz	R	A	R	C	-	-	R
P. (Mammilla) melanostomus (Gmelin)	C	R	R	R		R	C
Family : Neritidae							
Genus : *Nerita*							
N. albicilla Linnaeus	C	C	R	R	R	R	C
N. antiquata Recluz	R	-	-	-	-	-	-
N. chamaeleon	R	-	C	C	R	-	R
N. plicata Linnaeus	A	A	A	C	R	R	C
N. polita Linnaeus	C	R	C	C	R	R	R
N. undata Linnaeus	R	R	-	-	-	-	R
Family : Olividae							
Genus : *Oliva*							
O. episcopalis	R	R	-	-	-	-	R
O. nobilis	-	R	R	-	-	-	-
Family : Onchidiae							
Genus : *Onchidium*							
Onchidium sp.	R	-	-	-	-	-	-
Family : Patellidae							
Genus : *Cellana*							
C. testudinaria	R	R	R	-	-	-	R
Family : Phyllidae							
Genus : *Phyllidia*							
P. bourguini	R	R	C	-	R	-	-
Family : Potamididae							
Genus : *Terebralia*							
T. palustris Linnaeus	R	-	R	-	-	-	-
Family : Pyramidellidae							
Genus : *Pyramidella*							
P. terebellum	R	-	-	-	-	-	-
Family : Strombidae							
Genus : *Lambis*							
L. chiragra Linnaeus	C	C	R	C	C	R	C
L. crocata Link	R	R	R	-	-	-	-
L. lambis Linnaeus	R	R	C	C	C	R	C
L. truncata (Humphrey)	R	C	C	C	C	C	C
Genus : *Strombus*							
S. bulla Roding	R	R	-	-	-	R	R
S. canarium Linnaeus	R	-	R	-	-	-	R
S. dentatus Linnaeus	-	C	R	R	-	-	R
S. gibberulus Linnaeus	A	C	C	C	C	C	C
S. lentiginosus LInnaeus	R	R	R	R	-	-	R
S. mutabilis Swainson	A	A	A	A	C	A	A

	1	2	3	4	5	6	7
Family : Terebridae							
Genus : *Terebra*							
T. affinis Gray	R	R	-	-	-	-	R
T. babylonia Lamarck	R	R	R	R	-	R	R
T. crenulata Linnaeus	R	R	R	R	R	R	R
T. dimidiata Linnaeus	C	-	R	R	-	-	R
T. maculata Linnaeus	R	R	R	R	R	R	R
T. subulata Linnaeus	-	R	R	-	-	R	R
Family : Tonnidae							
Genus : *Malea*							
M. Pomum Linnaeus	-	-	R	-	-	-	-
Genus : *Tonna*							
T. canaliculata Linnaeus	R	-	-	R	-	-	R
T. cumingi	R	-	-	-	-	-	-
Family : Trochidae							
Genus : *Tectus*							
T. pyramis (Born)	C	R	R	R	R	R	C
Genus : *Trochus*							
T. maculatus	C	C	R	R-	-	-	R
T. venetus Reeve	R	R	-	-	-	R	R
Family : Umbraculidae							
Genus : *Umbraculum*							
U. umbraculum	R	-	R	-	-	-	-
Family : Vasidae							
Genus : *Vasum*							
V. ceramicum Linnaeus	R	R	R	R	R	R	R
V. tubiferum Anton	R	-	R	R	-	R	-
V. turblinellum Linnaeus	R	R	R	R	R	R	R
Family : Vermetidae							
Genus : *Serpulobris*							
S. xenophorus	R	-	R	-	-	R	-

A = Abundant, C = Common, R = Rare, - = Not observed

Table 6 Distribution of Fishes in four Islands of Lakshadweep.

(New records are indicated with arterisk)

Family Genus Species	Kavaratti 1	Kalpeni 2	Amini 3	Kadmat 4
Family : Acanthuriidae				
Genus : *Acanthurus*				
A. elongatus (Bloch & schneider)	R	C	-	-
A. leucosternon Bennett	C	R	-	-
A. linatus (Linnaeus)	C	A	A	A
A. bennenti Gunther	R	C	R	R
A. triostigus (Linnaeus)	C	A	C	A
Genus : *Ctenochaetus*				
C. strigosus (Bennett)	-	R	R	R
Genus : *Naso*				
N. lituratus (Schneider)	R	R	-	-
N. tuberosus (Lacepede)	R	R	-	-
N. unicornis (Foreskal)	R	R	-	-
Genus : *Zebrasoma*				
Z. veliferum (Bloch)	R	C	-	R
Family : Antennariidae				
Genus : *Histrio*				
H. histrio (Linnaeus)	R	-	-	-
Family : Apogonidae				
Genus : *Apogon*				
A. sagiensis Bleeker				
Genus : *Ostorhynchus*				
O. endekataenia (Bleeker)	C	R	C	R
Family : Balistidae				
Genus : *Balistapus*				
B. undulatus (Mungo Park)	R	C	R	R
Genus : *Balistoides*				
B. viridescens (Bloch & Schneider)	-	C	-	-
Genus : *Melichthys*				
M. niger (Bloch)	R	R	R	-
Genus : *Odonus*				
O. niger (Ruppell)	-	R	-	-
Genus : *Rhinecanthus*				
R. aculeatus (Linnaeus)	C	A	C	C
R. rectangulus (Bloch & Schneider)	-	R	-	-
Family : Bothidae				
Genus : *Bothus*				
B. pantherinus (Ruppell)	R	-	-	-
Family : Callyodontidae				
Genus : *Callyodon*				
C. bataviensis (Bleeker)	-	R	-	-

	1	2	3	4
C. niger (Forskal)	-	R	-	-
C. pectoralis (Valenciennes)	R	R	-	-
C. scaber (Valenciennes)	-	C	-	-
C. sexvittatus (Ruppell)	R	C	C	-
Family : Canthigasteridae				
Genus : *Canthigaster*				
C. cinctus (Richardson)	R	R	-	-
C. margaritatus (Ruppell)	C	C	-	R
Family : Chaetodontidae				
Genus : *Chaetodon*				
C. auriga Forsskal	C	A	C	R
C. citrinellus Cuvier	R	R	-	R
C. collare Bloch	R	C	R	-
C. falcula Bloch	R	C	R	R
C. lunula (Lacepede)	R	C	-	C
C. melanotus Block & Schneider	R	-	-	-
C. meyeri Block & Schneider	R	R	-	R
C. trifasciatus Mungo Park	C	A	C	C
C. vagabundus Linnaeus	R	C	R	R
C. xanthocephalus Bennett	C	A	R	R
Genus : *Forcipiger*				
* *F. flavissimus* Jordan & Mc Gregor	R	-	-	-
Family : Diodontidae				
Genus : *Diodon*				
D. hystrix Linnaeus	R	C	-	-
Genus : *Lophodiodon*				
L. calori (Bianconi)	R	C	-	-
Family : Dussumieriidae				
Genus : *Spratelloides*				
S. delicatulus (Bennett)	R	R	-	-
Family : Fistulariidae				
Genus : *Fistularia*				
F. petimba Lacepade	R	-	-	-
Family : Gaterinidae				
Genus : *Gaterin*				
G. orientalis (Bloch)	R	C	R	-
Family : Holocentridae				
Genus : *Holocentrus*				
H. diadema Lacepede	C	C	C	R
H. laevis Gunther	R	C	R	R
H. sammara (Forsskal)	C	C	R	-
H. violaceus Bleeker	-	R	-	-
Genus : *Myripristis*				
M. adusta (Bleeker)	C	C	R	-
Family : Kuhliidae				
Genus : *Kuhlia*				
K. taeniura (Cuvier)	R	-	-	-
Family : Labridae				
Genus : *Anampses*				
A. caeruleopunctatus Ruppell	-	C	C	R
A. diadematus Ruppell	-	C	R	R

	1	2	3	4
Genus : *Gomphosus*				
G. caeruleus Lacepede	C	C	R	R
G. varius Lacepede	R	C	C	R
Genus : *Halichoeres*				
H. argus (Bloch & Schneider)	-	R	-	R
H. centriquadrus (Lacepede)	C	C	R	R
H. kawarin (Bleeker)	-	R	C	C
Genus : *Labroides*				
L. dimidiatus (Valenciennes)	A	A	C	R
Genus : *Stethojulis*				
S. strigiventer (Bennet)	R	C	C	C
S. trilineata (Bloch & Schneider)	C	C	R	R
Genus : *Thalassoma*				
T. hardwicki (Bennett)	R	C	R	R
T. quinquevittatum (Lay & Bennett)	-	C	-	-
T. umbrostigma (Ruppell)	-	R	-	R
Family : Lagocephalidae				
Genus : *Sphoeroides*				
S. hypselogeneion (Bleeker)	-	R	-	-
Family : Lutjanidae				
Genus : *Lutjanus*				
L. kasmira (Forsskal)	C	A	C	R
L. russellii (Bleeker)	-	A	-	-
Family : Monacanthidae				
Genus : *Osbeckia*				
O. scripta (Osbeck)	R	-	-	-
Genus : *Oxymonacanthus*				
O. longirostris (Bloch & Schneider)	-	R	-	-
Family : Mullidae				
Genus : *Mulloidichthys*				
M. auriflama (Forsskal)	R	R	R	-
M. samoensis (Gunther)	-	C	-	C
Genus : *Parupeneus*				
P. barberinus (Lacepede)	C	C	C	R
P. bifasciatus (Lacepede)	C	-	R	C
P. trifasciatus (Lacepede)	R	-	-	R
Genus : *Upeneus*				
U. tragula (Richardson)	R	C	R	R
U. vittatus (Forsskal)	R	C	-	-
Family : Muraenidae				
Genus : *Echidna*				
E. nebulosa (Ahl)	R	C	C	C
E. polyzona (Richardson)	R	R	R	R
E. zebra (Shaw)	R	C	R	R
Genus : *Gymnothorax*				
G. buroensis (Bleeker)	C	R	R	C
G. rueppelliae (McClelland)	R	-	-	R
Family : Ophichthyidae				
Genus : *Callechelys*				
C. melanotaenia Bleeker	-	R	-	-

	1	2	3	4
Family : Ostraciidae				
Genus : *Lactoria*				
L. cornuta (Linnaeus)	-	B	-	-
Genus : *Ostracion*				
O. meleagris Shaw	-	R	-	-
Genus : *Rhynchostracion*				
R. nasus (Bloch)	C	C	-	-
Family : Parapersidae				
Genus : *Parapercis*				
P. hexophthalma (Cuvier)	C	-	R	R
Family : Platacidae)				
Genus : *Platax*				
P. orbicularis (Forskal)	R	R	-	-
Family : Pomacanthidae				
Genus : *Centropyge*				
C. multispinis (Playfiar)	-	R	-	-
Genus : *Pomacanthus*				
P. imperator (Bloch)	R	R	-	-
Genus : *Pygoplites*				
P. diacanthus (Boddaert)	R	-	-	-
Family : Pomacentridae				
Genus : *Abudefduf*				
A. bengalensis (Bloch)	A	A	C	C
A. saxatilis (Linnaeus)	A	C	R	R
A. septemfasciatus (Cuvier)	C	C	C	C
A. sexfasciatus (Lacedede)	A	A	C	C
Genus : *Amphiprion*				
A. chrysogaster Cuvier	R	R	-	-
A. nigripes Regan	R	R	-	-
Genus : *Chromis*				
C. caerulea (Cuvier)	A	A	C	C
C. dimidiata (Klunzinger)	-	C	R	-
Genus : *Dascyllus*				
D. aruanus (Linnaeus)	A	A	R	C
D. trimaculatus (Rupell)	-	C	-	-
Genus : *Pomacentrus*				
P. albifasciatus Scleger & Muller	C	C	R	C
P. nigricans (Lacepede)	C	C	C	R
Family : Scorpaenidae)				
Genus : *Pterois*				
P. antennata (Bloch)				
P. radiata (Cuvier)	-	R	-	-
P. volitans (Linnaeus)	C	C	R	C
Genus : *Scorpaenodes*				
S. guamensis (Quoy & Gaimard)	-	C	-	-
Family : Serranidae				
Genus : *Cephalopholis*				
C. argus Schneider	A	A	A	C
Genus : *Epinephelus*				
E. hexagonatus Schneider	C	C	-	C
E. tauvina (Forsskal)	R	C	R	R

	1	2	3	4
Genus : *Plectropomus*				
P. maculatus (Bloch)	R	C	R	R
Family : Siganidae				
Geus : *Siganus*				
S. stellatus (Forsskal)	R	R	-	-
S. tavus (Linnaeus)	-	R	-	-
Family : Solenostomidae				
Genus : *Solenostomus*				
S. cyanopterus Bleesker	R	-	-	-
Family : Synanceidae				
Genus : *Synanceia*				
S. verrucosa Bloch & Schenider	C	C	R	R
Family : Syngnathidae				
Genus : *Hippocampus*				
H. kuda Bleeker				
Genus : *Syngnathus*				
S. cyanospilus Bleeker	C	C	R	C
Family : Tetradontidae				
Genus : *Tetradon*				
T. hispidus (Linnaeus)	C	C	-	R
T. immaculatus (Bloch & Schneider)	R	R	R	-
T. nigropunctatus Bloch & Schneider	R	R	-	-
T. stellatus Bloch & Schneider	-	R	-	-
Family : Triacanthidae				
Genus : *Triacanthus*				
T. biaculeatus	-	R	-	-
Family : Zanclidae				
Genus : *Zanclus*				
Z. cornutus (Linnaeus)	C	C	R	-

A = Abundant, C = Common, R = Rare, - = Not observed

* = New records from Lakshadweep.

The present survey revealed 110 Species divided among 40 genera and 15 families. Out of this, 22 species are recorded here for the first time from Lakshadweep waters. Leptoseris, Pachyseris, Oulophyllia, and Herpolitha are the newly recorded genera. From the checklist of corals of Lakshadweep (Pillai, 1983a) and the latest record of corals from this area (Pillai and Jasmine, 1989), 4 genera and 22 species have not come across in the present survey. Including this there are 132 species of corals divided among 44 genera in Lakshadweep area.

Merulina ampliata (Ellis and solander) recorded by Gardiner, (1906) and Fungia somervilli (Fungia moluccensis Vander Horst) by Pillai (1971) from Minicoy have not been located later on from anywhere in Lakshadweep waters (Pillai and Jasmine, 1989). This survey detected live specimens of these species from Kavaratti and Kalpeni islands. The present survey extended our knowledge of Diploastrea, Lobophyllia, Pavona, Montipora, Tubastrea, Cyphastrea, Porites and Hydnophora. Pillai and Jasmine (1989) regarded Diploastrea heliopora (Lamarck) as monotypic, found only in Minicoy among Lakshadweep islands and Lobophyllia was known to Lakshadweep only from Minicoy by a single species - Lobophyllia corymbosa (Forskal). This survey revealed the presence of Diploastrea in Kavaratti; Lobophyllia in Kavaratti, Kalpeni, Agatti and Bangarum. The candidate could record the presence of an additional species - Lobophyllia hemprichii (Ehrenberg) from Kavaratti. The presence of Diploastrea, Podobaca and Lobophyllia in Minicoy, and their absence in central and northern islands; the absence of Montipora, Cyphastrea and Echinopore in Minicoy and their presence in other islands created an impression to Pillai and Jasmine (1989) that a sort of natural variation in the faunal coposition at generic level occurs between Minicoy and the rest of the islands. Detection of Diploastrea and Lobophyllia from other islands in the present survey clearly shows that our knowledge is far too less to consider the variation in the faunistic composition of corals in the Lakshadweep islands. The relatively low number of genera and absence of some species in certain islands are not clear indications of the paucity of the fauna. It can be due to less intensive survey. Pillai (1983a) attributed this to difference in the extent

of areas surveyed, intensity of collection, and the real absence of certain species. The non-detection of certain common species like Hydnophora exesa (Pallas) from this area until the present survey proves that Lakshadweep coral fauna was not studied intensively. Minicoy stood first in having maximum number of genera (28) (Pillai and Jasmine, 1989), but as evident from this survey Kalpeni ranks first with 33 genera and Kavaratti follows it with 30 genera. Deepwater Species of Lakshadweep have not yet been studied. An extensive deep water survey with a team of SCUBA divers may probably reveal existence of many more species. The record of 132 species and 44 genera from Lakshadweep is a relatively poor representation of coral fauna when compared to a total of 75 genera and 241 species (Pillai and Scheer, 1976) known from the adjacent Maldives. Though some of these islands harbour fairly good number of species and genera, the degree of their dominance differ considerably. Another feature is the disharmonic or patchy nature of distribution of many species. For example, Kavaratti Island has the highest number of species, but their area coverage is negligible. This is the case in Kadmat and Chetlat islands. Difference in dominance as well as patchy nature of distribution of many species may be caused by disturbance Grigg (1983). The coral habitat in Lakshadweep, is under increasing pressure of interference, both natural as well as manmade (Pillai, 1986; James et al., 1989). In this regard an elaborate, specified team study reaching down to the deeper areas is required to understand the species diversity and to assess the quantitative extent of damage occurred to this habitat, without which it will be premature to discuss elaborately on the diversity of coral fauna of Lakshadweep.

Early reports on crustacea show that a total of 132 species of brachyuran crabs, 6 species of lobsters, 5 species of penaeid prawns and 7 species of stomatopods have been recorded so far from Lakshadweep (Rao et al., 1989). Present survey recorded 41 species of crabs, 2 species of lobsters, and 7 species of prawns. It is evident from the present study that Lakshadweep islands do not possess any substantial resource of crustaceans, which could be exploited on a comercial level. Though there

is a rich fauna of brachyuran crabs, commercially important forms are not encountered in any of the islands, yet there are some crabs, large enough to be used for food. Rao et al. (1989) stated that Eriphia sebana, Atergatis subdentats and Liomera caeleta could be used for food. These species are large enough and available in good numbers in some islands. Crabs like Calappa calappa, Coenobita cylpeatus, Nucia speciosa, Ocypoda ceratophthalma, Atergatis subdentats and Eriphia sebana are common to all islands and available in varying degree of abundance. A limited population of palinurid lobsters were found to occur in many of the islands, but majority of them were juveniles of Panulirus versicolor which was found to be the most abundant species in all the islands. Prawns encountered at Lakshadweep Lagoons were not suitable for commercial exploitation because of the small size (Rao et al., 1989) and non availability of sufficient quantity. Shrimps like Hymenocera picta, and Stenopus hispidus are extremely colourful. The bright patterns and adaptability make it a familiar aquarium species (Walls, 1982). The Stenopous hispidus is common in almost all the islands, available in good numbers and can be caught from shallow areas using simple methods. Rao et al. (1989) suggested that colourful hermit crabs available here could be used as aquarium animals. Because of the hard bottom and other unfavourable environmental conditions (Rao et al., 1989) prawn culture has not much scope in Lakshadweep. Shallow water areas with plenty of creeks and crevices are excellent habitats for lobsters, but due to unknown reasons their population is less. Sea-ranching programmes for lobsters might increase the population and could be able to develop a commercial lobster fishery.

Altogether 255 species of echinoderms are known from Lakshadweep-Maldive area and 111 species from Andaman & Nicobar islands (James, 1989). Seventy eight species of echinoderms have been documented from Lakshadweep (James, 1989). The present survey recorded 46 species, divided among 31 genera and 19 families. The genus Mithrodia is recorded here for the first time from Lakshadweep islands by a single species Mithrodia clavigera (Lamarck), in Kavaratti Island. Thirteen species have been found

to occur in common to all the islands studied. But many species showed large degree of variations in their distribution in the islands. Tripneustes gratilla (Linnaeus), an echinoid, was found to be abundant in Kalpeni and Chetlat islands. The ripe gonads of this species have export value and are considered as a delicacy in Japan (James, 1989). The asteroid Acantharter plancii (Linnaeus), notorious for its devastative feeding on coral polyps has been recorded from Kavaratti and Kalpeni. Murthi et al. (1979) have reported its presence in Minicoy. This survey shows that their population is negligibly thin and therefore may not pose a threat to corals of this area. Of all the echinoderms, the economically important forms from Lakshadweep are holothurians used in the beche-de-mer industry. Lakshadweep is very important in this point of view (James, 1989). Among all the known species of holothurians from Lakshadweep, only 7 species are used in beche-de-mer preparation (James, 1989). Only 4 species viz. Holothuria nobilis (Selenka) Bohadschia argus Jaeger, Bohadschia marmorata Jaeger and Actino-pyga mauritiana (Quoy & Gaimard) occur in appreciable quantities in some islands, allowing commercial exploitation. In the whole of the Indian region, only at Lakshadweep the best quality holothurian - Holothuria nobilis, from which first grade beche-de-mer can be prepared, is available in appreciable quantities (James, 1989). The present study indicated that this species is available in all the seven islands surveyed. A rough estimate made for the whole Lakshadweep, the resources of H. nobilis and B. argus is between 3,000 and 5,000 tonnes (James, 1989). This shows that exploitation on a rational basis can be taken up. Since the exploitable area is very limited, the islands may not withstand large scale commercial exploitation. Hence the culture and farming feasibility in the islands should be examined, and possible measures should be initiated to increase the production without affecting the natural stock.

Latest documentation of molluses from Lakshadweep (Appukuttan et al., 1989) shows the presence of 141 species, of which 18 are gastropods, 28 bivalves, and 4 cephalopods. The present survey registered the presence of 230 species divided among 87 genera and 60 families. Among this 37 species belong to bivalves, 5 species to cephalopods and 188 species to

gastropods. From the species list in early documents, 43 were not observed in this survey. Including this there are 272 species of molluscs in the Lakshadweep. In the total number of species the gastropods rank highest. Though there are only 32 species found to be common to all the seven islands surveyed, the distribution appears to be wide. Bullia spp. according to Tayler (1971) is limited to the mainland, but this exists in Lakshadweep. Though the data available to date is not sufficient enough to compare the diversity of Lakshadweep molluscan fauna with other island ecosystems and the main land, presence of 384 species in the extreme remote Chagos Islands (Sheppard, 1984) and the lack of evidence to suggest that remoteness reduces the molluscan diversity (Sheppard, 1981), molluscan fauna of Lakshadeep is expected to be rich. Micromolluscs and deep water forms have not been sampled and many more species of these are likely to be found. Hence the list of molluscs available at present from Lakshadweep should be considered provisional

Present survey indicates that a large scale exploitation of many of the commercially important species from this area is a remote possibility. Four species of octopus, four species of cowries and in some seasons one bivalve species are being regularly exploited at present in minor quantities. Cephalopods being exploited are Octopus membranaceus (Appukuttan et al., 1989), Octopus vulgaris, Octopus cyaneus and Octopus macropus. Octopus vulgaris ranks highest in abundance. Octopus is considered as a delicacy in most of the islands. As Octopus has great overseas demand, attempts on farming can be taken up. They have favourable qualities for mariculture (Silas, 1985). Gartropods like Cypraea caputserpentis, Cypraea caputdraconis, Cypraea moneta and Cypraea tigris are the important species exploited regularly in a sustenance level. Appukuttan et al. (1989) estimated the yearly numerical production of Cypraea moneta to 5-7 Lakhs, Cypraea caputserpentis to 2-3 Lakh, and Cypraea tigris to 100 numbers. Strombus, Lambis, Murex, Trochus, Turbo, Casis and Cypracea are highly ornamental, but among all these, none was found to occur in commercially exploitable quantity. Sea-ranching programmes to increase the production of ornamental

molluscs can be tried in selected islands. Bivalves of importance are Pinctada, Modiolus, Tellina, Saccostrea and Tridacna. Modiolus tulipa is being exploited at present in a minor quantity during off seasons for food in Agathi, and others are not utilised at present. Occurrence of Pinctada sugillata (Appukuttan et al., 1989) and Pinctada fucata (present survey) hold promise for their culture at Lakshadweep. Experimental pearl culture showed success at Lakshadweep (Alagaraswami et al., 1989). In the light of this experimental success, oceanic lagoon based pearl culture appears to have great potential in some of the islands of Lakshadweep. Results presented at a work shop in James Cook University indicate that the mari-culture of giant tridacnid clams is both technically and economically viable with markets for flesh and shells in Taiwan and Japan (Copland and Lucas, 1988). This could be initiated at Lakshadweep also.

Major fish species of regular fishery value at Lakshadweep were not considered in this survey as they have been in constant study and considerable amount of information is available on them. So the present survey concentrated on the rather less studied lagoon and reef associated fishes, which do not contribute to the major fishery, but many of them hold potential for developing a fishery for aquarium purposes. Altogether 603 species of fishes belonging to 126 families have been reported from Lakshadweep (Jones and Kumaran, 1980). Atleast 300 species belonging to 40 families are considered to have ornamental value (Murty et al., 1989). They collected 139 species belonging to 33 families from this area in a recent survey during 1989. The present survey recorded 120 species belonging to 67 genera and 35 families. Of this, two species were hitherto unrecorded from Lakshadweep. All the species recorded during the present survey are lagoon associated and easily fishable with minimum requirements. Kalpeni Island showed the maximum diversity, followed by Kavaratti, Kadmath and Amini. Forty two species were found to be common to the islands studied. The data available at present are not sufficient to estimate the real potential of lagoon associated fishes, however, it gives a picture of the abundance and availability of some species of importance at the minimum effort. Most of the reef associated fishes have ornamental value, of which

the family Chaetodontidae are highly attractive for aquarium keeping. Family Acanthuridae, Pomacentridae, Balistidae, Calyodontidae, Holocentridae and Scorpinidae are also of highly ornamental value. Presently there is no fishery for ornamental purpose. But some forms belonging to Mullidae, Lutjanidae, Labridae, callyodontidae and Acanthuridae have ornamental as well as food value and are being fished from the lagoon especially during off seasons. The western and northern islands are rich in ornamental fishes (Murthy et al., 1989) but in the present survey Kalpeni Island showed a clear domination for total number of species and their abundance. In view of the considerable demand for marine ornamental fishes from different countries (Tomey, 1985) more detailed studies should be geared up for species abundance, availability, fishing methods,seasonality,biology,acclimatization to aquarium condition and non-conventional food, packing and transport methods.

Though the lagoon based resources of Lakshadweep are diverse and rich, many of these are not exploitable on a commercial basis, owing to the small area and low density of occurrence. Depletion of live coral cover in many islands adversely affect a number of useful organisms associated with this environment. Creation of artificial reefs can attract many organisms in the lagoon for recolonisation. Other possibility to increase production from this area is to utilize the lagoon and surroundings for mariculture, by using native species as well as by introduction from other areas. Since the coral ecosystems are extremely fragile proper care should be taken so that the ecology of the lagoons is not disturbed. Literacy rate in the island is high so that it will not be difficult to motivate local people to venture into culture activities in the islands and in imparting training to them.

CHAPTER - II

HYDROBIOLOGY OF KAVARATTI ATOLL

INTRODUCTION

The term coral reef encompasses a wide variety of structures which have predominantly formed of calcium carbonate, in tropical marine environment. They are characterised by high rates of primary productivity and vast assemblage of resources amid the apparently nutrient impoverished waters. Coral reef development, maintenance and survival are almost entirely related to local physical, chemical and biological environment.

Hydrography and nutrient dynamics in coral reefs have been the focus of great scientific interest in the recent time, as a result of this informations are pouring in from many parts of the world. Despite all these developments our knowledge on the hydrography of Lakshadweep coral reefs remained with very little attention.

Primary production is in effect the engine that drives the entire reef system. Primary productivity of the oceans historically has been associated with phytoplankton, but in tropical coral reefs, the benthic and symbiotic plants are the key participants in production (Lewis, 1977; Colinvaux, 1986). Though coral reef productivity has been intensively studied, data on productivity of specific taxa of benthic primary producers are limited (Wafar, 1977; Colinvaux, 1986).

Zooplankton washed into the lagoon across the reef from the sea form a rich source of food for the reef building animals as well as for the communities associated with reefs. Inspite of the importance of zooplankton in the reef ecology, these organisms in Lakshadweep coral reefs received very little attention. Nair et al. (1986) have invited detailed studies on zooplankton in the lagoons of Lakshadweep and the surrounding sea.

The dearth of information on these aspects from Lakshadweep is largely because of the remoteness of these atolls. What little information available with us are the results of short term and widely gaped studies made by authors periodically visiting this area. Hardly there has been any detailed long term study to have a clear picture of the hydrobiological conditions such as hydrography, primary productivity, zooplankton distribution and their dynamics as well as seasonality, till todate. A detailed knowledge on the above aspects are important parameters in understanding coral reef environment and their effective use and management for human benefits. Such a study would also help solving several lacunae in the ecology and biology of Lakshadweep coral reefs.

Attempts made to study the hydrobiological aspects of Lakshadweep Atolls and adjacent waters in the past by various authors are as follows. Wolfenden (1906) has studied the copepod contents of zooplankton of Lakshadweep. 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 Ramamiritham (1963) compared winter and summer conditions of Lakshadweep offshore waters and provided some information on the chemical charactors. Rao and Jayaraman (1966) reported upwelling in the Minicoy Atoll region of Arabian Sea. Qasim and Bhattathiri (1971) studied the productivity of seagrass beds at Kavaratti Atoll. Primary productivity of some coral reefs including Laksadweep has been studied by Nair and Pillai (1972). Goswami (1973) made preliminary observations on some planktonic groups of Kavaratti Atoll. Pillai and Nair (1972) carried out productivity studies on some hermatypic corals by means of both oxygen measurement and ^{14}C methods. Physical and chemical characters of water in and around Kavaratti, their diel variation in the lagoon, water circulation in the lagoon, productivity of the atoll, and individual production of algae, seagrasses and corals were studied by Qasim et al.(1972). Tranter and George (1972) have studied the zooplankton abundance at Kavaratti and Kalpeni Atolls of Lakshadweep and stated that zooplankton abundance in the lagoons are lesser than the surrounding sea. Chemical characters like temperature,

pH, dissolved oxygen, salinity and their diurnal variation in Kavaratti Atoll were investigated by Sankaranarayanan (1973). Information on chemical characters and zooplankton occurrence and abundance in and around Kavaratti Atoll have been provided by Goswami (1973, 1979, 1983). Lowering of surface temperature with the advance of South west monsoon in the Arabian Sea has been studied by Rao et al. (1976). Mathupratap et al. (1977) observed higher biomass and density of zooplankton in the sea surrounding this atolls than in the lagoons. Plankton production in Kavaratti and Agathi Atolls of Lakshadweep has been studied by Wafar (1977). Variation in calcium content of the Lakshadweep waters and production of $CaCO_3$ by reef flat and lagoon in Kavaratti Atoll have been studied by Naqvi and Reddy (1979). 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. Euphausiacea of the Indian seas have been studied by Mathew (1982). Nair et al. (1986) described the productivity of the seas around Lakshadweep. Studies on nitrogenous nutrients and primary production in Lakshadweep waters have been made by Wafar et al. (1986). Girijavallaban et al. (1989) made brief observations on the hydrobiology of Lakshadweep Atolls. Sing et al. (1990) studied the vertical distribution of nutrients in Lakshadweep waters. Wafar et al. (1990) studied the nitrification in reef corals and its importance in reef nitrogen economy.

Against this background the present investigations were carried out at Lakshadweep to provide a detailed base line information on the hydrobiological environment, concentrating the studies on Kavaratti Atoll.

MATERIALS AND METHODS

The environment

Kavaratti is a perfect atoll (Gardiner, 1903, 1906), located along Lat. 10°33'N and Long. 72°38'E (Plate 7,Figure 2) and has an island of 3.45 sq.km area, largely covered by coconut palms. The island is narrow, arcuate, trending roughly NE-SW and elevated only a few metres above

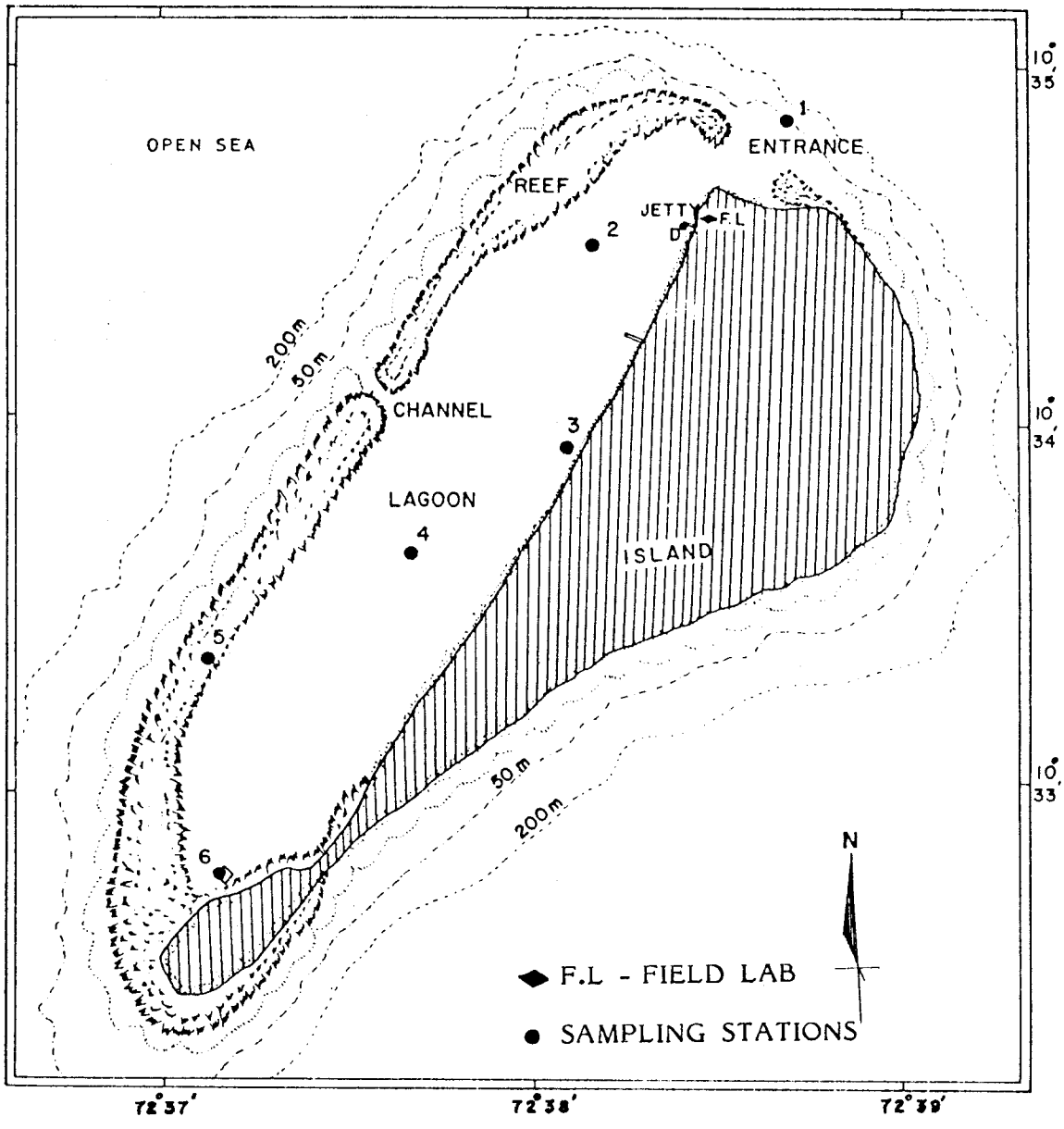

Figure 2. Location of sampling stations in Kavaratti Lagoon.

sea level. There is a shallow lagoon on the western side, about 4,500 m long and 1,200 m wide, having depth ranging from 1.5 to 1.8 m at low water and 2.04 to 3.5 m at high water (Qasim et al., 1972). Bordering the western area of the lagoon, there is a ring shaped reef with a width of about 250 to 300 m. The reef has a 60 m wide gap on the north west point, forming the main navigational entrance to the lagoon, and a narrow channel about 5 m wide, on the west. The transport of water from the sea to the lagoon is maintained all the time by the action of surf, which breaks across the reef and sweeps into the lagoon. The beach has a gentle slope with an exposure of about 60 m at the lowest low tides. The beach slope, from about low water neap tide, has a luxurient growth of macrophytes mainly Thalassia hemprichii and Syringodium isoetifolium, extending to a distance of 100 m into the lagoon. The portion of the lagoon toward the reef is characterised by living and dead corals, with irregular areas of coral rubble, algal beds and sand. Although patchy in distribution, all along the lagoon, corals are the dominant forms. The lagoon water shows a unidirectional flow in all seasons, accelerating enroute from the southwest corner to the entrance (Qasim et al., 1972). The current velocity depends on the prevailing wind and wave. Tides at Kavaratti are mixed semi diurnal type with maximum range of 1.7 m (Qasim et al., 1972).

Hydrography

Sampling stations: For regular study of hydrographical parameters, six sampling stations were fixed at different areas of the lagoon as shown in Figure 2. Five stations were inside the lagoon and one station outside The Station - 1 was located outside the lagoon, representing the open sea, about 50 m away from the main entrance of the lagoon, having a depth of more than 50 m. Station - 2 having an average depth of 1.5 m, with bottom characterised by white lagoon sand, coral rubbles and sparse growth of seagrasses and algae, situated inside the lagoon. Station - 3 was near the lagoon shore, with about 1 to 2.5 m depth, and bottom having a luxuri-ent growth of seagrasses, occasionally intermixed with algae. The middle area of the lagoon, characterised by white loose sandy bottom, without any apparent vegetation, having a depth ranging between 2.3 m, represented station - 4. Station-5 situated just over the reef which was characterised

by live and dead corals, and algal growth. Station - 6 located at the southern tip of the lagoon which was characterised by rich growth of corals, algal beds, and sandy patches. Bottom was of white loose sand, and depth ranged between 1.5 to 2.5 m. Distance between the stations was more than 1 to 1.5 Kilometres.

Sampling frequency: Sampling operations were carried out regularly once in a fortnight for a period of two years from January, 1988 to December, 1989. Sampling was conducted always in the morning hours. A small fibre glass boat fitted with "YAMAHA" out board engine was used for collecting the samples (Plate 8a). Since the boat was not worthy in rough weather, some stations, particularly the station - 1 were not covered regularly in rough seasons. The samples were analysed in the field laboratory, set up by the candidate at Kavaratti (Plate 8b).

Temperature: A 0-50°C, reversible thermometer was used to measure water temperature. Water was collected from the surface in a plastic bucket and the temperature was measured immediately.

Hydrogen ion concentration: The pH of the water samples was determined in the field laboratory immediately after sampling. A "BIOCHEM" digital pH meter with combination electrode was used for the purpose. Water samples were collected from about 5 cm 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: Water samples in duplicate were collected in 125 ml "corning" reagent bottles with airtight BOD stoppers, from about 5 cm below the surface. The samples were fixed using 1.0 ml Winkler-A and then Winkler-B solution. The samples were stored in insulated box till they were analysed the same day in the field laboratory. Analysis of the samples was made by following the "Winkler method" modified by Carritt and Carpenter (FAO 1975) using 0.02 N sodium thiosulphate as titrant and starch indicator. Results are expressed in millilitre oxygen per litre (ml O_2/l).

Salinity: Water samples in duplicate were collected in 100 ml clean airtight, polythene bottles, from about 5 cm below the surface. The samples were stored in insulated box till they were analysed the same day in the field laboratory, using "Mohr" titration method (Strickland and Parson, 1968). Ten ml sample was titrated against standard silver nitrate solution using potassium chromate as indicator. Silver nitrate solution, was standardised with standard sea-water supplied by the Oceanography Laboratory Copenhagen. Each sample was titrated thrice and means of these were considered for calculation of salinity in parts per thousand (‰).

Nutrients: For the analysis of nutrients like inorganic phosphate(PO_4-P), Silicate (SiO_4), nitrite (NO_2-N) and nitrate (NO_3-N), water samples in duplicate were collected in 500 ml clean polythene bottles, from about 5 cm below the surface. The bottles were stored in insulated box, and analysed the same day in the field laboratory. A "BIOCHEM" colorimeter was used for reading the absorbance of nutrients. The concentration of nutrients in the sample was found out from standard graphs prepared for each nutrient factor using known concentrations of standards. The results are expressed in international unit of microgram atoms per litre (/ug at/l).

Phosphate (PO_4-P): The method described by Murphy and Rilley (1962) given in FAO (1975) was followed for the analysis. The phosphate in water was allowed to react with ammonium molybdate, forming a complex heteropoly acid. This was reduced by ascorbic acid, in presence of Antimonyl tartarate as catalyst, into a blue coloured complex, the light absorption of which was measured in a photometer. Outline of the method is as follows.

Five ml 0.10 M potassium antimonyl tartarate solution was added to acid-molybdate reagent. From each sample, two 35 ml portions were transferred to 100 ml clean conical flasks. One of the portions was regarded as the sample and the other as turbidity blank. To each portion 1.0 ml acid-molybdate solution, prepared fresh every time was added, and to the sample 1.0 ml of 0.4 M Ascorbic acid solution was also added.

Mixed well and after 5 minutes the absorbance of the sample was measured against its turbidity blank in the colorimeter using 750 nm filter. Corrected the measured absorbance by subtracting the absorbance of a reagent blank, prepared in 35 ml distilled water following the same way, from that of the sample.

Silicate (SiO_4): Reactive silicate was determined by following the method described in FAO (1975).

To 35 ml sample taken in 50 ml plastic jars, 1.0 ml molybdate reagent was added. After 10 minutes, added 1.0 ml 0.7 M oxalic acid solution, immediately followed by 1.0 ml ascorbic acid solution of 0.1 M. Gently stirred while adding the reagents. After 30 minutes absorbance of the sample was measured against its turbidity blank with 750 nm filter in the colorimeter. Absorbance of the sample was corrected with a reagent blank.

Nitrite (NO_2-N): The modified Bendschneider and Robinson method (Koroleff, 1973) described in FAO (1975) was followed for the analysis.

To 25 ml sample and turbidity blank taken in clean 100 ml conical flasks, 0.5 ml sulphanilamide reagent was added. After not less than 3 minutes and not longer than 8 minutes, 0.5 ml diamine solution was added to the sample but not to the turbidity blank and mixed thoroughly. After 10 minutes the absorbance of the sample was taken against the turbidity blank on the colorimeter with 550 nm filter. Absorbance of the sample was corrected with a reagent blank.

Nitrate (NO_3-N): A method based on the reduction of nitrate into nitrite by hydrazine in presence of copper ions as catalyst, described by Mullin and Riley (1955) was followed for the analysis.

To 50 ml of the sample and turbidity blank, 2.0 ml buffer reagent and 1.0 ml reducing agent were added on gentle mixing. The samples were kept in total darkness for 20 hours, then 2.0 ml acetone, and after 2

minutes 1.0 ml of sulphanilamide solution were added. After 2 minutes and not later than 8 minutes added 1.0 ml N-(1-napthyl) ethylene diamine dihydrochloride (N.N.E.D.) solution to the sample, but not to the turbidity blank. After 10 minutes the absorbance of the sample was taken against its turbidity blank, using the 550 nm filter Corrections were made with a reagent blank.

Calcium: Calcium was determined by EDTA volumetric method (APHA, 1975). When EDTA (Ethylene diamine tetraacetic acid) is added to water containing both calcium and magnesium, it combines first with calcium. Calcium can be determined directly, using EDTA, when pH is made sufficiently high that the magnesium is largely precipitated as the hydroxide and an indicator is used that combines with calcium only, which will give a color change when all of the calcium has been complexed by the EDTA at a pH of 12 to 13.

A fraction of sample taken for salinity determination was used for Ca determination. Ten ml sample was diluted to 50 ml with distilled water and added 1.0 N sodium hydroxide sufficient enough to raise the pH between 12 and 13 and then added 0.2 g "Murexide"(Ammonium purpurate) indicator. After thorough mixing, this pink solution was titrated with 0.01 M EDTA, till the pink colour changed into purple. The end point was compared with that of a standard. Results are expressed in milligram calcium per litre (mg/l).

Diurnal study: Diurnal study was carried out at station - D (Figure 2) near the fisheries jetty, at the northern end of the lagoon. The area was of 1.5 to 3 m deep with the bottom having a lush growth of seagrasses and algae. The studies were conducted in April, 1989 for hydrographical parameters. Water samples in duplicate were collected from this station at an interval of 3 hours, continuously for 24 hours, starting from 0900 hrs. Samples were analysed in the field laboratory immediately after collection. Tidal range was measured using a graduated scale.

Statistical analysis: Statistical analysis were done with the help of computer. Two way analysis of variance (ANOVA-2) programmed in "BASICA" was used to study the seasonal fluctuations and station to station difference in hydrographical parameters. Results of the fortnightly observations for the two years were pooled seasonwise, such as Pre-monsoon (Feb-May), monsoon (June-Sept), and post-monsoon (Oct-Jan) and into stations 1 to 6. The seasons were taken as replicates and stations as treatments for analysis of variance test. The results are presented as ANOVA tables. Relationship between the various environmental parameters at each station was worked out by constructing six "correlation matrices", programmed in "BASICA". Results are presented as tables of correlation matrix.

Productivity

Productivity of phytoplankton, two species of seagrasses and three species of corals were studied twice in every month at station - 6 (Figure 2). The method followed are given below.

Phytoplankton: Productivity of phytoplankton was studied for a period of one year. The standard, light and dark bottle method was used for the study. Freshly collected seawater was taken in 300 ml, clean, transparent glass bottle, and same quantity in dark, air tight, light proof bottles. These bottles were exposed to sunlight for 4 hours by suspending them in the lagoon at a depth of 1 metre. Dissolved O_2 was determined by "winkler" method (FAO, 1975) for the seawater before incubation (initial) and after the incubation. Productivity was calculated in the following way.

Gross production = Lb - Db

Net production = Lb - Ib

Respiration = Ib - Db

Where LB = ml O_2 in light bottle

I b = ml O_2 in initial bottle

Db = ml O_2 in dark bottle

$$\text{Production in milligram carbon/m}^3 = \frac{\text{ml } O_2 \times 0.536 \times 1000}{\text{PQ}}$$

Where PQ (photosynthetic quotient) = 1.25

Results are expressed in the text as milligram carbon per cubic meter per hour (mg C/m^3/hour).

Seagrasses: The method described by Qasim and Bhattathiri (1971) and Qasim et al. (1972) was followed for the study. Two species of seagrasses Thalassia hemprichii (Ehrenb) Syringodium isoetifolium (Aschers) leaves were collected from the lagoon, and thoroughly cleaned with freshly collected millipore filtered seawater to remove all epiphytes and epifauna. Keeping in a beaker containing filtered seawater, weighed out 3.0 g and transferred into glass jars of 300 ml capacity. Another portion of same weight was kept in black, light proof bottle of same capacity. The bottles were filled with freshly collected seawater, filtered through millipore filter paper of pore size 0.45/um and closed airtight by keeping the jars immersed in the filtered seawater. It was assumed that the filteration removed phytoplankton and all other plant and animal materials from the seawater. Care was taken not to trap any air bubbles in the bottles. A set of one light and dark bottles of same capacity, filled with the filtered seawater was used as controls. These jars were exposed to sunlight for three hours by suspending them in the lagoon at 1 m depth. Every time two replicate sets of light and dark bottles were exposed to light. Productivity was calculated as described in the case of phytoplankton production. Results are expressed in milligram carbon per gram plant per hour (mg C/g/hr).

Production from corals: Similar experiments were carried out on three species of corals following the method described by Qasim et al. (1972). Actively growing tips from Porities cylindrica (Dana) Acropora formosa (Dana) and Pocillopora damicornis (Linnaeus) were collected, cleaned of all associated organisms and plant materials while still in seawater. The branches were allowed to acclimatise by holding them in running filtered seawater for one night. A known weight (7-10 g) from the growing tips, whose polyps were expanded after acclimatisation, were kept in light bottle and same weight in dark bottle of 300 ml capacity, having filtered fresh seawater. Care was taken for not to expose the branches to air while weighing and also not to make any damage. Productivity was calculated as in the case of seagrasses. In the text of the Thesis the results are presented as milligram carbon per gram of coral per hour (mgC/g/hr).

Statistical analysis: Seasonal fluctuation in productivity was worked out through one way analysis of variance (ANOVA-1). The productivity was correlated with important hydrographical parameters using "correlation matrix" Since the experiments were conducted at station-6, hydrographical parameters studied in this station were used for correlation studies.

Zooplankton distribution

Samples were collected from stations - 2,3,5 and 6 for day time, and from station - D (Figure 2) for night time sampling. Since towing was not possible, the method of filtering a known volume of water through a hand net was adopted for the study.

Thousand litres of water (1 cubic metre) was filtered through a hand net made of bolting silk with a collecting bucket. The filtering was carried out using a plastic bucket of 10 litre capacity, by pouring quickly drawn 100 buckets of water through the net. The zooplankton collected in the collecting bucket were preserved in 5% formalin. All the operations were made from the boat used for sampling. Results are expressed as total number of organisms of each broad taxonomic groups per cubic metre ($1m^3$) of water filtered. Seasonal fluctuation in occurrence and abundance, and station to station variation are also given in the results.

Diurnal study: Using the filtering method, zooplankton samples were collected from Station - D (Figure 2), at an interval of 3 hours, continuously for 24 hours This was carried out along with the diurnal study for hydrographical parameters.

Statistical analysis: Two-way ANOVA was used to study the variation between stations and over seasons.

RESULTS

Hydrography

Results of the studies on the hydrographical parameters for the entire period of study, are presented graphically. For this purpose a

parameterwise pattern is followed, that is, a particular parameter from all the six stations are assembled together. Graphs are drawn using monthly mean values of each parameter. The vertical line at each mean point indicates the standard deviation on either side of the mean. For convenience of expression, the year 1988 and 1989 are regarded as first and second year. In the ANOVA tables, stations were considered as "treatment" and seasons as "replicates". Results of the diurnal studies are also presented graphically. The correlation coefficient 'r' value obtained for each station are presented in tabular form. Only significant correlations are considered in the running text.

Monthly variations of water temperature in stations 1 to 6 during the study period are shown in Figure 3. Maximum temperature recorded during the first year was 30.5 ±0.4°C in May, 31.0±1.4, 31.3±1.1, 31.5±1.4, 31.8±1.1 and 31.8±1.1°C in March respectively for stations 1 to 6. Minimum temperatures were 27.5±0.5°C for station-1 and 28.0±0.7°C for stations 2 to 6 in June. During second year the highest temperature for station -1 was 30.5±0.5°C in May; 30.3±0.3, 30.05±0.1, 30.3±0.4, 30.3±0.1°C respectively for stations 2 to 5 in November and 30.5°C in April and May for station - 6. The lowest 27.5°C for all stations in July. It is evident from Figure 3 and two way ANOVA (Table 7) that there was no significant variation in temperature between stations, but showed significant variation over seasons ($P < 0.01$). Seasonal means and standard deviations are given in Table 8. Table 9 shows the average values of temperature for all the stations.

Figure 4 shows the monthly fluctuation in pH over the entire period of study. There was no observation for pH in January, 1988. As shown in the graph, during the first year, maximum pH observed for stations-1 and 2 was 8.33±0.01 and 8.32±0.00 respectively in April, stations - 3 and 4 showed maximum in December (8.32±0. 01 and 8.32±0.00) respectively, Whereas for station - 5 the maximum pH was in October (8.34±0.01), for station - 6 it was in April (8.37±0.02). While the lowest pH observed in station - 1 was 7.01±0.00 in June, for all other stations it was in July,

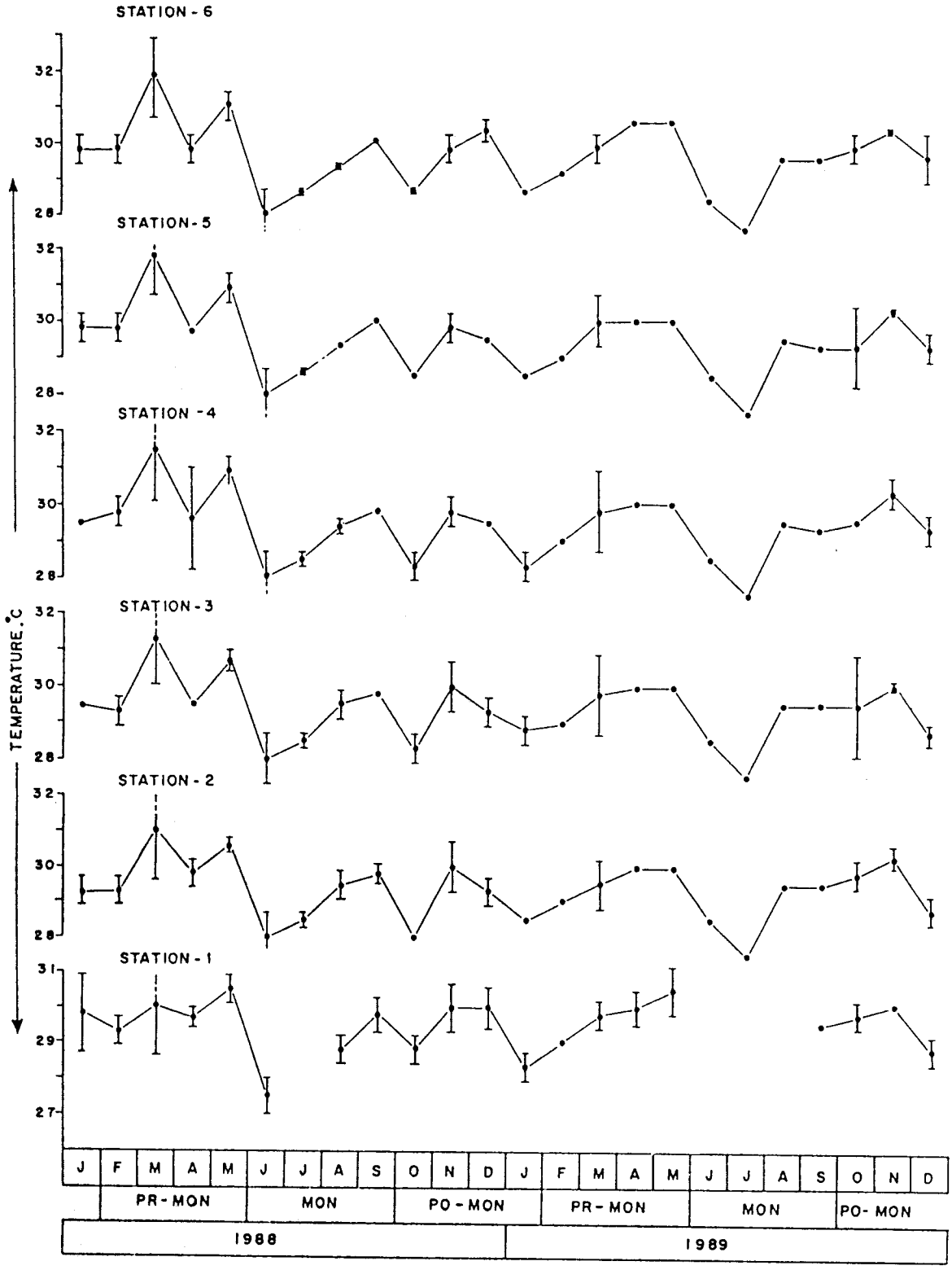

Figure 3. Monthly average and standard deviation of water temperature in various stations.

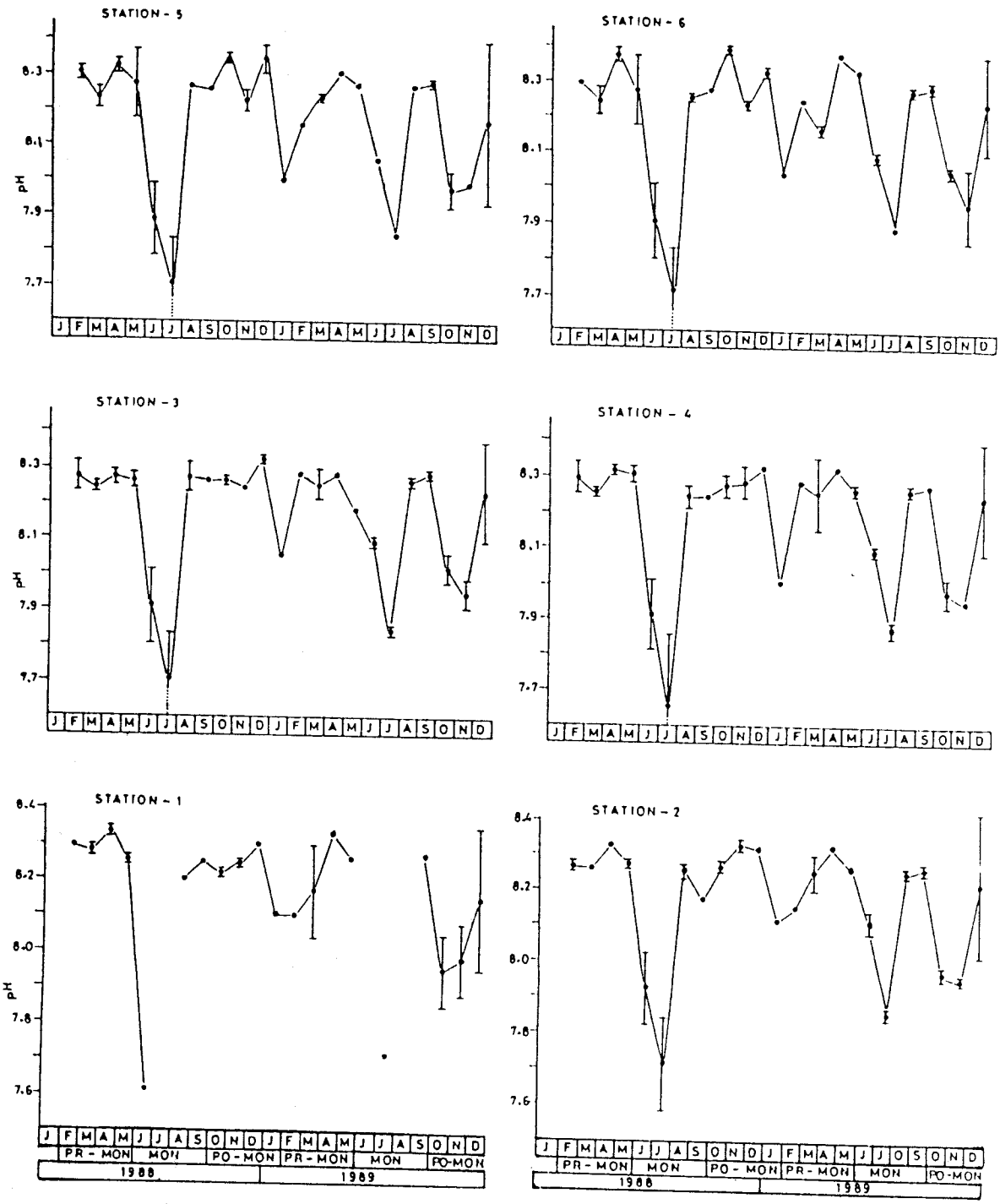

Figure 4. Monthly average and standard deviation of pH in various stations.

which being 7.71±0.13, 7.7±0.13, 7.65±0.2, 7.7±0.13 and 7.71±0.13 respectively in stations 2 to 6. During second year the distribution of pH in all the stations was uniform. The maximum pH values obtained were 8.33±0.001, 8.32±0.00, 8.28±0.00, 8.32±0.00, 8.30±0.00 and 8.37±0.00 in April for stations-1 to 6 respectively and the minimum were 7.71±0.00, 7.85±0.00, 7.84±0.01, 7.87±0.02, 7.84±0.00 and 7.88±0.00 respectively for stations - 1 to 6. Two way analysis of variance (Table 7) showed no significant variation of pH with location of stations, but showed highly significant seasonal variations ($P < 0.01$). Average values of pH for all the stations are given in Table 9, and Table 8 shows its seasonal averages and standard deviations.

Figure 5 explains the monthly dissolved oxygen concentration for the entire period of study from all stations. During first year, the maximum dissolved oxygen concentration for station - 1 was in January (5.39±0.70 ml/l), for stations - 2 to 5 in June, the values being 6.89±0.1, 6.54±0.4, 6.50±03 and 6.66±0.08 ml/l respectively. The station - 6 showed a peak in May (6.58±0.10 ml/l). Minimum concentrations noted were 3.92±0.3 for station - 1 in April, 4.17±0.5, 3.84±0.00 and 3.66±0.00 ml/l respectively for stations - 2,3 and 5 in February, 3.83±0.04 and 3.74±0.10 ml/l for stations 4 and 6 respectively in November. During first year the highest concentration observed was in the early monsoon season. During the second year, the pattern of dissolved oxygen distribution showed slight variation. Maximum values of 6.04±0.7, 6.1±0.70, 5.14±0.60, 6.51±1.4 and 7.30±0.8 ml/l were obtained for stations - 1 to 3,5 and 6 in January. Station - 4 showed maximum value in February (6.29±0.08 ml/l). Minimum values were observed in July for station - 1 (4.00±0.00 ml/l), 3.45±0.00 and 2.99±0 ml/l for stations 2 and 3 in May, 3.84±0.00 ml/l in October for stations - 4, 3.28±0.00 ml/l in April for station - 5 and 3.91±0.20 ml/l in March for station - 6. A two way ANOVA showed significant variation ($P < 0.05$) between stations and no significant seasonal variations (Table 7). Average seasonal values of dissolved oxygen for different stations are shown in Table 8. Lagoon stations showed a higher concentration than the open sea station (Station - 1). Average values for all stations are shown in Table 9.

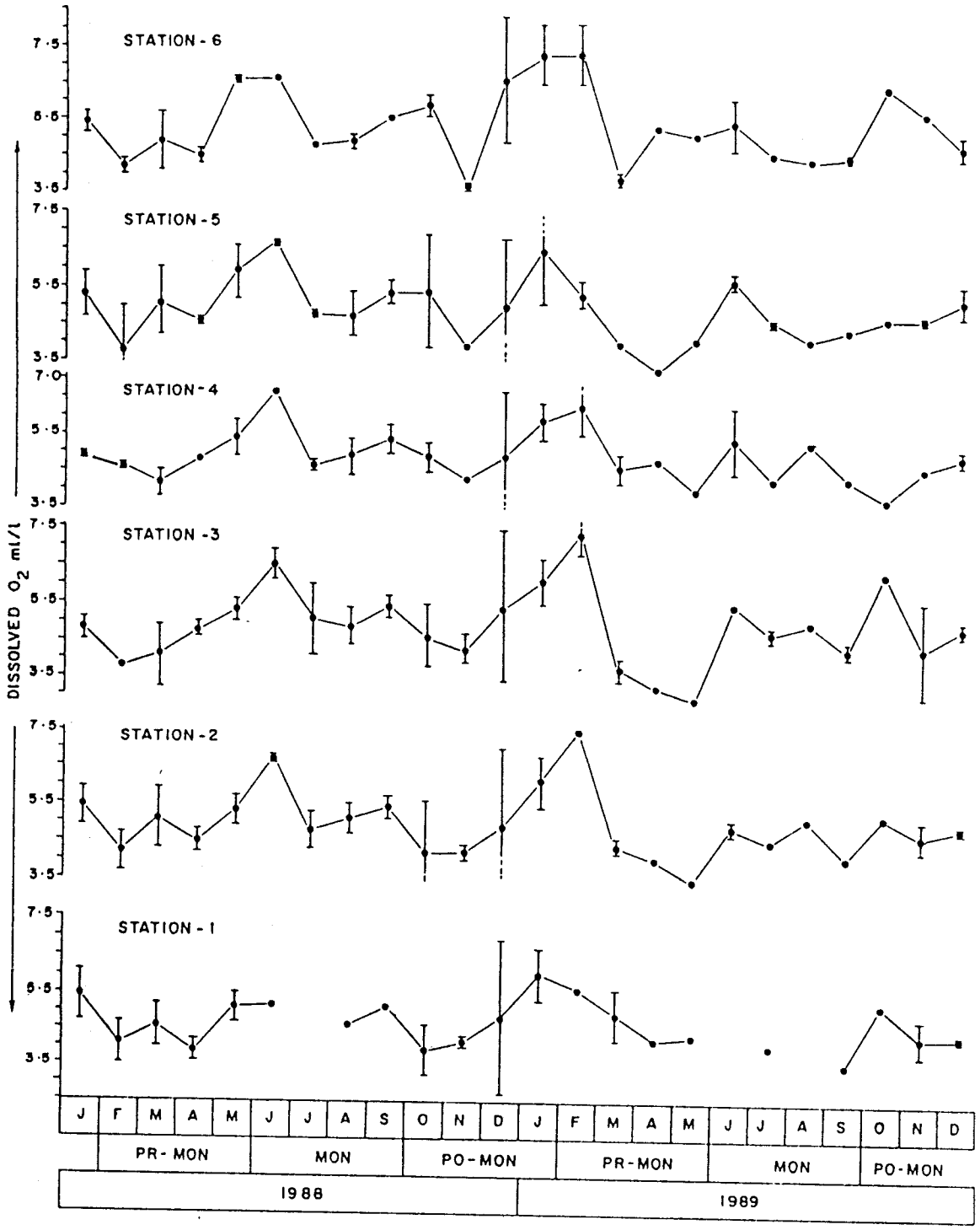

Figure 5. Monthly average and standard deviation of dissolved oxygen in various stations.

Salinity showed a steady pattern in its fluctuation during the entire period of study (Figure 6). During first year, stations - 1 and 6 showed maximum salinity in January (34.99±0.13 and 35.00±0.00‰ respectively). Stations - 2 to 5 showed highest salinity in March, the values being 35.19± 0.10, 35.05±0.20, 35.10±0.10 and 35.06±0.50‰ respectively. Minimum values were observed for station -1 in June (33.15±1.01‰) and 36.67±0.04, 33.72±0.02 33.71±0.30, 33.70±0.40 and 33.75±0.04‰ in July for stations - 2 to 6 respectively. In the second year, the maximum salinity observed was 35.15±0.01, 35.17±0.02 (January and February), 33.29±0.20, 35.27±0.13, 35.33±0.20 and 35.30±0.20 respectively for station - 1 to 6 in January and minimum values of 33.05±0.10, 33.67±0.04, 33.61±0.1, 33.76±0.10, 33.71±0.01 and 33.72±0.1‰ respectively for stations - 1 to 6 in July. Two way ANOVA showed no statistically significant variation in salinity between stations, whereas it showed highly significant ($P < 0.01$) seasonal fluctuations (Table 7). Average salinity for all stations are given in Table 9 and seasonal average and standard deviation in salinity are given in Table 8. The high pre-monsoon salinity decreased during monsoon and again increased during post-monsoon season. This pattern was evident in the first year as well as during the second year.

Monthly average and standard deviations of silicate concentration for all stations during the period of study are indicated in Figure 7. During first year, the silicate concentration was maximum for station - 1 to 5 in March, the values being 5.80±0.28, 5.00±0.71, 4.65±0.92, 4.65±0.92 and 5.50±0.00 /ug at/l respectively and 3.90±0.57 /ug at/l in April for station - 6. Minimum values were observed for station - 1 and 2 in June (2.95±0.00 and 2.35±0.64 /ug at/l) and stations - 3 to 6 in July, the concentration being 2.30±0.71, 1.8±0.85, 1.80±0.85 and 1.60±0.57 /ug at/l respectively. During second year, the maximum values of Silicate for station - 1 was in March (6.25±0.35 /ug at/l) and for station - 2 to 6 in April, the values being 5.65±0.49, 6.15±1.20, 6.10±0.99, 5.70±0.42 and 5.60±0.56 /ug at/l) respectively. Minimum concentrations observed being 3.50±0.00, 2.20±0.14,

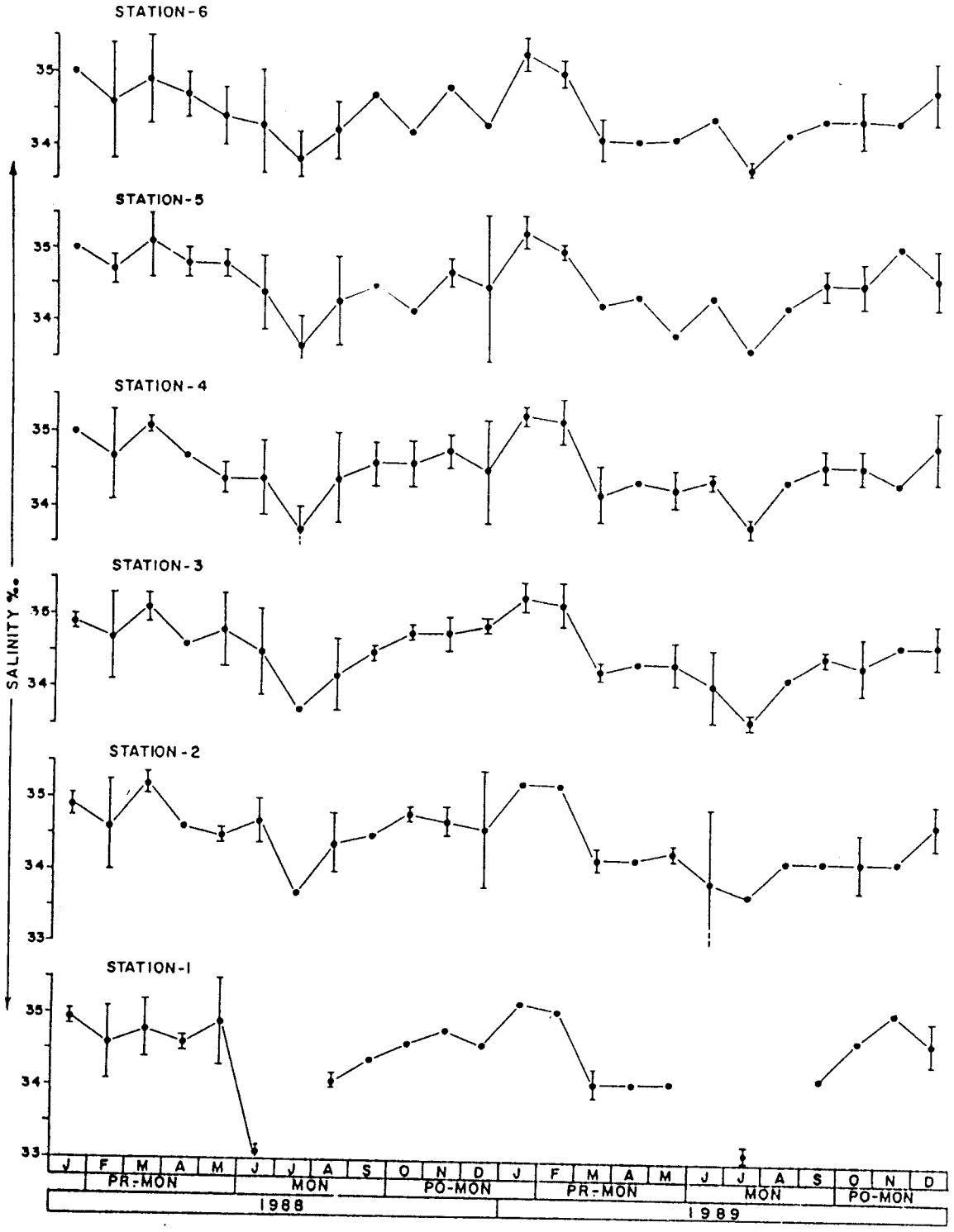

Figure 6. Monthly average and standard deviation of salinity in various stations.

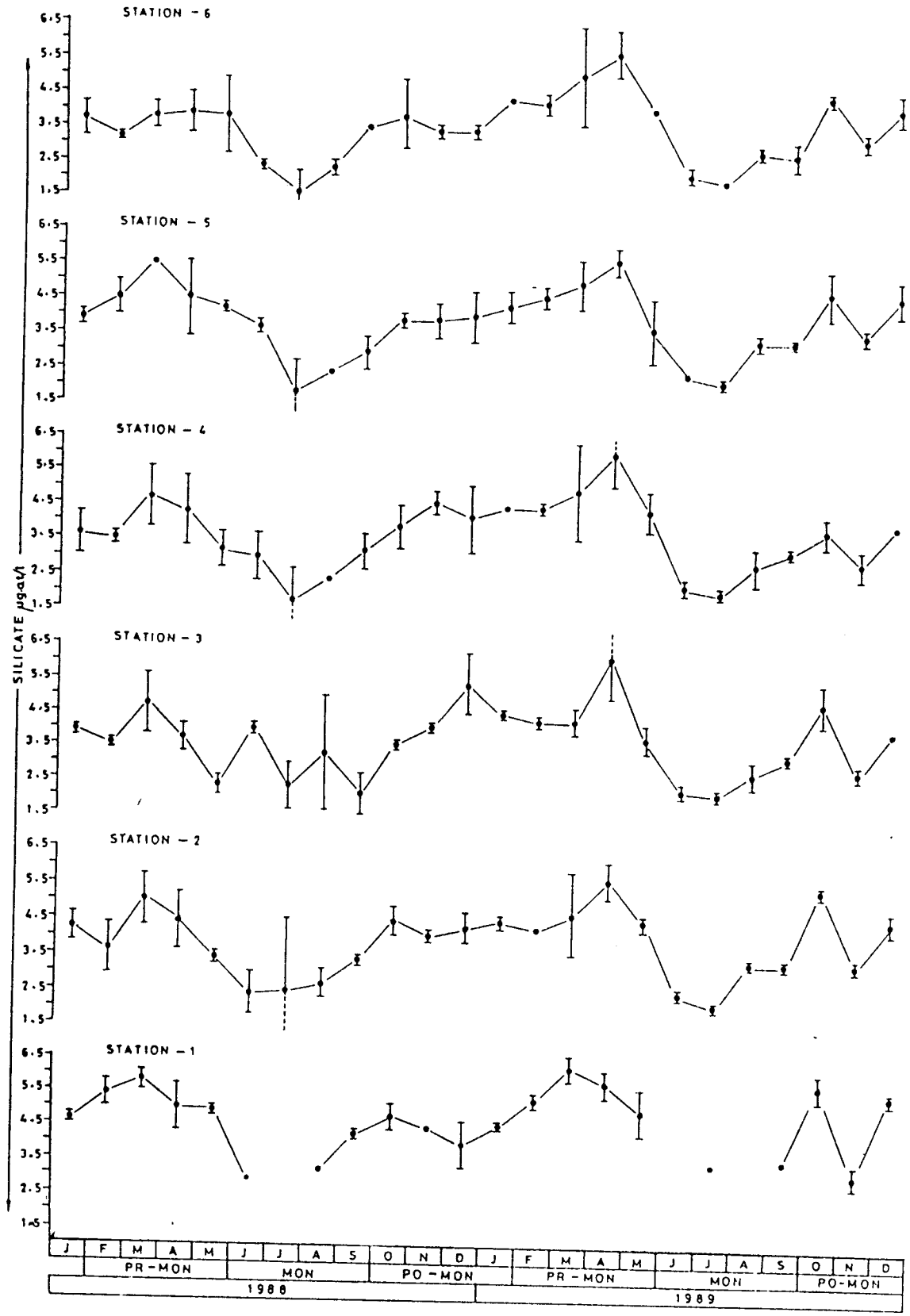

Figure 7. Monthly average and standard deivation of silicate in various stations.

2.15±0.07, 2.10±0.14, 2.20±0.14 and 2.00±0.00 /ug at/l respectively for stations - 1 to 6 in July. It is inferred from Figure 7 and Table 7 that there is highly significant variation ($P < 0.01$) in silicate between stations and over seasons. On an average, silicate was highest in open sea (station - 1) and lowest in station - 6. The average silicate concentration for each station is given in Table 9. Table 8 shows the seasonal average and standard deviation of silicate for all the stations. The concentration was highest during pre-monsoon season and lowest during monsoon. The general pattern of fluctuation of silicate in all the stations is similar, with a maximum during pre-monsoon and minimum during monsoon. This pattern was followed throughout the entire period of study.

Figure 8 shows the monthly values of phosphate concentration in all the six stations for the period of study. During the first year, phosphate concentration for station - 1 was highest in September (0.425±0.02 /ug at/l), for stations - 2 and 3 (0.390±0.13, 0.48±0.00 /ug at/l) in May, for station - 4 in December (0.490 ± 0.00 /ug at/l) and for station -5 and 6 in April (0.480±0.10 and 0.470±0.04 /ug at/l). The lowest values were 0.155±0.10 /ug at/l in March for station - 1, and 0.105±0.01, 0.145±0.02, 0.100±0.00, 0.150±0.10 and 0.180±0.03 /ug at/l respectively for stations - 2 to 6. During second year the maximum concentration of phosphate was observed in May for station - 1 (0.465±0.02 /ug at/l), June for station - 2 (0.365±0.05 /ug at/l), March for stations - 3 to 5 (0.375±0.05, 0.360±0.06 and 0.360±0.06 /ug at/l) and April for station - 6 (0.320±0.03 /ug at/l). Minimum concentrations observed for stations–1 to 4 was in October, the values being 0.260±0.20, 0.200±0.10, 0.195±0.10 and 0.140±0.04 /ug at/l respectively and for station - 5 and 6 in January (0.100±0.13 /ug at/l). The two way ANOVA showed significant variation in concentration between stations ($P < 0.05$) and highly significant variation ($P < 0.01$) over seasons (Table 7). As given in Table 9 phosphate showed higher concentration in Station - 1 when compared to other stations. Among lagoon stations, station - 5 showed highest concentration, and lowest of all in station - 6. Average seasonal values and standard deviations are given in Table 8.

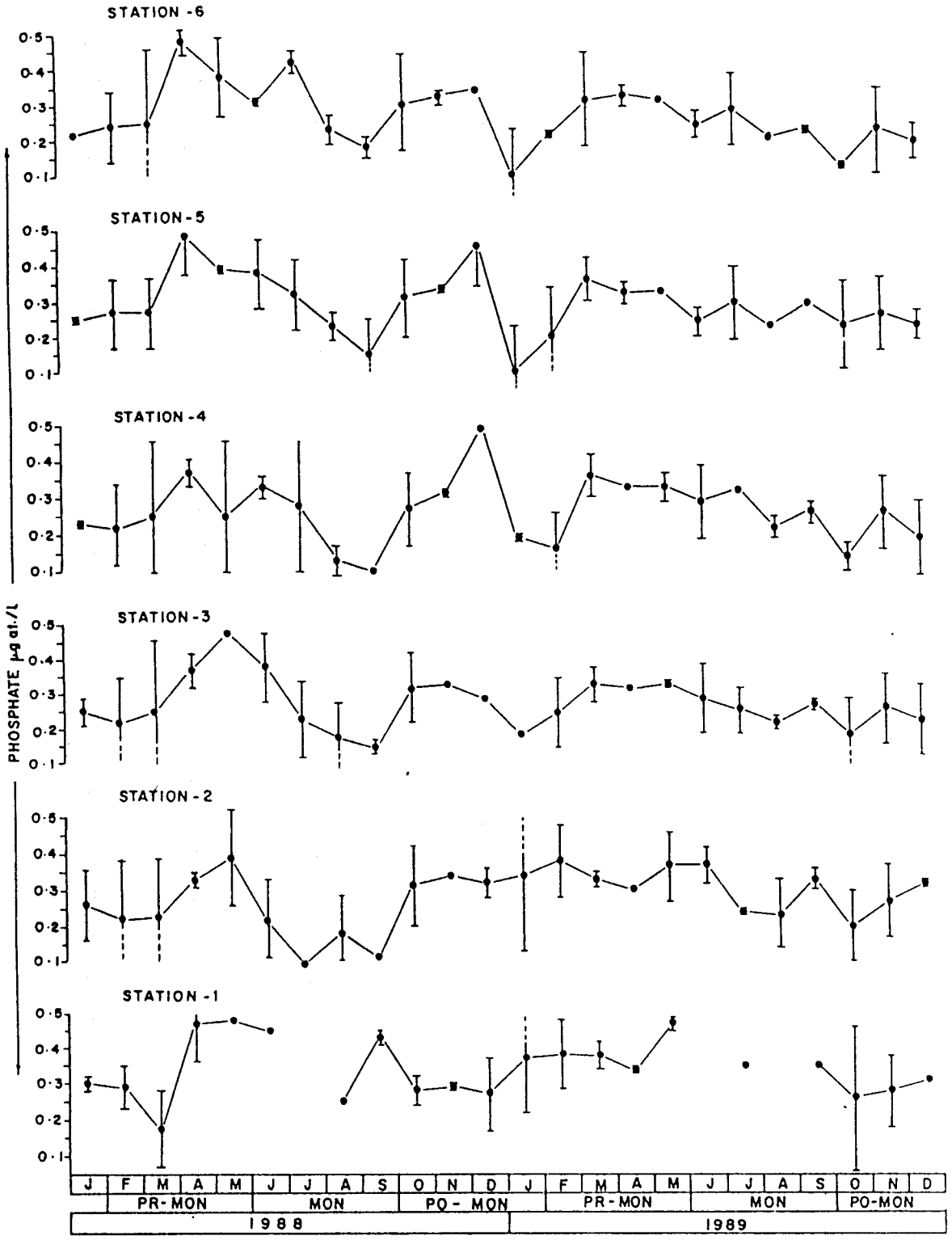

Figure 8. Monthly average and standard deviation of phosphate in various stations.

It is evident from Tables 7, 8 and Figure 8, that there is significant seasonal fluctuation in phosphate concentrations. The maximum values were observed during the pre-monsoon, during the monsoon it decreased and again increased during the postmonsoon season. First year and second year showed the same pattern of fluctuation.

Monthly average concentrations and standard deviations of nitrite for all the statios are given in Figure 9 which shows a maximum concentration for stations - 1 and 2 in April, the values beinng 1.500±0.00 and 1.00±0.60 /ug at/l respectively). Maximum concentration observed for station - 5 was in March (1.375±0.20 /ug at/l). The lowest values were 0.025±0.01, 0.035±0.01, 0.025±0.01, 0.035±0.01, 0.040±0.00 and 0.025±0.01 /ug at/l for stations - 1 to 6 respectively in November. During the second year the highest values were obtained in May for all stations. The values were 1.725±0.04, 1.730±0.03, 1.745±0.01, 1.685±0.10, 1.74±0.01, and 1.785±0.02 /ug at/l for stations - 1 to 6 respectively. The lowest values were 0.45±0.01, 0.35±0.01, 0.30±0.01, 0.040±0.00, 0.030±0.00 and 0.025±0.01 /uf at/l respectively for stations - 1 to 6 in January. Nitrite showed large variations and standard deviations in the months of pre-monsoon and post-monsoon. Two way ANOVA showed significant variations ($P < 0.05$) between stations and highly significant ($P < 0.01$) seasonal fluctuations (Table 7). As shown in Table 9, station - 1 showed the highest overall average concentration and the lowest of all observed was in station - 3. On an average, pre-monsoon season showed maximum nitrite in samples, during monsoon it decreased and again increased during post-monsoon season. Seasonal average and standard deviations are shown in Table 8.

It is inferred form Figure 10, that nitrate showed large monthly fluctuations and very large standard deviations in its concentration. During the first year, high nitrate values observed in stations - 1,3 and 4 were 0.215±0.01 (January and April), 0.210±0.00 and 0.200±0.00 /ug at/l in January respectively. In station - 5 and 6 the maximum values were in August (0.458±0.62 and 0.478±0.70 /ug at/l). The lowest concentration in station-1

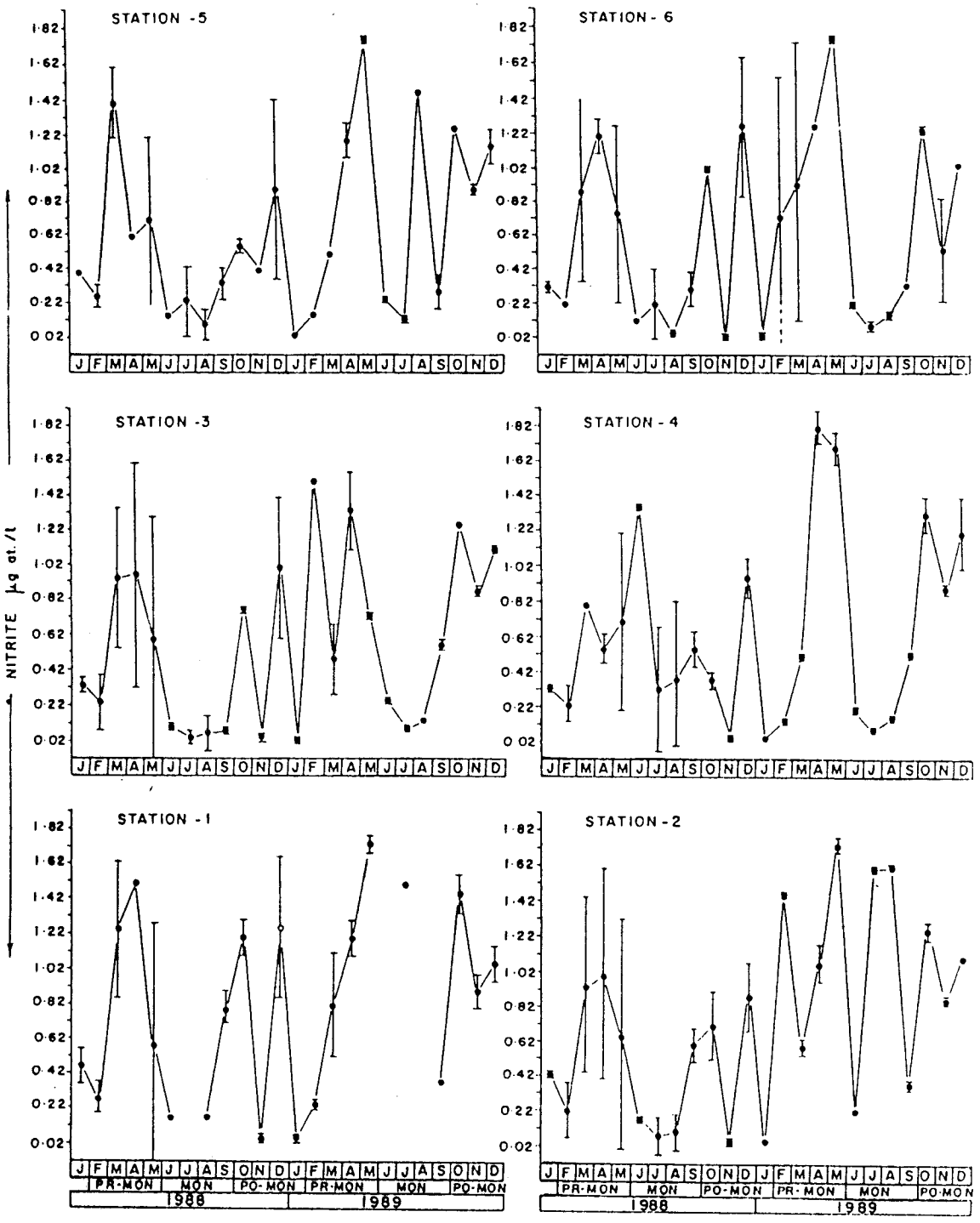

Figure 9. Monthly average and standard deviation of Nitrite in various stations.

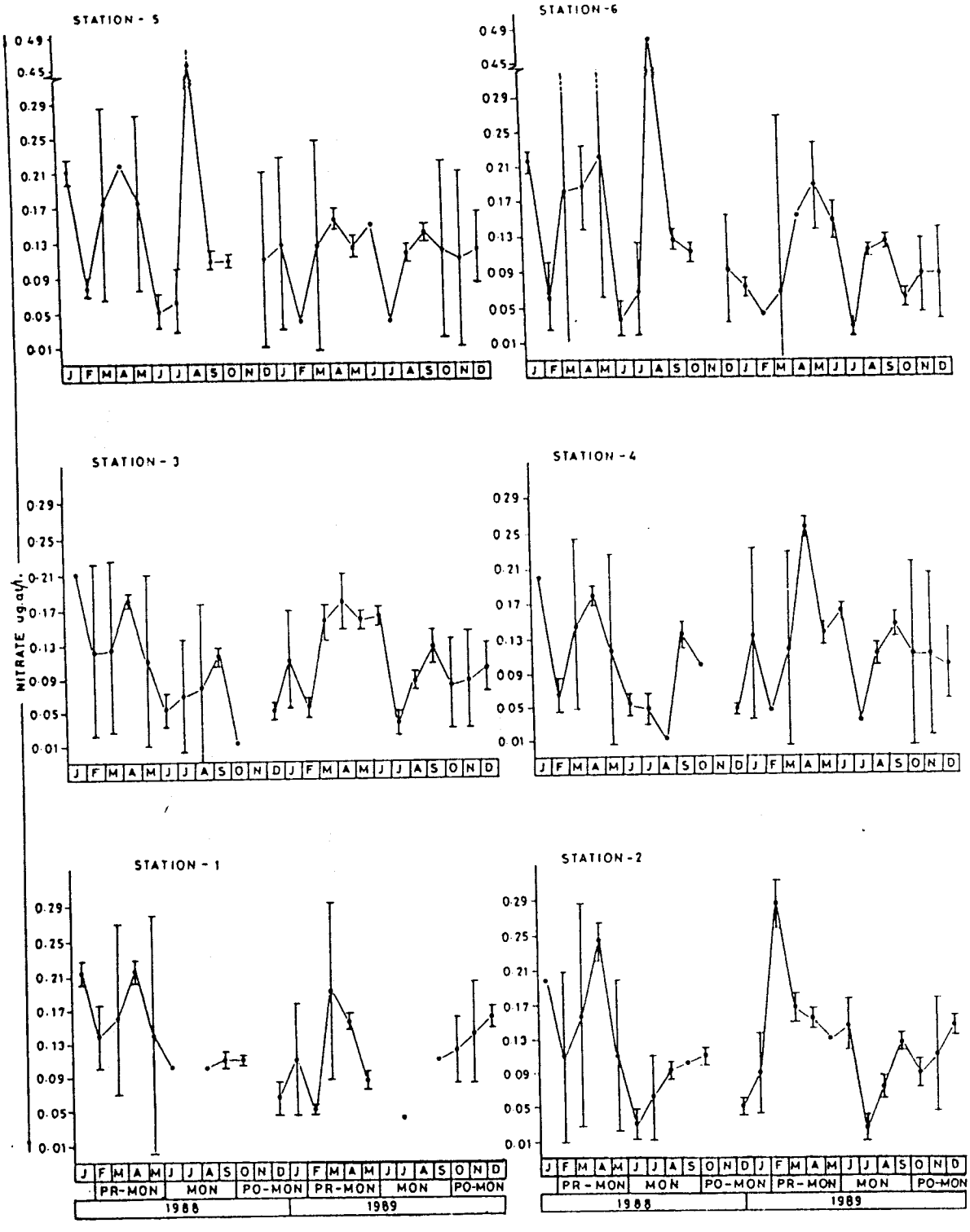

Figure 10. Monthly average and standard deviation of nitrate in various stations.

was in June and August (0.100±0.00 /ug at/l), 0.026±0.02 and 0.05±0.02 /ug at/l for stations - 2 and 3 in June, 0.011±0.001 /ug at/l for station - 4 in August, and for stations - 5 and 6, 0.052±0.02 and 0.038±0.02 /ug at/l) in June. During the second year peak nitrate value was observed in March for stations - 1 and 2 (0.192±0.10 and 0.165±0.01 /ug at/l), June for station - 3 and 4 (0.106±0.01 /ug at/l). April for stations - 5 (0.155± 0.01 /ug at/l) and May for stations - 6 (0.185±0.05 /ug at/l). The lowest concentrations of 0.04±0.00, 0.25±0.01, 0.035±0.01, 0.040±0.00, and 0.025±0.01 /ug at/l were observed in July for stations - 1 to 6 respectively. Nitrate showed large monthly fluctuations, but the two-way ANOVA test showed no significant variation over seasons and between stations (Table 7). Average values, for nitrate from all stations are given in Table 9. Seasonal averages and standard deviations are given in Table 8.

Figure 11 explains the monthly variation in calcium for the entire period of study. The maximum concentration for station - 1 was observed in May (440.0±0.00 mg/l) and for stations - 2 to 6 in June, the values being 439.0±1.4, 435.0±0.0, 437.0±1.4, mg/l respectively. The minimum values were 424.0±5.6, 416.0±5.66, 421.0±4.2 and 415.0±7.1 mg/l for stations - 4,5 and 6 respectively in January and for stations - 2 and 3 in October (418.0±2.8 and 419.0±4.2 mg/l). During the second year, the highest values in station - 1 was in September (441.0±0.0 mg/l), Stations - 2 to 5 in June (437.0±1.4, 436±0.0, 436.0±2.8 and 437.0±1.4 mg/l respectively) and for station - 6 in July (431.0±7.1 mg/l). The lowest values were 425.0±0.00 mg/l in April for station - 1, 422.0±2.8 mg/l for station - 2 in October, 417±1.4, 418.0±0.0 and 417.0±1.4 mg/l for stations - 3,4 and 6 in December and 419.0±1.4 mg/l in August for station - 5. It is inferred from Table 7 that calcium exhibited highly significant variation ($P < 0.01$) between stations and over seasons ($P < 0.01$). It is evident from Figure 11 and Table 9 that calcium concentration is slightly higher in station - 1, and lowest in station - 6. Though there is variation between stations, the pattern of fluctuation over the entire period of study was almost similar in all stations. While the pre-monsoon showed a lower concentration, it increased during monsoon and again decreased almost to pre-monsoon levels during post-monsoon (Table 8).

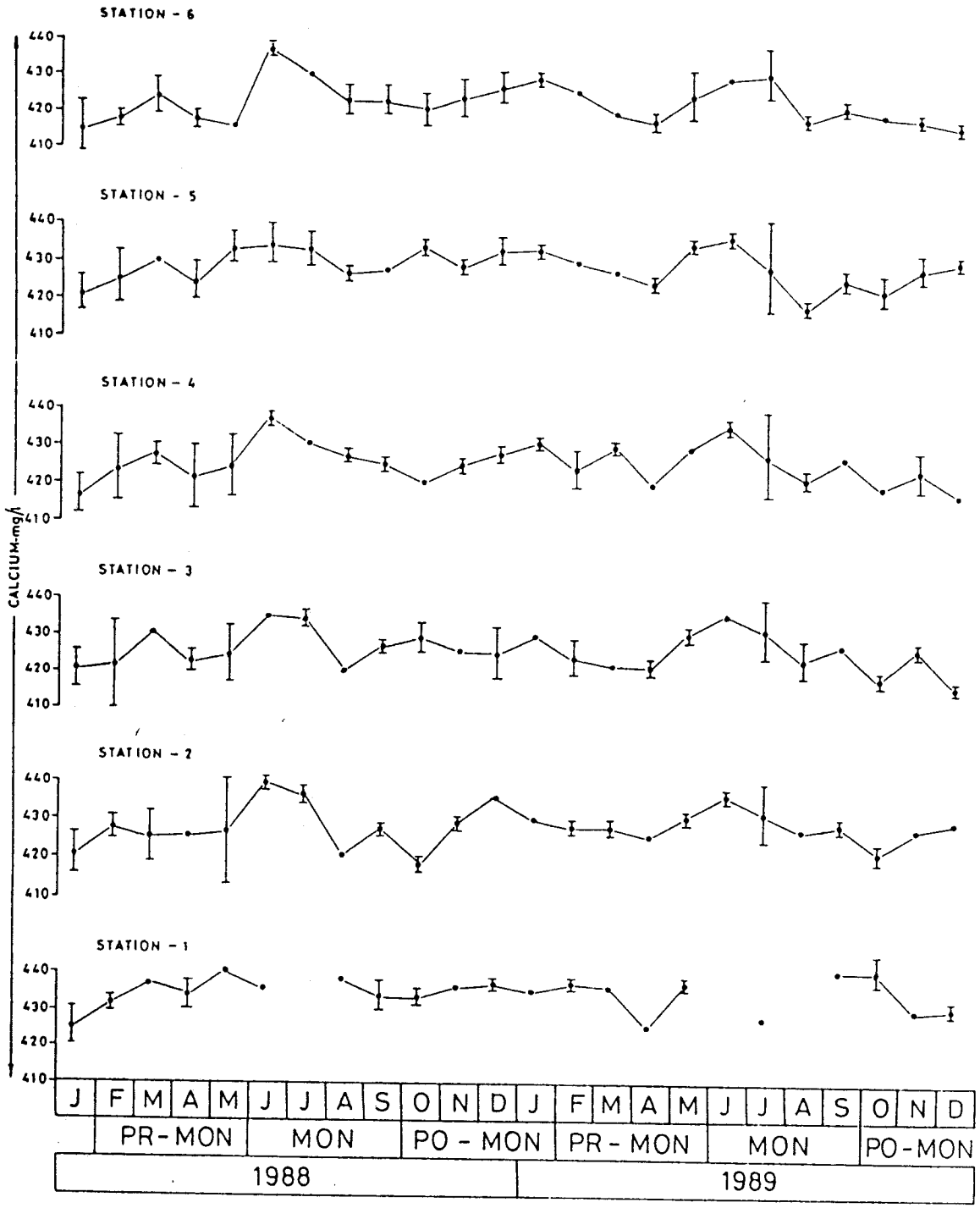

Figure 11. Monthly average and standard deviation of calcium in various stations.

Table 7. Two way analysis of variance (ANOVA) tables, showing the level of significance in variation of different parameters between stations and over seasons

Temperature

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	5	0.194	0.039	1.99	N.S.
REPLIC	2	6.161	3.081	157.73	HI.SIG(1%)
ERROR	10	0.195	0.020		

H^+ion concentration (pH)

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	5	0.007	0.001	2.00	N.S.
REPLIC	2	0.158	0.079	117.73	HI.SIG(1%)
ERROR	10	0.007	0.001		

Dissolved Oxygen

SOURCE	D.F.	SUM SQR	MEAN SQR	F-VAL	REMARKS
TREAT	5	0.955	0.191	4.83	SIG(5%)
REPLIC	2	0.225	0.112	2.84	N.S.
ERROR	10	0.395	0.040		

Salinity

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	5	0.178	0.036	0.73	N.S.
REPLIC	2	0.951	0.476	9.82	HI.SIG(1%)
E RROR	10	0.484	0.048		

Silicate

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	5	1.974	0.395	14.00	HI.SIG(1%)
REPLIC	2	9.758	4.879	173.03	HI.SIG(1%)
ERROR	10	0.282	0.028		

Phosphate

SOURCE	D.R.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	5	0.014	0.003	4.31	SIG(5%)
REPLIC	2	0.013	0.007	10.03	HI.SIG(1%)
ERROR	10	0.007	0.001		

Nitrite

SOURCE	D.F	SUM.SQR	MEANSQR	F-VAL	REMARKS
TREAT	5	0.066	0.013	3.51	SIG(5%)
REPLIC	2	1.117	0.558	148.49	HI.SIG(1%)
ERROR	10	0.038	0.004		

Nitrate

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	5	0.002	0.000	0.34	N.S.
REPLIC	2	0.005	0.002	2.21	N.S.
ERROR	10	0.010	0.001		

Calcium

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	5	233.00	46.600	15.40	HI.SIG(1%)
REPLIC	2	68.750	34.375	11.36	HI.SIG(1%)
ERROR	10	30.250	3.075		

Table 8. Pre-monsoon, Monsoon and Post-monsoon seasonal averages of hydrographical parameters for stations 1 to 6

PR-MON. = Pre-monsoon, MON. = Monsoon, PO-MON. = Post-monsoon

	STATIONS					
	1	2	3	4	5	6
Temp.						
PR-MON.	29.98±0.80	29.94±0.83	29.96±0.85	30.13±0.93	30.25±0.92	30.30±0.94
MON.	28.60±0.92	28.80±0.83	28.78±0.84	28.75±0.79	28.77±0.79	28.77±0.82
PO-MON.	29.45±0.78	29.26±0.80	29.28±0.76	29.31±0.73	29.38±0.69	29.54±0.71
pH						
PR-MON.	8.25±0.1	8.26±0.05	8.25±0.03	8.28±0.03	8.26±0.10	8.27±0.10
MON.	7.94±0.31	8.05±0.22	8.06±0.23	8.05±0.23	8.05±0.23	8.07±0.22
PO-MON.	8.16±0.17	8.19±0.16	8.18±0.15	8.18±0.16	8.18±0.17	8.19±0.16
Diss, O_2						
PR-MON.	4.69±0.68	4.96 ±1.23	4.56±1.37	4.85±0.78	4.64±0.98	5.23±1.24
MON.	4.48±0.68	5.06±0.81	5.19±0.74	5.10±0.76	5.08±0.82	5.14±0.70
PO-MON.	4.73±0.99	4.93±0.96	5.01±1.01	4.81±0.82	5.12±1.06	5.69±1.22
Salini.						
PR-MON.	34.58±0.45	34.61±0.42	34.68±0.42	34.63±0.44	34.59±0.42	34.52±0.48
MON.	33.81±0.65	34.19±0.46	34.18±0.44	34.27±0.42	34.25±0.42	34.22±0.42
PO-MON.	34.79±0.37	34.74±0.37	34.81±0.29	34.76±0.37	34.73±0.45	34.69±0.48
Silic.						
PR.MON.	5.41±0.56	4.35±0.88	4.13±1.19	4.43±1.07	4.71±0.79	4.18±0.91
MON.	3.48±0.47	2.78±0.76	2.76±0.86	2.60±0.62	2.76±0.68	2.45±0.61
PO-MON.	4.61±0.82	4.34±0.63	4.17±0.81	3.96±0.62	4.13±0.53	3.88±0.51
Phosp.						
PR-MON.	0.37±0.12	0.32±0.10	0.49±0.68	0.26±0.12	0.33±0.10	0.31±0.11
MON.	0.37±0.10	0.22±0.10	0.24±0.10	0.24±0.10	0.26±0.10	0.25±0.01
PO-MON.	0.29±0.10	0.29±0.10	0.26±0.10	0.26±0.11	0.27±0.11	0.22±0.11
Nitri.						
PR-MON.	0.95±0.58	0.79 ±0.56	0.79±0.60	0.71±0.56	0.81±0.56	0.95±0.57
MON.	0.33±0.26	0.23±0.17	0.16±0.17	0.29±0.22	0.19±0.10	0.18±0.11
PO-MON.	0.79±0.54	0.65±0.44	0.67±0.47	0.64±0.49	0.64±0.47	0.67±0.52
Nitra.						
PR-MON.	0.14±0.10	0.17±0.11	0.13±0.10	0.13±0.10	0.14±0.10	0.15±0.10
MON.	0.08±0.03	0.08±0.04	0.09±0.05	0.09±0.06	0.14±0.21	0.14±0.22
PO-MON.	0.13±0.10	0.10±0.06	0.09±0.06	0.11±0.07	0.12±0.66	0.09±0.06
Calc.						
PR-MON.	434.40±5.02	427.06±5.10	424.56±5.73	424.38±5.44	428.75±4.67	420.63±5.54
MON.	435.00±4.90	431.06±6.60	429.50±6.16	429.13±5.89	429.13±6.65	426.90±6.36
PO-MON.	433.44±5.46	426.53±6.14	422.88±5.26	422.75±5.46	427.94±5.14	421.50±5.49

Table 9. Average values of different parameters studied in Stations 1 to 6

	STATIONS					
	1	2	3	4	5	6
Temp.	29.36	29.32	29.38	29.41	29.52	29.63
pH	8.12	8.16	8.16	8.17	8.15	8.18
Diss. O_2	4.58	5.04	4.94	4.92	4.97	5.37
Salin.	34.37	34.51	34.26	34.54	34.51	34.47
Silic.	4.54	3.86	3.68	3.66	3.83	3.50
Phosp.	0.35	0.28	0.28	0.26	0.28	0.26
Nitri.	0.71	0.56	0.54	0.55	0.55	0.60
Nitra.	0.12	0.12	0.11	0.13	0.13	0.13
Calc.	433.97	428.26	425.33	425.26	428.53	422.56

Results of the diurnal studies conducted for hydrographical parameters are given in Figure 12. The surface water temperature showed a diurnal variation in a range of 2.0°C. The temperature increased from 0900 hrs (30.0°C) upto 2100 hrs (30.5°C) and decreased gradually to 28.5°C at 0300 hrs, then again started to increase upto 0900 hrs (29.8°C). The diurnal variation in pH was within 0.2, showing an increase during day time and a decrease during night. Maximum value was observed at 1800 hrs (8.36) and minimum at 0300 hrs (8.16). The day time dissolved oxygen values increased from 4.4 ml/l at 0900 hrs to 5.5 ml/l at 1800 hrs and in the night it gradually decreased to 4.1 ml/l at 0600 hrs and again showed an increasing trend. The range of fluctuation was within 1.4 ml/l. Salinity varied within a range of 0.37‰, showing an increase from 0900 hrs (34.13‰) upto 2400 hrs (34.60‰) and gradually dropped to 34.23‰ at 0600 hrs. As shown in the figure silicate did not conform into any definite pattern of variation. However, the maximum value was observed during day, at 0900 and 1200 hrs (5.3 µg at/l). Minimum concentration was noted at 2400 hrs at night (4.0 µg at/l). In general the diurnal variation of phosphate showed uniformly lower values during day and higher values during night. Minimum value was observed at 1800 hrs (0.18 µg at/l) and maximum at 0300 hrs (0.54 µg at/l), with a range of variation by 0.35 µg at/l. Nitrite and nitrate also followed the general pattern of phosphate, having lower values during day time and higher values at night. Nitrite decreased from 1.50 µg at/l at 0900 hrs upto 1.10 µg at/l at 1500 hrs and gradually increased during night upto 1.50 µg at/l, then started dropping towards morning. Concentration of nitrate increased from 0.50 µg at/l (0900 hrs) to 0.52 µg at/l (1200 hrs) and decreased upto 0.35 µg at/l (1800 hrs), then increased upto 0.54 µg at/l (0600 hrs) and dropped to 0.44 µg at/l at 0900 hrs. Concentration of calcium also followed the same trend. The 0900 hrs value of 387 mg/l was decreased to 339 mg/l by 1500 hrs and increased gradually to 411 mg/l by 0300 hrs and again decreased towards morning. In general it showed a decrease during day and an increase at night. The observed tide was of a semidiurnal type with a maximum of 149 cm at 1200 hrs and minimum of 51 cm at 0900 hrs as shown in Figure 12. Temperature, pH, salinity and dissolved oxygen were found to increase

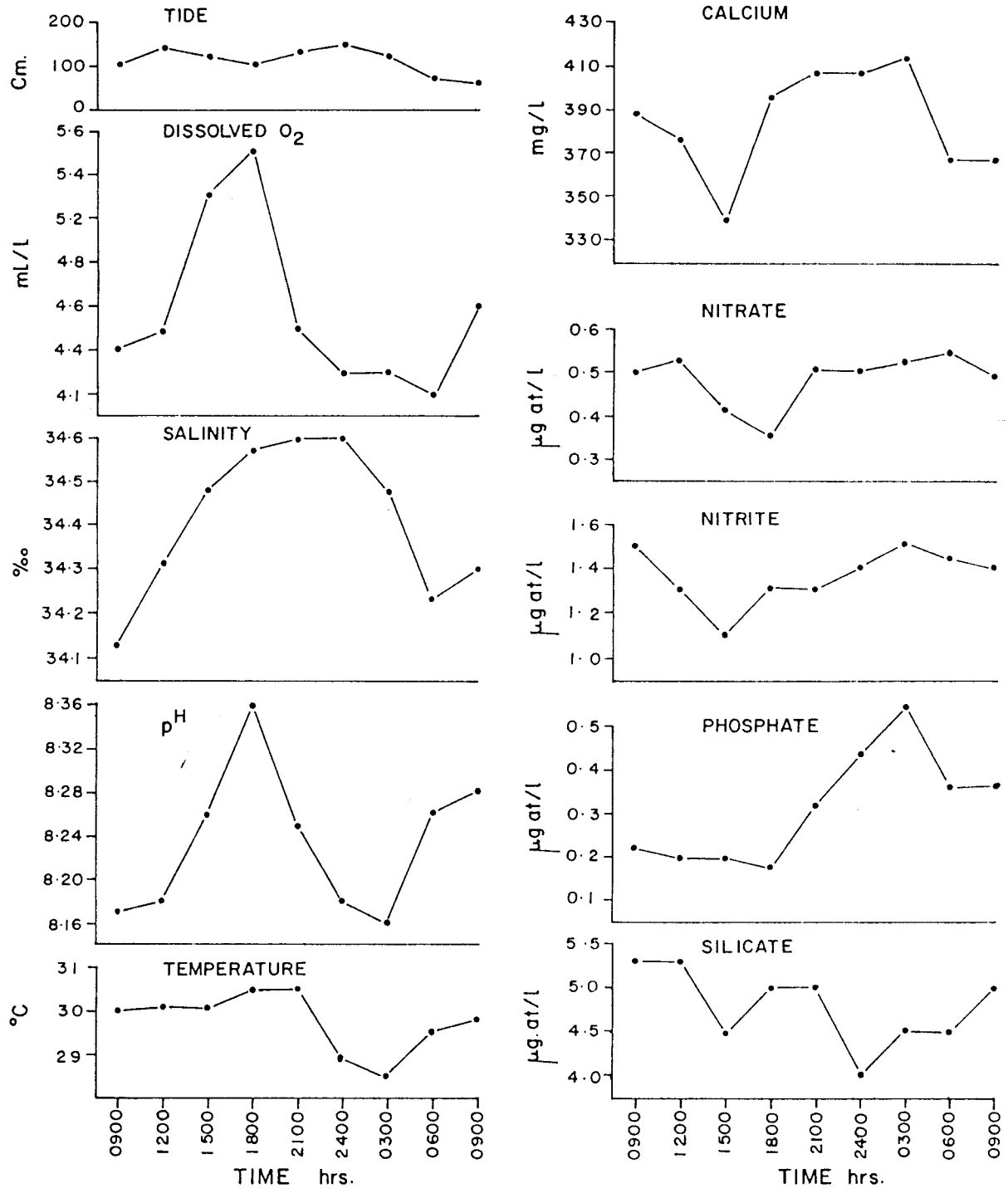

Figure 12. Diurnal changes in temperature, pH, salinity, dissolved oxygen, silicate, phosphate, nitrite, nitrate, calcium and tidal range during the period of observation.

with decreasing tide, and except silicate the rest of the parameters were found to decrease with decreasing tide. Silicate did not show any relation with tide.

Estimates of correlation coefficient exhibiting interrelationship of different parameters in station - 1 are given in Table 10. The temperature showed highly significant positive correlation with pH ($r = 0.510$, $P \leq 0.01$), correlation of pH with nitrate was significant and positive ($r = 0.510$, $P \leq 0.01$), correlation of pH with nitrate was significant and positive ($r = 0.378$, $P \leq 0.05$). Salinity exhibited a significant positive correlation with silicate ($r = 0.322$, $P \leq 0.05$). Silicate was correlated positively with nitrite and nitrate which was highly significant with nitrite ($r = 0.425$, $P \leq 0.01$) and significant with nitrate ($r = 0.375$, $P \leq 0.05$). Correlation between nitrite and nitrate was highly significant and positive ($r = 0.406$, $P \leq 0.01$).

The Table 10 shows the correlation between different environmental parameters in station-2. Dissolved oxygen and salinity showed a positive and highly significant correlation ($r = 0.474$, $P \leq 0.01$). Silicate and nitrite were positively correlated ($r = 0.313$, $P \leq 0.05$). Phosphate correlated significantly and positively with nitrite ($r = 0.329$, $P \leq 0.05$).

Nature of correlation between different parameters in station-3 are given in Table 10 which showed highly significant positive correlations of temperature and pH ($r = 0.420$, $P \leq 0.01$), Silicate and nitrite ($r = 0.462$, $P \leq 0.01$), nitrite and nitrate ($r = 0.465$, $P \leq 0.01$). The negatively correlated parameters were pH and dissolved oxygen ($r = -.316$, $P \leq 0.05$), dissolved oxygen and nitrate ($r = -.401$, $P \leq 0.01$) and salinity and calcium ($r = -.415$, $P \leq 0.01$).

Table 11 shows the nature of correlation between different parameters in station-4. The pH showed a highly significant negative correlation with dissolved oxygen ($r = -.393$, $P \leq 0.01$). pH also showed negative correlation with nitrite ($r = -.313$, $P \leq 0.05$). Dissolved oxygen showed a

Table 10. Estimates of coefficient of correlation between various environmental parameters for station 1 to 3

CORRELATION MATRIX

Station - 1

(1)	Temperature	1.000								
(2)	pH	0.150**	1.000							
(3)	Diss. oxygen	0.021	-.214	1.000						
(4)	Salinity	0.172	-.054	0.302	1.000					
(5)	Silicate	0.199	0.102	0.125	0.322*	1.000				
(6)	Phosphate	-.181	-.120	-.174	-.179	-.048	1.000			
(7)	Nitrite	0.094	0.029	-.012	-.123	0.425**	-.002	1.000		
(8)	Nitrate	0.252	0.378*	-.118	0.028	0.375*	-.033	0.406**	1.000	
(9)	Calcium	0.026	-.138	0.118	0.013	-.077	0.005	-.030	-.216	1.000
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

n-2=39, *p≦0.05, **p≦0.01

Station - 2

(1)	Temperature	1.000								
(2)	pH	0.173	1.000							
(3)	Diss. oxygen	0.062	-.034	1.000						
(4)	Salinity	0.164	0.207	0.474**	1.000					
(5)	Silicate	0.259	-.106	0.100	0.292	1.000				
(6)	Phosphate	0.086	0.205	0.196	0.108	0.140	1.000			
(7)	Nitrite	0.226	-.011	0.088	-.005	0.313*	0.329*	1.000		
(8)	Nitrate	0.084	0.204	0.140	0.204	0.260	0.260	0.182	1.000	
(9)	Calcium	-.011	-.093	0.237	0.100	-.258	-.071	0.003	-.143	1.000
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

n-2=37, * p≦0.05, **p≦0.01

Station - 3

(1)	Temperature	1.000								
(2)	pH	0.402**	1.000							
(3)	Diss. oxygen	-.092	1.000	1.000						
(4)	Salinity	0.222	-.120	0.338*	1.000					
(5)	Silicate	0.064	-.168	-.103	0.326*	1.000				
(6)	Phosphate	0.095	0.055	0.009	-.056	0.097	1.000			
(7)	Nitrite	0.106	-.263	-.040	0.270	0.462**	0.241	1.000		
(8)	Nitrate	0.133	-.034	-.401**	-.193	0.217	0.267	0.465**	1.000	
(9)	Calcium	-.026	0.077	0.083	-.415**	-.240	-.086	-.169	-.204	1.000
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

n-2=39, *p ≦ 0.05, ** p≦0.01

Table 11. Estimates of coefficient of correlation between various environmental parameters for station 4 to 6

Station - 4

(1)	Temperature	1.000								
(2)	pH	-.149	1.000							
(3)	Diss. Oxygen	-.157	-.393**	1.000						
(4)	Salinity	0.099	-.035	0.075	1.000					
(5)	Silicate	0.142	-.243	-.014	0.223	1.000				
(6)	Phosphate	0.048	-.110	-.106	-.214	0.213	1.000			
(7)	Nitrite	-.114	-.313*	0.020	-.065	0.357*	0.008	1.000		
(8)	Nitrate	-.068	-.027	-.346*	-.171	0.440**	0.132	0.259	1.000	
(9)	Calcium	0.069	-.024	0.065	-.326*	-.362*	0.207	0.098	-.192	1.000
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

n-2=39, *$p \leq 0.05$, **$p \leq 0.01$

Station - 5

(1)	Temperature	1.000								
(2)	pH[x]	0.248	1.000							
(3)	Diss. Oxygen	-.007	-.360*	1.000						
(4)	Salinity	0.302	-.184	0.166	1.000					
(5)	Silicate	0.329*	-.021	-.086	0.437**	1.000				
(6)	Phosphate	0.080	0.348*	-.117	-.065	0.224	1.000			
(7)	Nitrite	0.132	-.127	0.276	-.038	0.478**	0.209	1.000		
(8)	Nitrate	0.064	-.126	-.011	0.015	-.013	-.073	0.149	1.000	
(9)	Calcium	0.019	-.218	0.198	-.379*	-.235	0.047	0.104	-.021	1.000
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

n-2=37, *$p \leq 0.05$, **$p \leq 0.01$

Station - 6

(1)	Temperature	1.000								
(2)	pH	0.398**	1.000							
(3)	Diss. Oxygen	-.122	-.362*	1.000						
(4)	Salinity	0.193	0.079	0.115	1.000					
(5)	Silicate	0.224	-.117	0.129	0.160	1.000				
(6)	Phosphate	-.046	0.114	0.023	-.272	0.002	1.000			
(7)	Nitrite	0.007	-.053	0.118	0.136	0.590**	0.208	1.000		
(8)	Nitrate	0.021	-.071	0.036	0.046	-.041	0.134	0.069	1.000	
(9)	Calcium	-.114	-.088	0.002	-.277	-.368*	-.151	-.179	-.139	1.000
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

n-2=43, *$p \leq 0.05$, **$p \leq 0.01$

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negative correlation with nitrate ($r = \bar{}.346$, $P \leq 0.05$). Salinity correlated negatively with calcium ($r = \bar{}.326$, $P \leq 0.05$). Silicate correlated positively with nitrite and nitrate ($r = 0.357$, $P \leq 0.05$ and 0.440, $P \leq 0.01$). Silicate also correlated negatively with calcium ($r = \bar{}.362$, $P \leq 0.05$).

As shown in the Table 11 for station - 5, temperature and silicate correlated positively ($r = 0.329$, $P \leq 0.05$), pH and dissolved oxygen correlated negatively ($r = \bar{}.360$, $P \leq 0.05$) and pH and phosphate correlated positively ($r = 0.348$, $P \leq 0.05$). Salinity and silicate showed a positive highly significant correlation (0.437, $P \leq 0.01$) while salinity showed a negative correlation ($r = \bar{}.379$, $P \leq 0.05$) with calcium. Silicate and nitrite correlated positively which is highly significant at $r = 0.478$, $P \leq 0.01$.

Correlation between environmental parameters studied in station - 6 and their coefficient of correlation are given in Table 11 which gives a positive and highly significant correlation between temperature and pH ($r = 0.398$, $P \leq 0.01$). Significant negative correlation was exhibited by pH and dissolved oxygen ($r = \bar{}.362$, $P \leq 0.05$), silicate and nitrite correlated positively ($r = 0.590$, $P \leq 0.01$) and there was a negative correlation between silicate and calcium ($r = \bar{}.368$, $P \leq 0.05$).

Productivity

Results of the productivity studies carried out on phytoplankton, and seagrasses - Thalassia hemprichii, Syrinogdium isoetifolium, for one year (January, 1988 to 1989, December); and on three species of corals Porites cylindrica, Acropora formosa and Pocillopora damicornis for 2 years are given in Figures 13 to 15. The figures were drawn using monthly averages of gross and net productivity, indicated by bars. The vertical line on the monthly average points of each bar represents the standard deviation on both sides of the mean.

Results of the correlation studies to find out the factors which influence productivity are given in Table 15.

Phytoplankton: Figure 13 shows the monthly average gross and net productivity of phytoplankton for the entire period of study. The shaded areas represent average net production. Maximum gross production was noted in December (6.09±2.5 mg $C/m^3/hr$) and minimum in March (0.62±0.01 mg $C/m^3/hr$), where as the highest net production was noted in April (1.46±0.85 mg $C/m^3/hr$) and lowest in July (0.20±0.13 mg $C/m^3/hr$). One way ANOVA test conducted to study the seasonality in production showed highly significant ($P < 0.01$) seasonal fluctuations in gross production (Table 12) whereas the net production showed no significant seasonal variation (Table 13). The seasonal average and standard deviation are shown in Table 14. The data indicate that the contribution of phytoplankton to the secondary trophic level remains more or less the same throughout the year in Kavaratti Atoll.

Seagrass: Figure 14 gives the monthly average and standard deviation in productivity of Thalassia hemprichii and Syringodium isoetifolium. Two different designs are used to differentiate the species and also to indicate gross and net productivity of each species as shown in the Figure 14.

Thalassia showed maximum gross production in April (1.37±0.29 mg C/g/hr) and minimum in August (0.28±0.10 mg C/g/hr) whereas net production was highest in May (0.769±0.26 mg C/g/hr) and lowest in July (0.154±0.10 mg C/g/hr). Results of the one way ANOVA test proved that statistically there was no seasonality in gross production (Table 12), whereas net productivity showed highly significant ($P < 0.01$) seasonal fluctuations (Table 13). The seasonal averages and standard deivations of gross and net productivity are shown in Table 14. The net productivity was highest during pre-monsoon season and lowest during monsoon. The results show that eventhough the seasons have no influence on gross production, the contribution of Thalassia hemprichii to the secondary level (net production) is influenced by seasons.

Figure 14 also shows the monthly values of productivity of Syringodium isoetifolium. As inferred from the figure, gross and net productivity was found to be highest in April, the values being 0.812±0.10 mg C/g/hr

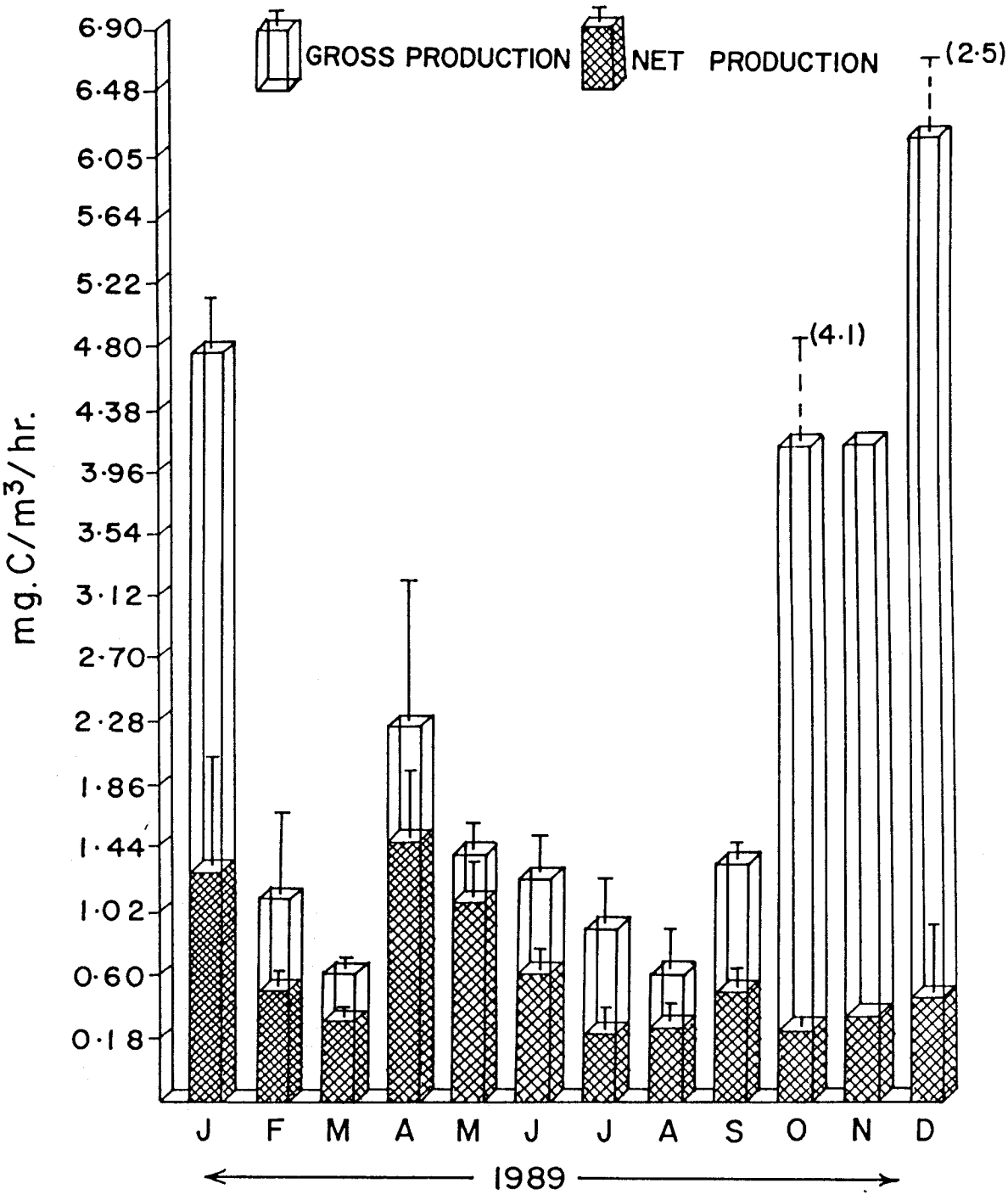

Figure 13. Monthly averages and standard deviations in gross and net productivity of phytoplankton.

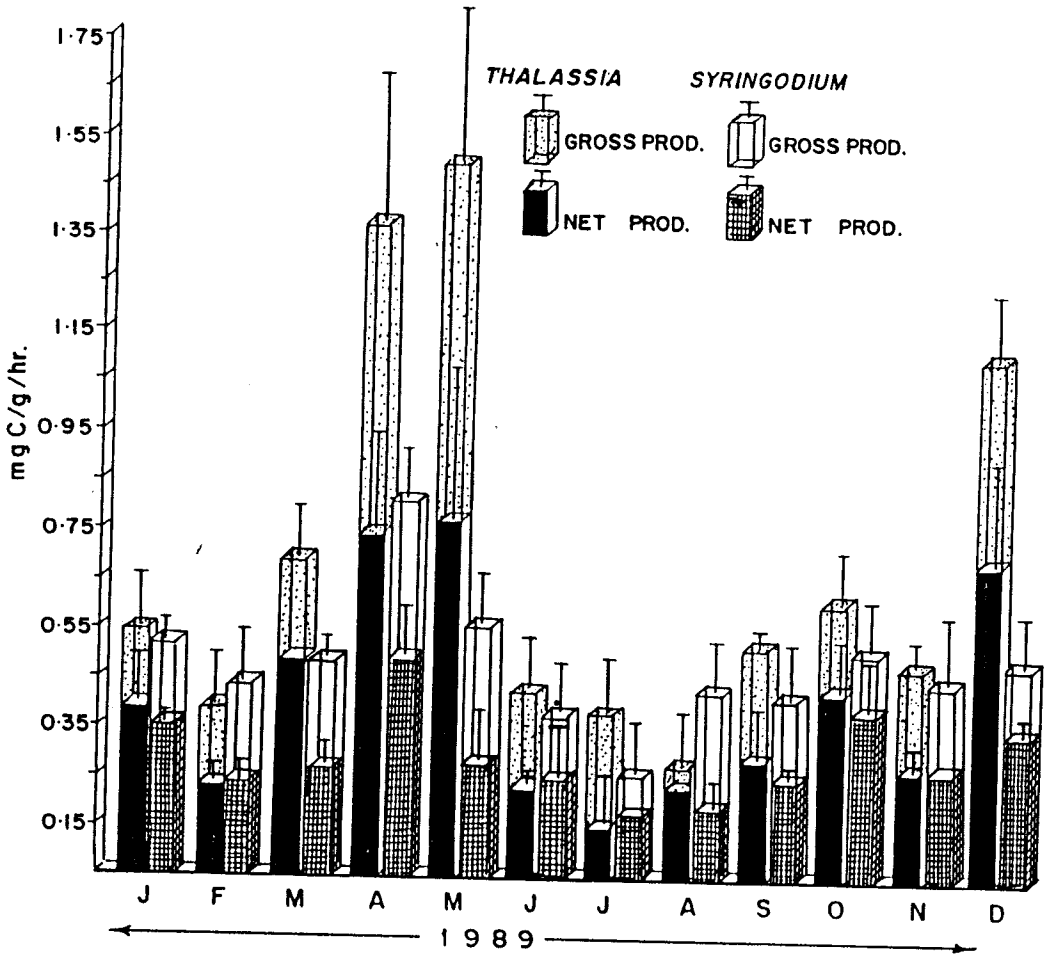

Figure 14. Monthly averages and standard deviation in gross and net productivity of seagrasses - Thalassia hemprichii and Syringodium isoetifolium.

gross and 0.494±0.10 mg C/g/hr net. Lowest production was found to be in July (0.255±0.10 mg C/g/hr gross and 0.175±0.13 mg C/g/hr net). One way ANOVA test showed highly significant seasonal fluctuations ($P < 0.01$) in gross productivity (Table 12) and no significant variation in net production over seasons (Table 13). Gross productivity was found to be highest during pre-monsoon season and lowest during monsoon season. In sharp contrast from that of Thalassia hemprichii, Syringodium isoetifolium showed seasonal fluctuation in gross production,but its net production was not influenced by seasons. Seasonal averages and standard deviations of gross and net productivity are given in Table 14. Among the two species, Thalassia hemprichii was found to have maximum productivity.

Corals: Gross and net productivity of three species of corals for the entire period of study (January, 1988 to 1989, December) are shown in Figure 15. In the running text, the year 1988 is regarded as first year and 1989 as second year. Shaded portions in the figure represent net prodction.

During first year, Porites cylindrica showed a maximum gross production in December (0.050 mg C/g/hr) and minimum in March (0.027 mg C/g/hr) whereas the net production showed highest value in February (0.266 mg C/g/hr) and lowest in April (0.009 mg C/g/hr). During second year the maximum values of gross and net production were found in January (0.052 mg C/g/hr gross and 0.027 mg C/g/hr net), minimum gross production of 0.029 mg C/g/hr in September and 0.011 mg C/g/hr net production in June. Results of the one way ANOVA test showed that there is no significant seasonal variation in both gross (Table 12) and net (Table 13) production. Seasonal averages of gross and net productivity and their standard deviations are shown in Table 14.

The maximum productivity of Acropora formosa observed during first year was in January (0.073 mg C/g/hr gross and 0.039 mg C/g/hr net), and minimum values noted were in July (0.22 mg C/g/hr gross and 0.10 mg C/g/hr net). During second year the maximum productivity was observed in January (0.065 mg C/g/hr gross, 0.037 mg C/g/hr net) whereas the minimum values of gross production was in September (0.033 mg C/g/hr).

It was evident from the one way ANOVA test that gross production exhibited highly significant seasonal variations ($P < 0.01$) - Table 12. The net productivity showed no such variations (Table 13). Seasonal averages and standard deviation in gross and net production are shown in Table 14, which indicated that highest productivity was during pre-monsoon season, and lowest during monsoon. Post-monsoon values were almost similar to that of the pre-monsoon values.

Monthly average productivity of Pocillopora damicornis is shown in Figure 15. In the first year, the maximum productivity was observed in January, the values being 0.095 mg C/g/hr gross and 0.058 mg C/g/hr net and lowest in July being 0.025 mg C/g/hr gross and 0.011 mg C/g/hr net. During second year the maximum gross production was observed in November (0.119 mg C/g/hr) and net production in September (0.047 mg C/g/hr). Productivity was lowest in August, the values being 0.040 mg C/g/hr gross and 0.009 mg C/g/hr net. One way ANOVA test proved that there is highly significant seasonal variation ($P < 0.01$) in both gross and net production (Tables 12 and 13). Productivity was highest during post-monsoon season, and minimum during monsoon (Table 14). On a comparison between the three species, the smaller form Pocillopora damicornis showed an average maximum production.

The productivity was correlated with environmental parameters studied at station - 6 (Figures 3 to 11). Results of the analysis exhibiting correlation coefficient are given in Table 15. Productivity of phytoplankton showed positive correlation with temperature ($r = 0.420$), Thalassia and Syringodium correlated negatively with temperature ($r = -.353$ and -0.326) but the relationship was not significant. The phytoplankton production correlated positively with pH, but the relation was weak ($r = 0.076$), while that of Thalassia was negatively significant ($r = -.548$, $P \leq 0.05$) and of Syringodium was negative but insignificant ($r = -.469$). Productivity of all the species was positively correlated with dissolved oxygen but not significant in any case. With salinity phytoplankton production showed a positive correlation ($r = 0.677$, $P \leq 0.05$). Thalassia and Syringodium

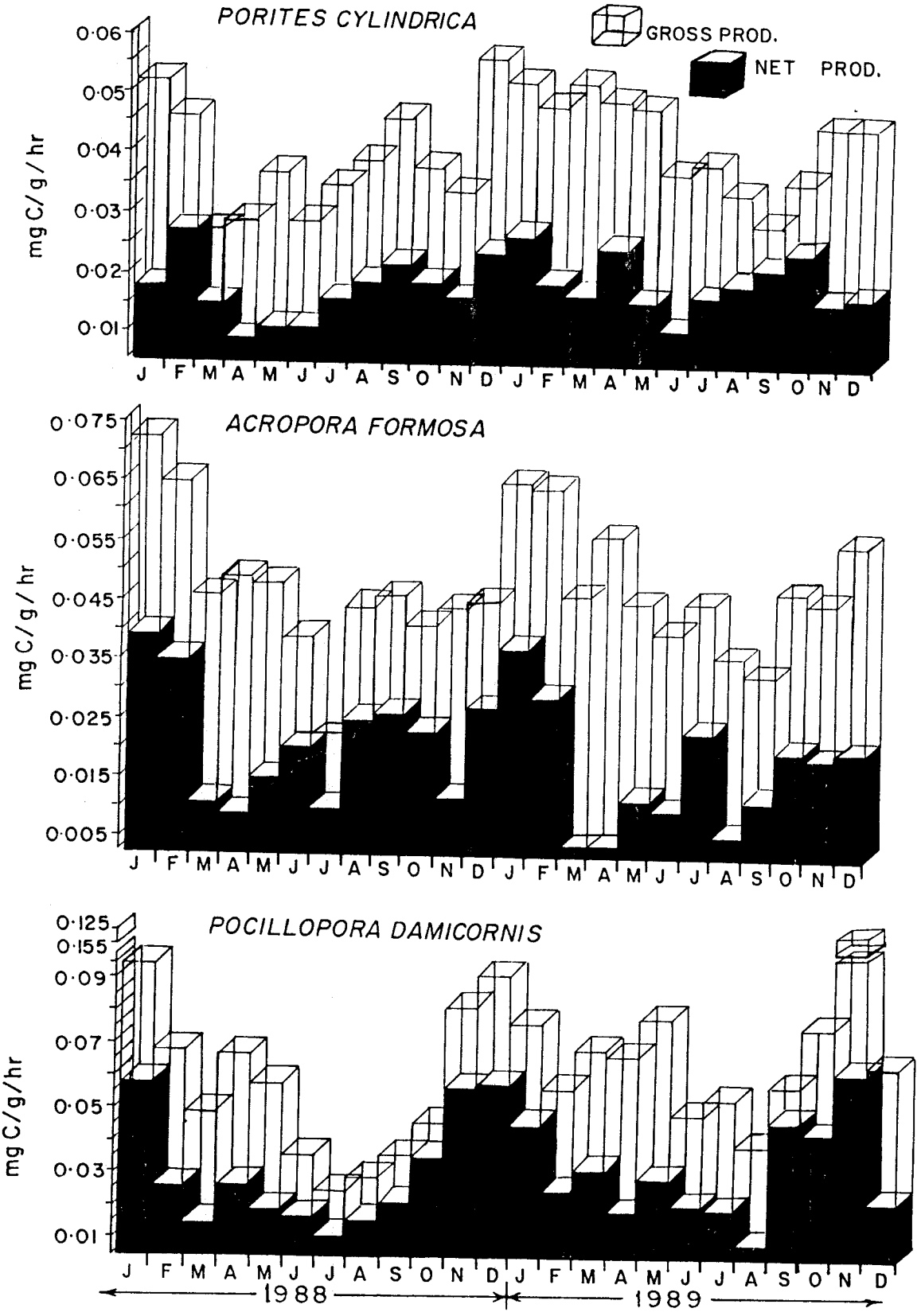

Figure 15. Monthly average productivity of corals - Porites cylindrica, Acropora formosa and Pocillopora damicornis.

Table 12. One way analysis of variance (ANOVA-1) tables showing the level of seasonal variation in gross primary productivity

Phytoplankton

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	59.707	29.854	13.94	HI.SIG(1%)
ERROR	15	32.131	2.142		

Thalassia hemprichii

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	0.989	0.495	5.58	N.S
ERROR	21	1.862	0.089		

Syringodium isoetifolium

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	0.174	0.087	6.39	HI.HIG(1%)
ERROR	21	0.286	0.014		

Porites cylindrica

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	0.000	0.000	2.42	N.S.
ERROR	21	0.001	0.000		

Acropora formosa

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	0.001	0.001	5.97	HI.SIG(1%)
ERROR	21	0.002	0.000		

Pocillopora damicornis

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	0.007	0.003	14.15	HI.SIG(1%)
ERROR	21	0.005	0.000		

Table 13. One way analysis of variance (ANOVA - 1) tables showing the level of seasonal variationn in net primary productivity

Phytoplankton

SOURCE	D.F.	SUM.SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	0.512	0.256	0.84	N.S.
ERROR	15	4.595	0.306		

Thalassia hemprichii

SOURCE	D.F.	SUM.SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	0.470	0.235	7.04	HI.SIG(1%)
ERROR	21	0.702	0.033		

Syringodium isoetifolium

SOURCE	D.F.	SUM.SQR	MEAN SQR	F-VAL	N.S.
TREAT	2	0.042	0.021	2.95	N.S.
ERROR	21	0.149	0.007		

Porites cylindrica

SOURCE	D.F.	SUM.SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	0.000	0.000	1.04	N.S.
ERROR	21	0.000	0.000		

Acropora formosa

SOURCE	D.F.	SUM.SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	0.000	0.000	2.53	N.S.
ERROR	21	0.002	0.000		

Pocillopora damicornis

SOURCE	D.F.	SUM.SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	0.004	0.002	14.74	HI.SIG(1%)
ERROR	21	0.003	0.000		

Table 14. Seasonal average and standard deviation (±) of gross and net productivity

PR-MON - Pre-monsoon, MON - Monsoon, PO-MON - Post-monsoon.

	PR-MON	MON	PO-MON
Phytoplankton	1.342±0.69 (0.835±0.53)	1.030±0.33 (0.405±0.21)	4.75±0.93 (0.59±0.49)
Thalassia hemprichii	0.902±0.44 (0.556±0.26)	0.405±0.11 (0.225±0.06)	0.673±0.25 (0.469±0.17)
Syringodium isoetifolium	0.575±0.16 (0.321±0.11)	0.368±0.10 (0.246±0.07)	0.494±0.07 (0.339±0.06)
Porites cylindrica	0.042±0.01 (0.017±0.01)	0.036±0.01 (0.017±0.004)	0.045±0.01 (0.020±0.003)
Acropora formosa	0.052±0.01 (0.015±0.01)	0.038±0.01 (0.017±0.01)	0.052±0.01 (0.025±0.01)
Pocillopora damicornis	0.064±0.01 (0.024±0.01)	0.041±0.01 (0.020±0.01)	0.081±0.02 (0.048±0.01)

Values in parenthesis indicate net production.

showed feeble negative relation with salinity (r = ⁻.145 and ⁻.024). Productivity of the three forms was correlated positively with silicate among which the relation of phytoplankton was feeble (r = 0.303), but that of Thalassia was significant (r = 0.677, P ≤ 0.05) and Syringodium was highly significant (r = 0.838, P ≤ 0.01). The phytoplankton productivity and phosphate showed a weak negative correlation (r = ⁻.527) whereas Thalassia and Syringodium exhibited positive relation with phosphate but it was feeble and insignificant (r = 0.417 and 0.105). Thalassia showed highly significant positive correlation with nitrite (r = 0.782, P ≤ 0.01) and Syringodium showed significant correlation (r = 0.640, P ≤ 0.05). The phytoplankton showed a feeble positive relationship (r = 0.146). With nitrate, phytoplankton showed a feeble negative correlation (r = ⁻.414), with Thalassia and Syringodium also it was feeble but positive (r = 0.434 and 0.484).

Productivity of the three species also showed significant intercorrelations. The results prove that at Kavaratti Atoll, except for salinity and silicate, no other parameter has direct significant effect on plant productivity. Correlation between the productivity of all the three forms was also positive, but only that between Thalassia and syringodium was significant (r = 0.814).

Productivity of Porites cylindrica correlated negatively with temperature, but it was feeble (r = ⁻.236), whereas those of Acropora formosa and Pocillopora damicornis were also feeble but positive (r = 0.186 and 0.201). With pH, all the three species showed negative, feeble relationships (r = ⁻.331 for Porites, ⁻.0 41 for Acropora and ⁻.151 for Pocillopra). With dissolved oxygen, all species showed weak positive correlation (Porites r= 0.291, Acropora r = 0.191 and Pocillapora r = 0.307). P roductivity of Porites was negatively correlated with salinity (r = ⁻.0 31) but it was feeble. Acropora showed a significant positive relationship with salinity (r = 0.486 P ≤ 0.05). Pocillopora also showed a positive correlation with salinity but it was weak (r = 0.293). Productivity of all the three species showed significant positive correlation with silicate (r = 0.453 P ≤ 0.05 for Porites; r = 0.581, P ≤ 0.01 for Acropora and r = 0. 512, P ≤ 0.05 for Pocillopora). With phosphate, all the species showed insignificant negative correlation (r = ⁻.173, ⁻.319 and r = ⁻.109 for Porites, Acropora and Pocillopora respectively). Productivity and nitrite correlated positively but was not

Table 15. Estimates of correlation coefficients of productivity of phytoplankton sea grasses and corals with different environmental parameters

Phytoplankton	Thallassia	Syringodium	Porites	Acropora	Pocillopora	Parameters
0.420	-.353	-.326	-.236	0.186	0.201	Wat. Temp.
0.076	-.548*	-.469	-.331	-.041	-.151	H^+ion Con.(pH)
0.166	0.167	0.203	0.291	0.191	0.307	Dissolved O_2
0.677*	-.145	-.024	- .031	0.486*	0.293	Salinity
0.303	0.677*	0.838**	0.453*	0.581**	0.512*	Silicate
-.527	0.417	0.105	-.173	-.319	-.109	Phosphate
0.146	0.782**	0.640*	0.215	0.157	0.353	Nitrite
-.414	0.434	0.438	-.005	-.125	-.217	Nitrate
n-2=10, *$p \leq 0.05$, **$p \leq 0.01$			n-2=22, *$p \leq 0.05$, **$p \leq 0.01$			

significant (r = 0.215, 0.187 and r = 0.353 for Porites, Acropora and Pocillopora respectively). With nitrate and calcium also the correlation was not significant but negative (r = ⁻.005, ⁻.125 and ⁻.217 with nitrate, r = ⁻.087, ⁻.298 and ⁻.361 with calcium respectively for Porites, Acropora and Pocillopora).

Zooplankton distribution

Zooplankton occurence and numerical abundance for a period of January, 1988 to 1989, December are given in Tables 16 to 20. Monthly average counts of different zooplankton groups were used to present in the tables. The rows of number marked 1 and 2 against each group in the table indicate first year (1988) and second year (1989). In the text, averages of the two years were used to describe monthly variations.

Table 16 shows the monthly average numerical abundance of different zooplankton groups for station-2. Total abundance was found to be maximum in December (1,383/m^3) and minimum in September (179/m^3). A total of 23 groups were observed. Occurance of important groups in the order of abundance were Fish eggs, Copepods, Decapod larvae, Gastropod larvae, Zoea, Bivalve larvae, and Foraminiferans. Monthly average numerical abundance of Fish eggs, Gastropod larvae and Zoea was found to be maximum in December (385.5, 49.0 and 36.5/m^3 respectively), minimum values being 8/m^3 for Fish eggs and 6.5/m^3 for Zoea in November and 6.5/m^3 for Gastropod larvae in June. Copepods, Decapods and Bivalve larvae were maximum in February, their averages being 193.5, 77.0 and 34.0/m^3 respectively. The minimum for Copepods and bivalves were 5.0 and 2.0/m^3 in November and 8.5/m^3 for Decapod larvae in May. Maximum abundance of Foraminiferans was observed in November (15.5/m^3) and minimum in September (2.0/m^3. Other groups were observed in lesser abundance as given in the Table 16.

Monthly average zooplankton counts from station - 3 are given in Table 17. All groups occured in station - 2 were observed in this station, but in varying degrees. Total abundance was found to be highest in December (980/m^3) and lowest in November (201/m^3). Major groups in

Table 16. Monthly counts of different zooplankton groups in station - 2 (Nos/m^3)

		J	F	M	A	M	J	J	A	S	O	N	D
Copepods	1.	49	201	79	18	40	50	30	20	13	10	5	90
	2.	70	186	107	37	56	34	48	80	28	30	5	75
Siphonophores	1.	27	11	18	13	16	1	-	-	5	9	6	-
	2.	8	21	-	3	2	1	1	8	-	-	-	3
Fish eggs	1.	307	70	150	30	-	30	11	5	9	11	9	470
	2.	89	186	79	5	78	17	17	30	13	30	7	301
Fish larvae	1.	3	-	1	1	1	3	5	-	-	-	3	1
	2.	2	1	-	-	-	1	-	3	4	1	1	1
Megalopa	1.	5	4	3	-	5	7	1	-	-	4	3	1
	2.	-	-	1	-	1	-	-	-	-	1	-	-
Zoea	1.	30	17	18	3	7	14	20	-	8	-	-	23
	2.	5	7	30	17	9	20	51	79	21	30	5	50
Decapod larvae	1.	40	57	18	30	6	20	19	13	-	-	31	18
	2.	38	97	28	23	11	25	78	60	21	37	21	96
Phyllosoma	1.	1	1	-	-	3	-	-	-	1	-	-	-
	2.	-	-	-	-	-	-	-	-	-	-	-	-
Chaetognaths	1.	30	21	10	17	6	5	1	1	1	-	-	7
	2.	5	31	6	15	3	7	1	7	3	-	-	-
Medusae	1.	15	5	70	13	5	3	3	3	2	1	-	1
	2.	21	7	5	8	3	-	-	1	-	-	-	-
Mysids	1.	3	1	1	7	6	4	-	-	-	-	1	7
	2.	3	7	1	3	2	-	-	5	-	3	-	4
Polychaete larvae	1.	30	16	7	8	9	1	17	4	-	-	6	8
	2.	-	11	19	-	8	6	3	1	1	2	-	3
Amphipods	1.	20	13	1	27	3	11	19	4	-	1	24	26
	2.	4	25	7	6	1	-	-	1	-	3	18	30
Ostracods	1.	-	1	3	4	7	5	-	11	-	3	-	2
	2.	5	7	1	-	-	15	7	2	1	5	15	3
Bivalve larvae	1.	15	48	30	19	10	8	20	13	6	5	1	-
	2.	27	20	7	11	8	21	30	16	9	10	3	9
Gastropod larvae	1.	41	30	28	10	27	9	15	28	5	31	28	57
	2.	16	24	11	51	8	4	7	71	20	34	30	41
Isopods	1.	-	-	2	1	-	5	4	7	5	-	1	5
	2.	-	-	-	-	-	2	-	-	-	-	-	3
Stomatopod larvae	1.	-	-	-	3	-	1	-	-	7	-	-	1
	2.	-	-	1	-	-	-	-	4	1	-	-	-
Appendicularia	1.	1	-	-	-	-	3	-	-	-	-	-	-
	2.	-	-	-	-	1	-	-	-	-	1	-	-
Lucifers	1.	5	1	6	-	1	5	-	-	3	-	-	-
	2.	-	-	1	2	-	-	-	-	-	-	1	-
Cirripede larvae	1.	1	2	5	10	-	7	-	4	-	-	1	-
	2.	1	-	-	-	-	-	3	-	-	-	1	-
Invertebrate eggs	1.	7	4	17	6	5	-	-	1	3	5	1	19
	2.	-	17	8	-	9	-	-	1	5	-	-	3
Foraminiferans	1.	14	10	8	-	-	15	5	7	3	9	4	7
	2.	10	10	4	6	6	5	1	1	1	20	27	18

1 - First year (1988), 2 - Second year (1989)

Table 17. Monthly count of different zooplankton groups in station - 3 (Nos/m^3)

	J	F	M	A	M	J	J	A	S	O	N	D
Copepods	1- 69 2- 35	106 115	133 157	12 61	38 45	49 41	34 55	25 76	11 37	8 40	1 3	86 57
Siphonophores	1- 12 2- 3	14 19	15 -	20 -	11 1	4 2	6 2	7 3	4 -	1 3	- -	3 7
Fish eggs	1- 214 2- 46	150 90	147 7	26 3	10 -	20 3	20 18	9 45	7 18	10 21	8 74	369 20
Fish larvae	1- 1 2- 3	1 7	2 -	1 -	- -	- 1	- 3	- 2	- -	- 1	- -	5 1
Megalopa	1- 6 2- -	6 4	1 -	- 1	1 -	1 -	1	- -	- -	- -	- -	- -
Zoea	1- 12 2- 7	6 9	23 2	2 14	9 7	12 13	15 48	- 89	- 19	- 27	- 1	15 70
Decapod larvae	1- 36 2- 19	35 60	10 19	28 1	8 -	11 20	23 67	11 66	2 28	- 39	29 1	19 158
Phyllosoma	1- 4 2- -	3 1	- -	- -	11 -	- -	- 2	- -	- -	- -	- -	1 -
Chaetognaths	1- 21 2- 1	18 19	11 1	7 -	1 2	2 2	3 5	- 7	- 3	1 3	- -	- 5
Medusae	1- 13 2- 7	9 8	20 7	11 1	4 2	7 1	5 -	- -	- 2	- 1	2 2	5 -
Mysids	1- 7 2- 2	3 1	3 2	2 -	- -	- 3	4 13	- 20	- 7	- 5	1 -	1 -
Polychaetes	1- 25 2- -	18 21	6 4	5 -	6 -	4 1	13 7	6 5	1 -	1 -	- -	1 -
Amphipods	1- 17 2- -	23 28	- -	19 -	7 -	9 -	10 -	9 -	3 -	- 3	- 28	- 19
Ostracods	1- 5 2- 4	- 3	2 7	1 1	- -	8 7	7 16	6 -	2 9	2 13	- 2	2 2
Bivalve larvae	1- 24 2- -	31 30	37 -	9 6	7 -	9 3	15 7	12 3	4 3	- -	- -	9 4
Gastropod larvae	1- 25 2- 18	26 20	34 11	16 47	12 2	8 9	20 9	15 4	7 19	26 7	30 6	43 37
Isopods	1- 1 2- 4	- -	3 4	2 -	1 -	4 -	3 -	6 3	6 -	- 5	3 -	11 3
Stomatopod larvae	1- - 2- -	- -	1 -	4 -	- -	- -	- -	- -	- -	- 1	- -	1 1
Appendicularia	1- 1 2- 1	- -	- 1	- -	- -	- -	- -	- 1	- -	- 1	- -	- -
Lucifers	1- 4 2- -	5 -	- -	2 -	- -	- -	- 1	- 1	1 -	- (1	- -	- -
Cirripede larvae	1- - 2- -	3 1	4 1	5 3	- 1	- 1	- 7	- 1	- -	- 3	- -	- 1
Invertebrate Eggs	1- 5 2- -	6 -	7 5	9 5	3 -	6 9	4 17	2 19	1 -	1 7	2 -	1 7
Foraminiferans	1- 5 2- 13	6 7	7 15	8 5	7 7	11 13	5 11	15 18	13 11	9 19	4 4	9 7

1 - First year (1988), 2 - Second year (1984)

their order of abundance were Fish eggs, Copepods, Decapod larvae, Gastropod larvae, Zoea, Foraminiferans, and Bivalve larvae. Maximum monthly average abundance of Fish eggs, Zoea, Decapod larvae and Gastropod larvae, was 194.5, 42.5, 88.5 and 40/m^3 in December, minimum for Fish eggs and Decapod larvae were 10 and 8/m^3 in May. Minimum for Zoea was in November (1/m^3) and 8.5/m^3 for Gastropod larvae, in June. Maximum for copepods were in May (145/m^3), Bivalve larvae in February (30.5/m^3) and Foraminif erans in August (16.5/m^3). Minimum abundance of Copepods and Foramini ferans was in November (2 and 4/m^3) and for Bivalve larvae in September (3.5/m^3). Bivalves were not observed in October and November. Abundance of other groups is shown in Table 17.

Table 18 depicts the monthly average count of different zooplankton groups encountered in station - 5. Due to rough weather, sampling was not possible in June and September of first year and July and September of second year. Total zooplankton was found to be maximum in December (1,978/m^3) and minimum in June (151/m^3). Major groups in the order of abundance were Copepods, Zoea, Fish eggs, Decapod larvae, Gastropod larvae, Foraminiferans and Bivalve larvae. Maximum abundance of Copepods was observed in December (506/m^3) and minimum in November (8/m^3). Maximum Fish eggs occured in February (269.5/m^3) and minimum in November (1/m^3). Zoea and Gastropod larva were found to be highest in May (762 and 43.5/m^3) and minimum in November (4 and 3/m^3). Decapods, Bivalves and Foraminiferans were maximum in January, the values being 221, 21.5 and 15/m^3 respectively. Minimum abundance of Decapod larvae was in May (2/m^3), Bivalve larvae in October (3/m^3) and Foraminiferans in August (15/m^3). An unusually high abundance of zoea was observed in March, second year, amounting to 1,500/m^3.

Numerical abundance of different zooplankton groups in Station - 6 are given in Table 19. Total zooplankton count was found to be maximum in December (1,474/m^3) and minimum in October (142/m^3). Important groups in their order of abundance were Copepods, Fish eggs, Decapod larvae, Gastropod larvae, Foraminiferans, Zoea and Bivalve larvae. Copepods,

Table 18. Monthly average count of different zooplankton groups in station - 5 (Nos/m^3)

	J	F	M	A	M	J	J	A	S	O	N	D
Copepods	1- 78 2- 385	89 101	132 123	45 13	39 24	NS 30	27 NS	21 69	NS NS	6 28	1 15	943 69
Siphonophores	1- 13 2- 2	18 13	24 -	11 -	4 -	NS -	13 NS	9 2	NS NS	1 -	- -	30 1
Fish eggs	1- 154 2- 43	238 301	97 1	29 1	27 5	NS 9	13 NS	17 30	NS NS	21 18	- 1	233 47
Fish larvae	1- 3 2- 4	2 11	3 -	2 -	1 -	NS -	- N S	1 -	NS NS	- -	- 1	1 -
Megalopa	1- 3 2- -	- -	7 -	- -	- -	NS -	- NS	- -	NS NS	- -	- -	- -
Zoea	1- 7 2- 29	6 3	24 1500	3 1	4 1	NS 30	21 NS	1 98	NS NS	- 13	- 4	9 48
Decapod larvae	1- 14 2- 408	12 49	20 211	22 -	- 2	NS 15	41 NS	3 79	NS NS	7 40	- -	8 207
Phyllosoma	1- 2 2- 1	- 2	5 -	- -	- -	NS -	3 NS	- -	NS NS	- -	- -	3 -
Chaetognaths	1- 19 2- 23	7 9	7 23	3 -	4 -	NS 1	4 NS	- 2	NS NS	- 5	- -	175 9
Medusae	1- 12 2- 3	15 20	10 3	12 1	5 -	NS -	14 NS	2 -	NS NS	2 3	1 -	12 2
Mysids	1- 5 2- 6	- 3	- 6	2 -	1 -	NS 7	5 NS	- 9	NS NS	- 2	- -	- 3
Polychaetes	1- 15 2- 4	25 17	12 4	14 -	4 4	NS 3	10 NS	1 -	NS NS	- 1	- 2	8 -
Amphipods	1- 20 2- 4	22 35	19 4	8 -	13 -	NS -	16 NS	5 -	NS NS	2 -	- -	4 7
Ostracods	1- 9 2- 4	2 1	1 7	3 -	- -	NS 11	- NS	9 4	NS NS	2 4	- -	5 -
Bivalve larvae	1- 31 2- 12	22 11	24 11	13 -	10 -	NS 2	10 NS	15 -	NS NS	- 3	- -	15 3
Gastropod larvae	1- 26 2- 36	21 18	27 60	32 7	17 6	NS 13	22 NS	13 13	NS NS	13 9	2 4	55 9
Isopods	1- - 2- 3	- -	3 4	1 -	4 -	NS -	1 NS	5 1	NS NS	- -	- -	8 1
Stomatopod larvae	1- 1 2- 1	- 1	- 1	7 -	- -	NS -	- NS	- -	NS NS	- -	1 -	- 11
Appendicularia	1- - 2- 4	- -	- 4	- -	- 1	- -	- NS	- -	- NS	- -	- 2	12 1
Lucifers	1- 1 2- -	- -	- -	1 -	1 -	NS 1	1 NS	- -	NS NS	- -	- -	1 -
Cirripede larvae	1- 2 2- -	- 1	- -	- 2	2 2	NS -	- NS	- -	NS NS	- -	- -	2 -
Invertebrate eggs	1- 6 2- -	4 -	9 6	7 7	4 3	NS 11	4 NS	6 8	NS NS	- -	4 1	3 4
Foraminiferans	1- 11 2- 19	11 13	3 20	13 3	13 5	NS 18	3 NS	17 13	NS NS	18 8	18 8	8 21

1 - First year (1988), 2 - Second year (1989), NS - Sampling

Table 19. Monthly average count of different zooplankton groups in station - 6 (Nos/m^3)

		J	F	M	A	M	J	J	A	S	O	N	D
Copepods	1-		62	146	48	47	12	48	4	14	19	2	239
	2-	328	60	127	201	99	9	22	35	16	22	13	185
Siphonophores	1-	NS	18	21	7	13	5	6	7	1	5	4	7
	2-	19	3	9	-	3	2	-	-	-	-	2	9
Fish eggs	1-	NS	75	176	24	19	6	20	3	8	18	9	264
	2-	170	14	98	17	5	9	7	21	12	14	9	94
Fish larvae	1-	NS	-	1	2	1	-	-	-	-	-	-	1
	2-	2	-	-	-	-	-	-	-	-	-	-	1
Megalopa	1-	NS	3	-	-	-	4	-	-	-	-	-	-
	2-	7	-	-	3	-	-	-	-	-	-	-	3
Zoea	1-	NS	20	45	5	7	17	-	3	-	-	6	31
	2-	174	18	78	28	13	7	30	11	3	2	4	91
Decapod larvae	1-	NS	43	38	27	18	18	18	14	6	-	9	20
	2-	108	112	64	14	-	30	42	18	10	7	3	221
Phyllosoma	1-	NS	7	-	-	-	-	-	-	-	-	-	-
	2-	1	-	-	-	-	-	-	-	1	3	-	-
Chaetognaths	1-	NS	45	19	7	-	-	-	-	-	1	7	-
	2-	28	14	4	-	5	-	7	2	4	3	-	14
Medusae	1-	NS	3	-	1	5	3	-	-	-	-	-	1
	2-	7	17	2	-	4	-	-	-	-	1	-	2
Mysids	1-	NS	7	-	5	8	5	-	1	-	3	-	3
	2-	41	9	5	3	14	1	11	4	2	4	-	-
Polychaetes	1-	NS	25	15	9	15	14	14	4	13	8	-	8
	2-	12	14	18	5	9	3	4	-	-	-		3
Amphipods	1-	NS	20	1	18	3	-	8	4	7	1	-	5
	2-	11	23	-	7	4	-	-	2	-	-	17	26
Ostracods	1-	NS	4	-	-	-	2	4	2	1	-	-	7
	2-	18	11	9	4	-	4	10	9	3	1	-	9
Bivalve larvae	1-	NS	47	28	13	10	3	20	7	8	4	-	17
	2-	13	41	7	17	-	5	3	-	5	3	7	34
Gastropod larvae	1-	NS	61	43	20	18	5	16	17	5	10	27	38
	2-	49	32	14	39	7	9	5	7	2	4	13	48
Isopods	1-	NS	4	8	9	3	1	-	4	2	-	4	8
	2-	7	-	7	-	-	-	-	4	2	3	4	5
Stomatopod larvae	1-	NS	6	5	3	1	-	2	-	4	-	7	4
	2-	-	-	-	-	-	3	-	-	-	1	7	8
Appendicularia	1-	NS	-	3	-	-	-	-	-	-	-	-	-
	2-	-	2	3	-	-	-	-	1	-	-	1	2
Lucifers	1-	NS	-	1	5	-	-	1	1	-	-	-	3
	2-	9	1	3	-	-	-	-	1	-	-	-	4
Cirripede larvae	1-	NS	1	-	-	-	1	2	-	-	-	-	4
	2-	3	1	-	2	1	-	4	-	1	-	-	1
Invertebrate eggs	1-	NS	7	11	-	2	18	13	3	-	-	-	8
	2-	11	-	8	17	6	-	11	7	-	-	-	18
Foraminifera	1-	NS	4	13	4	11	15	21	7	11	5	10	13
	2-	18	13	20	13	3	4	14	9	3	-	-	15

1 - First year (1988), 2 - Second year (1989), NS - No sampling

Fish eggs and Decapod larvae were found to be maximum in December, the abundance being 212, 179 and 120.5/m^3 respectively. Copepods and Decapod larvae were minimum in November (7.5 and 60/m^3) and that of Fish eggs was in June (7.5/m^3). Highest values for Zoea was in May (61.5/m^3) and Foraminiferans in July (17.5/m^3). Their minimum was found to be in October (2 and 5/m^3). Bivalve and Gastropod larvae were found to be maximum in February (44.0 and 46.5/m^3) and minimum for Bivalve larvae in October (3.5/m^3) and Gastropod larvae in September (3.5/m^3).

Night time monthly average zooplankton abundance for station - D is shown in Table 20. There was no sampling in January and February in the first year. Maximum total abundance was noted in August (10,647/m^3) and minimum in February (1,404/m^3). A total of 27 groups were observed in the night samples. The additional groups were Doliolum, Salps, Euphausids, Tunicates and Tanidaceae, but their abundance was negligible. Major groups in their order of importance were Decapod larvae, Ostracods, Copepods, Fish eggs, Zoea, Megalopa, Foraminifera, invertebrate eggs, Mysids, Gastropod larvae, Medusae and Fish larvae. Except Chaetognaths, all other groups were found to be more during night than all the day time samples. Copepods and Fish larvae were found to be maximum in December (879 and 89.5/m^3) and minimum in February (105 and 1/m^3). Fish eggs and Medusae were maximum in May (610.5 and 25.5/m^3) and minimum for Fish eggs was in February (951/m^3) and for Medusae in June (4/m^3). Megalopa, Decapod larvae, Ostracods, Gastropod larvae, and Foraminiferans were found to be maximum in August (1,020, 1,053.5, 1,986, 62.5 and 138.5/m^3 respectively). Minimum observed for Megalopa was in January (18/m^3), Decapod larvae in December (459.5/m^3), Ostracods and Gastropod larvae in May (14.5/m^3 and 8/m^3) and Foraminiferans in November (14/m^3). Maximum abundance for zoea was noted in July (920/m^3), Mysids in September (58.5/m^3) and Invertebrate eggs in November (45/m^3). Minimum values of Zoea and Mysids was 49/m^3 and 9/m^3 in January and that of Invertebrate eggs being 12/m^3 in April.

Two-way analysis of variance (ANOVA-2) showed highly significant variation ($P < 0.01$) with location of all day time stations and over seasons

Table 20. Monthly average count of different zooplankton groups at night in station - D (Nos/m^3)

	J	F	M	A	M	J	J	A	S	O	N	D
Copepods	1- NS 2- 1607	NS 105	200 170	450 395	180 200	340 307	207 298	308 336	371 300	188 103	138 98	1470 288
Siphonophores	1- NS 2- 28	NS 1	5 2	1 5	3 1	9 7	4 3	9 11	4 7	3 -	- 19	7 7
Fish eggs	1- NS 2- 613	NS 95	276 175	313 370	650 571	470 491	118 128	280 200	450 370	70 189	98 140	109 166
Fish larvae	1- NS 2- 7	N S 1	3 7	5 9	1 3	8 13	5 4	18 11	11 7	- 4	7 3	13 166
Megalopa	1- NS 2- 18	NS 85	13 28	40 70	75 101	186 100	470 380	1170 870	170 430	107 186	46 28	26 81
Zoea	1- NS 2- 49	NS 157	59 71	70 86	109 201	800 750	960 880	358 288	470 384	288 270	180 189	76 107
Decapod larvae	1- NS 2- 478	NS 700	730 680	570 740	470 513	670 571	780 796	1100 1007	2113 983	869 340	688 196	579 340
Chaetognaths	1- NS 2- 11	NS 5	- 1	- -	- -	7 13	3 9	5 7	9 1	3 9	- 1	5 7
Medusae	1- NS 2- 18	NS 70	18 20	28 19	20 31	- 4	4 28	2 9	17 38	28 19	13 -	7 3
Mysids	1- NS 2- 9	NS 21	7 18	19 27	27 40	16 19	17 18	25 31	71 46	13 17	7 11	3 36
Polychaete larvae	1- NS 2- 6	NS 6	18 35	7 5	19 7	9 13	7 4	20 18	11 7	7 4	18 3	4 11
Amphipods	1- NS 2- 98	NS 5	1 4	- 1	- 1	3 9	- -	18 -	9 1	4 3	47 180	168 211
Ostracods	1- NS 2- 67	NS 41	13 38	19 28	10 19	986 1871	750 1776	2101 1871	41 861	88 486	103 570	50 430
Bivalve larvae	1- NS 2- -	NS 8	3 11	- -	7 7	9 19	7 8	19 13	7 7	6 16	5 7	- 16
Gastropod larvae	1- NS 2- -	NS 30	7 11	13 18	7 9	40 38	19 28	76 49	18 37	19 19	7 36	- 9
Isopods	1- NS 2- 5	NS 5	4 7	1 3	9 5	7 9	5 7	9 6	7 3	3 7	9 -	1 2
Stomatopod larvae	1- NS 2- 4	NS 6	1 4	1 -	- 1	1 12	- 4	6 3	4 8	4 -	2 7	6 3
Appendicularia	1- NS 2- -	NS 1	3 1	- -	- -	3 2	5 3	7 1	11 -	3 4	1 1	3 1
Lucifers	1- NS 2- 1	NS 1	3 -	- -	- 1	1 3	5 1	4 1	1 7	5 3	7 -	- 7
Cirripede larvae	1- NS 2- 3	NS 1	5 4	- 1	3 5	1 7	5 1	13 7	5 18	1 4	3 11	7 9
Invertebrate eggs	1- NS 2- 16	NS 27	18 19	17 7	19 37	13 28	28 18	38 19	27 49	18 15	16 74	9 71
Foraminiferans	1- NS 2- 107	NS 21	19 27	31 18	47 18	76 49	49 38	171 106	74 76	30 19	17 11	18 21
Doliolum	1- NS 2- 1	NS -	- -	- 2	- -	- -	- -	1 -	1 4	3 -	- -	- -
Salpa	1- NS 2- -	NS -	- -	- -	- -	- -	- -	- 3	- 1	3 -	- -	- -
Euphausids	1- NS 2- -	NS -	- -	- -	- 3	- 4	6 -	- -	7 7	- -	- -	7 1
Tunicates	1- NS 2- 1	NS 3	1 2	3 1	- -	1 5	- -	4 5	7 -	1 1	7 -	- 3
Tanadiceae	1- NS 2- 3	NS 9	- -	- 1	- 7	- 9	- -	- 13	5 26	7 46	3 11	- 3

1 - First year (1988), 2- Second year (1989), NS - No sampling

(Table 21). Maximum abundance among day time stations was noted in station - 2 followed by station - 5, then station - 6 and lowest in station 3 (Table 22). On a comparison with all the day time stations, the night time abundance showed remarkably high values (Table 22).

Samples from stations - 2 and 6 showed maximum abundance during post-monsoon and that of stations - 3 and 5 showed maximum during pre-monsoon. Minimum abundance was observed during monsoon in all stations, except the samples from night station. In sharp contrast from all day time samples the night samples showed maximum abundance during monsoon and minimum during post-monsoon season. Seasonal averages for all stations are given in Table 22.

Percentage occurence of different zooplankton groups during various seasons for all the stations are shown in Figure 16. As with total zooplankton, the individual groups also showed distinct seasonal variation. All the day time stations showed minor difference among one another, whereas the night station showed a distinct character from all the day time stations. In the night samples, except Decapod larvae, Ostracods and Zoea, all other groups were found to be lower in their percentage, than the day time stations but their numerical abundance was higher. Ostracods were found to be maximum during monsoon in all stations.

Diurnal variations in numerical abundance of different zooplankton groups over the entire tidal range are shown in Table 23. Total day time count was very low, which decreased upto 1500 hrs ($124/m^3$) and increased to a maximum of $3,356/m^3$ by 0600 hrs, then sharply declined to just $160/m^3$ by 0900 hrs. Diel fluctuation of percentage occurence in major groups are shown in Figure 17. Percentage of copepods was almost uniform upto 1800 hrs (32.8%). it declined sharply to 9.9% at 2100 hrs, then increased to the maximum level of 64.1% at 0300 hrs and again declined towards 0900 hrs. Highest percentage of fish eggs was noted at 2100 hrs (42.1%), whereas Gastropod larvae showed maximum percentage only during day time at 1200 hrs (37.4%). Zoea was found to be maximum in the morning

Table 21. Two way ANOVA showing the level of variation in total numerical count of zooplankton between stations and over seasons

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	3	216174.90	72058.29	16.42	HI.SIG(1%)
REPLIC	2	182907.10	91453.56	20.83	HI.SIG(1%)
ERROR	6	26337.63	4389.60		

Table 22. Seasonal averages of numerical zooplankton abundance and their average occurence in different stations

PR-MON - Pre-monsoon, MON - Monsoon, PO-MON - Post-monsoon

	STATIONS				
	2	3	5	6	D.(NIGHT)
PRE-MON	682.8	270.1	501.8	346.4	1571.9
MON	359.0	137.1	202.0	122.4	4275.1
PO-MON	722.8	261.1	457.5	482.8	2020.0
AVERAGE	587.9	222.8	387.1	317.2	2622.3

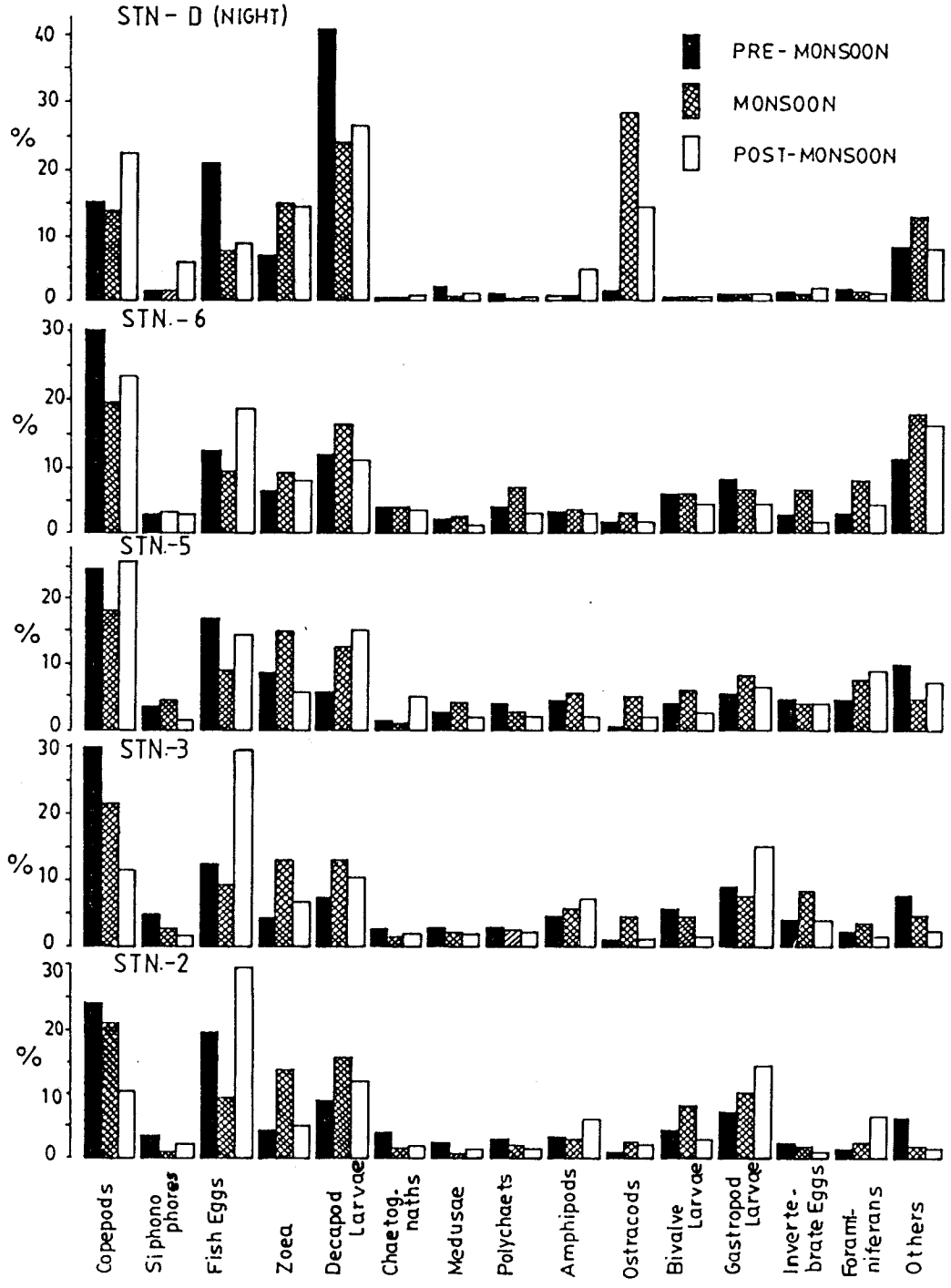

Figure 16. Percentage occurence of different zooplankton groups during Pre-monsoon, Monsoon, and Post-monsoon seasons at various stations.

Table 23. Variation in numerical abundance of different zooplankton groups for a period of 24 hour, over the tidal cycle

	Time hr								
	0900	1200	1500	1800	2100	2400	0300	0600	0900
Copepods	69	51	31	41	168	727	1550	1249	35
Fish eggs	22	5	7	10	714	63	201	97	17
Fish larvae	7	--	--	1	3	4	--	35	1
Decopod larvae	89	20	30	35	275	130	150	673	41
Megalopa	1	--	--	--	200	50	--	28	--
Medusae	18	3	--	--	35	143	130	672	3
Polychete larvae	3	9	4	3	22	10	6	2	7
Mysides	--	--	--	--	13	7	11	--	--
Ostracods	3	--	--	--	15	11	7	8	1
Gastropod larvae	69	70	19	13	64	62	--	228	25
Zoea	163	10	3	17	93	56	275	281	20
Foraminiferans	--	--	--	--	21	41	7	15	--
Invertebrate eggs	8	13	19	5	13	--	17	14	--
Others	30	19	11	13	58	43	75	54	10
Total	482	200	124	138	1694	1347	2429	3356	160
Tidal height(Cm)	100	149	120	100	135	150	120	70	60

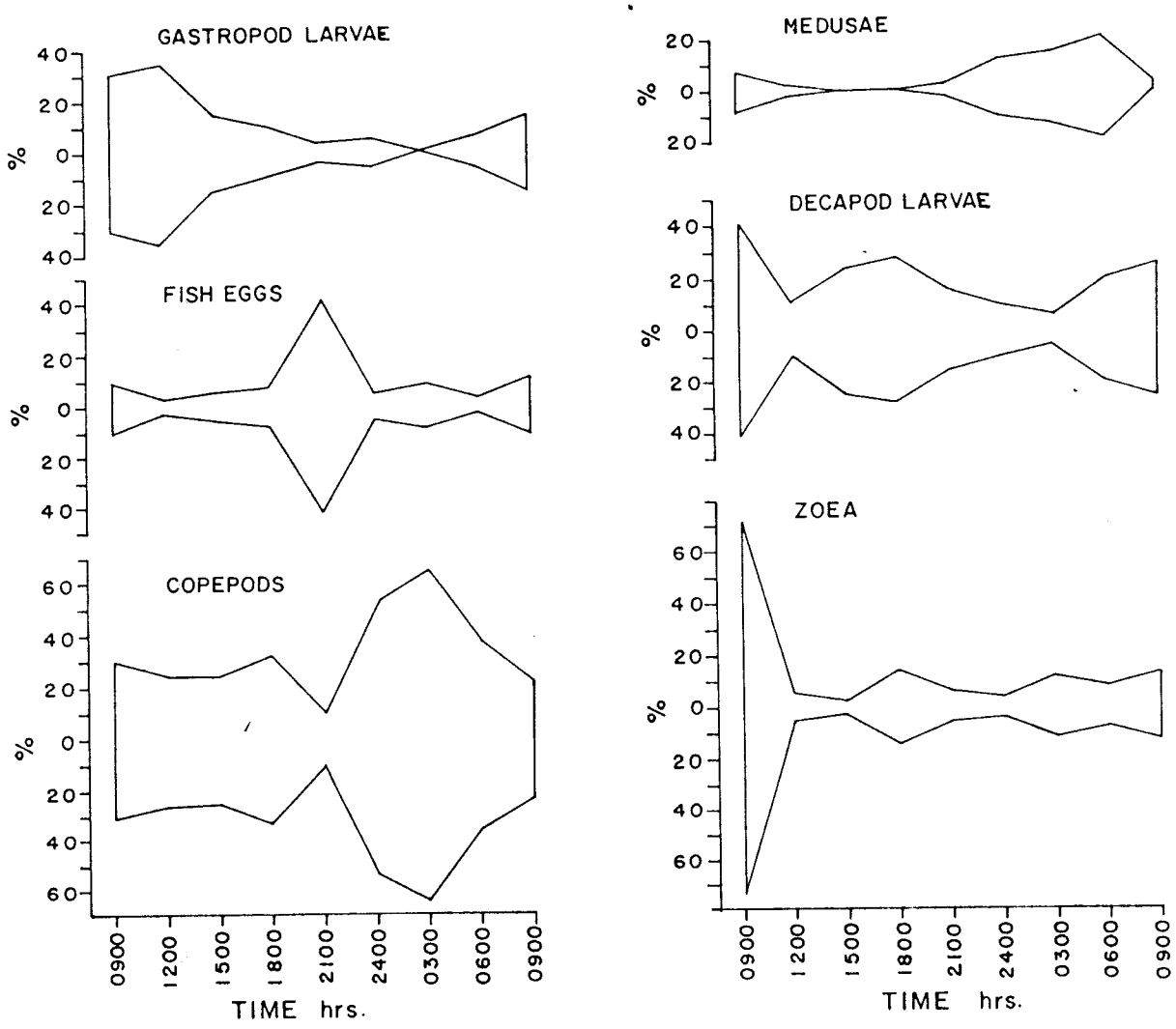

Figure 17. Diurnal variation in percentage occurrence of major zooplankton groups.

(73.4%) and decreased sharply to be fluctuated within 2.4 and 8.4% for the whole day and night. Decapod larvae also showed maximum percentage at 0900 hrs (40.1%), which declined to 10.6% at 1200 hrs and increased upto 28% at 1800 hrs and again declined towards morning. The medusae were found to be absent during 1500 and 1800 hrs, but they increased towards morning, with a peak at 0600 hrs (20.0%) and decreased to 1.9% by 0900 hrs. Table 23 depicts the fluctuation of other groups. The diurnal variations did not show any distinct relation with tide.

DISCUSSION

The atoll of Kavaratti is characterised by the shallowness of the lagoon, the average depth being 2 m. The clarity of water allows light to reach the lagoon bottom in full intensity. This atoll receives heavy south-west monsoon from June to September (monsoon-season), and light north-east monsoon from November to December (post-monsoon), February to May is the pre-monsoon period, in which April presents a more or less stable environment (Goswami, 1973).

Earlier reports by Sankaranarayanan (1973) and Goswami (1973, 1979, 1983) showed a higher temperature in the lagoon water than the open sea around Kavaratti atoll. They attributed this to the shallowness of the lagoon. Contrary to this, the present study revealed no significant variation in temperature between the open sea and lagoon stations. The difference in temperature observed by earlier workers must have been due to the short-time involved in their observations, in which brief temporal variations might have occured depending on the tide and flushing of water into the lagoon. During lowest low tides seawater flushing into the lagoon is reduced, this gives more resident time for water in the lagoon, allowing it to warm up from normal on sunny days. This is evident from the diurnal study, in which the temperature increased with decreasing tide. Otherwise there was no marked, consistent temperature difference between lagoon water and the sea surrounding it as the present study proved.

The lowering of temperature during June to August is due to the effect of monsoon. This has been reported earlier by Rao et al. (1976) from the Arabian Sea.

Diurnal fluctuation in water temperature was within 2°C. Quasim et al. (1972), Sankaranarayanan (1973) and Goswami (1979) reported almost similar diurnal fluctuations in temperature. This is a reflection of diel atmospheric temperature cycle.

As with temperature, pH and salinity also showed no variation between stations. Sankaranarayanan (1973) reported similar results from Kavaratti, whereas Goswami (1973, 1983) found higher values for salinity, and lower values of pH in the lagoon than the surrounding sea. These differences could also be due to the short term observations in which the tides influenced salinity and pH, which is evident from the dirunal study. Eventhough minor variations were noted in the present study, none of these were found to be statistically significant over a long period of time.

Both pH and salinity showed seasonal fluctuations by a decrease in monsoon period. Though the fluctuation was within a narrow range (pH: 0.1, salinity: 0.5‰ it is well marked because of the steady pre and post-monsoon values. pH varies depending up on the temperature, salinity and partial pressure of CO_2. (Sverdrup et al., 1961). During monsoon, the lower temperature, decrease in salinity due to dilution by rain and decreased photosynthetic rate by plants increase the CO_2 level and these tend to decrease the ionic product resulting in a lower pH. The slight drop in salinity during the peak monsoon months may also be due to rain which slightly dilutes the surface water. Dilution is a factor which decrease pH and salinity (Sverdrup et al., 1961).

pH and salinity showed diurnal variation from 8.16 to 8.36 and 34.1‰ to 34.6‰ respectively. Sankaranarayanan (1973) reported a diurnal variation of 0.3 pH units and Goswami (1979) observed a variation of 0.6 pH units. Present study showed a lower difference of 0.2 pH units. The

positive correlation between pH, temperature, and photosynthetic activity (Sverdrup et al., 1961) could explain this variation. Williams and Barghoorn (1963) observed high pH in bright sunlight and it dropped after dark in Florida Bay. The high photosynthetic activity of algae and seagrasses in the waters may have a good bearing on the precipitation of carbonates (Sankaranarayanan, 1973) which makes pH variation.

As reported earlier by Qasim et al. (1972) Sankaranarayanan (1973), Goswami (1973, 1979); salinity exhibited marked dirunal fluctuation. The correlation between salinity and temperature shows that this is a reflection of diel change in temperature and may also be due to metabolic activity in the lagoon.

High values of dissolved oxygen obtained from lagoon stations and lower values outside agrees with Qasim et al. (1972), Sankaranarayanan (1973) and Goswami (1973, 1979, 1983), which indicate the active photosynthetic activity in the lagoon. The extreme shallowness and strong illumination assist high rate of photosynthesis by benthic plant communities.

Dissolved oxygen did not show significant seasonal fluctuations, whereas the diurnal changes in the level of oxygen in the lagoon were very high. Maximum values were observed at 1800 hrs and minimum at 0600 hrs. Qasim et al. (1972), Sankaranarayaan (1973) and Goswami (1973, 1979) have observed the same pattern of diel variation. This fluctuation is due to the high rate of photosynthesis during daytime and intense respiration at night(Odum, 1956; Hansen et al., 1978).

Areas where coral reefs established themselves are often nutrient impoverished (Sargent and Austin, 1949; Odum and Odum, 1955; Lewis, 1977). This is true in the case of Kavaratti Atoll also. Agreeing with the results of Goswami (1979, 1983) concentration of silicate varied with location of stations, and showed a low concentration in the lagoon than outside. This suggests an active utility in the lagoon. The primary use of silicate by marine organisms is in the precipitation of siliceous tests

(Sverdrup et al., 1961; Smith and Jokiel, 1975). Diatoms and other silica secreting organisms play a role in the lowering of silicate concentration (Sverdrup et al., 1961). Epiphytic diatoms of Thalassia sp. in Biscayne Bay, Florida, may be more than equal the weight of leaf blade (Rayes-Vazquez, 1965). Diatom crop in Kavaratti lagoon was 44,440 cells/m^3, which was many times higher than the open sea-670 cells/m^3 (Qasim et al., 1972). These indicate that the lagoon and seagrasses system at Kavaratti Atoll could sustain a resident diatom population, and a possible bloom of these during monsoon can decrease the ambient silicate concentration. Lowering of surface silicate values even up to zero during monsoon in Arabian sea has been reported by Senguptha et al., 1979.

Diurnal variation of silicate did not conform into any definite pattern, which indicates the less important role of silicate in the metabolic activity of coral reafs as described by Smith and Jockiel (1975). From the above finding it becomes evident that there is no photosynthetically related variation in silicate in Kavaratti Atoll.

Qasim et al. (1972) and Goswami (1983) observed extremely low phosphate-P and Nitrate-N in Kavaratti lagoon. Present study also showed a considerably low concentration of phosphate, nitrite and nitrate.

Phosphate concentration in lagoon stations was lower than the open sea stations. These indicate an active uptake of phosphate by lagoon plant communities as suggested by Odum and Odum (1955), Pilson and Betzer (1973), Sankaranarayanan (1973), Atkinson (1987). Twilley et al. (1977) and Penhale and Thayer (1980) have reported the absorption of phosphate by angiosperms in marine and freshwater areas. The lush growth of sea-grasses and benthic algae found in Kavaratti lagoon may be deriving phosphate from water.

Phosphate being a factor which is essential for plant growth, how Kavaratti lagoon sustains such high productivity and plant biomas, which is among the highest reported for coral reefs (Qasim et al., 1972), in this low concentrations? Mechanism might exist within the reef ecosystem

to conserve phosphorus by tightly recycling it (Pilson and Betzer, 1973). In nature seagrasses act either as a sink or as a source for available phosphorus The root rhizome system of seagrass is the site of major phosphorus uptake (Penhale and Thayer, 1980). The extensive seagrass beds in Kavaratti Atoll may be playing an important role in the phosphate recycling. Coral reef sediments are an important source of phosphorus (Patriquin, 1972). The bulk of phosphorus absorbed for plant production is to be found as an integral part of the reef matrix itself (Entsch et al., 1983) and indicates a vast and nearly uniform pool of inorganic-P There are biological pathways to retain phosphorus in sediment (Di Salvo, 1974; Entsch et al., 1983). Also there is net import of phosphorus to the reef from plankton and detritus (Di Salvo, 1974; Wafar et al., 1986), faecal pellets and dead organic matter (Entsch et al., 1983) and coral mucus (Ducklow and Mitchell, 1979). As reported by Entsch et al. (1983), phosphate concentration varied with time of the year. Pre and post-monsoon season showed higher values than that of the monsoon season.

The increase in phosphorus concentration at night and decrease during day suggests an uptake, while photosynthesis is taking place. Qasim et al. (1972) and Goswami (1979) reported that the diel variation in phosphate is photosynthetically related. Net uptake of phosphate is highest around mid-day (Johannes et al., 1983).

Coral reef water contains very low dissolved inorganic nitrogen (Webb et al., 1975; Wiebe et al., 1975; Atkinson, 1988) and frequently too low to detect (Bellamy et al., 1982; Andrews, 1983). As with phosphate, the concentration of nitrite and nitrate in Kavaratti was also very low during the present observations. Such low levels of dissolved inorganic nitrogen are insufficient to maintain the high reef productivity (Webb et al., 1975; Hatcher and Hatcher, 1981). The lagoon stations showed lower concentrations of nitrite than the open sea stations, indicating removal of some amount of it from the ambient water in the lagoon. Though the variation of nitrate with location of stations was not statistically significant, the actual concentration in the lagoon stations was slightly higher suggesting a higher rate of nitrogen fixation and release of fixed products in the form

of nitrate. Furnas et al. (1990) also observed higher nitrate in a semi enclosed lagoon throughout the year in the Great Barrier Reef. The process of nitrogen fixation starts with the deamination of dissolved organic or particulate nitrogen into ammonia (NH_4^+), which is oxidized to nitrite (NO_2^-) and the NO_2^- oxidized to (NO_3^-) nitrate (Webb et al., 1975). But the reef water contains no appreciable amount of nitrite. It appears that there may be a tight and closed cycling of some components with benthos. The reef nitrogen fixation is mostly resulted by bluegreen algae (Webb et al., 1975; Wiebe et al., 1975) Apart from this, there is biological oxidation of ammonia to nitrate (nitrification) (Webb et al., 1975; and Webb and Wiebe, 1975), strictly mediated through bacteria (Wiebe, 1976).

Coral reef sediments and seagrass bed sediments are areas of nitrogen storage (Iizumi et al., 1980; Entsch et al., 1983; Boon, 1986). Concentrations of nitrite and nitrate are invariably higher in sediments than those in overlying water (Iizumi et al., 1980). Crossland and Barnes (1983) observed high concentrations of NH_4^+ in the interstitial waters of lagoon sediments. A fraction of the oxygen which is produced by photosynthesis in seagrass leaves is transported to sediments through their rhizomes and roots, which can be used for the oxidation of ammonia to nitrite and nitrate by bacteria (Iizumi et al., 1980). This illustrates the role of sediments, seagrasses and bacteria in nitrogen cycle in coral reefs. The vast bed of seagrasses in Kavaratti Atoll indicates their possible role in nutrient recycling and maintaining high productivity. The exact role and importance of the seagrasses system with reference to Kavaratti Atoll has to be investigated in detail.

The seasonal fluctuation observed in nitrite is due to interactions between production, regeneration, loss, biological utilization (Hatcher and Hatcher, 1981) and change in denitrification or autotrophic oxidation of NH_3^+ to NO_2^- and NO_3^- (Webb and Wiebe, 1975). It is probably because the denitrification and nitrification are of the same rate in all seasons, which keeps the nitrate level unchanged over seasons.

The values of nitrite and nitrate decreased during day and increased during night. Goswami (1979) has reported the same trend for nitrate from Kavaratti Atoll. Qasim et al. (1972) observed a reverse trend that, nitrate increased during day and decreased at night. Nitrogen fixation is strongly light dependent (Webb et al., 1975; Wiebe, 1976). The decrease in nitrite during day is probably because of its fixation into nitrate, which is strongly light dependent (Webb et al., 1975; Wiebe, 1976). Hence this process should increase nitrate concentration during day time, agreeing with the observations of Qasim et al. (1972), but Sankaranarayanan (1979) and the present study, did not observe this trend. This is probably because of the high rate of assimilation. Nitrate is assimilated from solution even at low concentration (D' Elia and Webb, 1977). Uptake rates of nitrate is higher in natural light than dark (Mc Carthy, 1972). Maximum uptake by photosynthetic organisms was centered around noon, and minimum around midnight, which tends to increase the nitrogen at night and decrease during day. This invites further studies on the nitrogen flux in Kavaratti Atoll to reveal the exact mechanism of the flux.

Average concentration of calcium in open-sea station was found to be slightly higher than the lagoon stations. This has been reported earlier from Kavaratti Atoll by Sengupta et al. (1979). They observed 416±0.5 mg/l calcium in the lagoon and 425±1.0 mg/l in open sea. Average for Arabian sea is 431 mg/l (Sengupta et al., 1979). The only process which affects concentration of calcium is the biological removal by organisms (Naqvi and Reddy, 1979). Coral reefs are overwhelmingly characterised by the presence of calcifying organisms. This intense rate of biological precipitation of calcium carbonate in the lagoon accounts for the reduction in calcium concentration. Variation in concentration with location of stations in the lagoon reflects the spatial variation in uptake.

Increased calcium levels during monsoon season may be due to its reduced precipitation. Calcification is light dependent (Crossland and Barness, 1977; Schneider and Smith, 1982; Gladfelter, 1984). Calcification on cloudy days can be only 50% of that on sunny days(Crossland and Barnes, 1977). The decreased light intensity coupled with fluctuating level of other hydrographical parameters might be reducing the rate of calcium

uptake. The diurnal fluctuation in calcium also reflects on the role of light and photosynthesis in calcification.

Kavaratti Atoll is one of the most productive marine communities reported sofar (Qasim et al., 1972). Illumination at the bottom of the lagoon would be 80-90% of that at the surface (Qasim et al., 1972), which encourages the biota to become massive. Most of the primary production in coral reefs come from benthic primary producers (Sourina, 1976; Lewis, 1977; Browitzka et al., 1983; Colinvaux, 1986). Oceanic atolls harbour relatively low phytoplankton standing stock and their contribution to reef production is very low, often insignificant (Sargent and Austin, 1949; Sourina, 1976; Sourina and Ricard, 1976; Lewis, 1977). Wafar (1977) reported a production of 22.7 mg C/m^3/day from Kavaratti Atoll. Nair et al. (1986) reported 8 to 34 mg C/m^3/day from Lakshadweep waters. The present study recorded the maximum production of the year in December, to be 6.09±2.48 mg C/m^3/hr (gross) and 0.46±0.39 mg C/m^3/hr (net), which worked out to be 73.08 mg C/m^3/day (gross) and 4.8 mg C/m^3/day (net), Qasim et al. (1972) reported 2.49 mg C/m^3/hr (April)0.51 mg C/m^3/hr (November) and 1.43 mg C/m^3/hr in December from Kavaratti Atoll. These results show a highly variable nature of phytoplankton production in Kavaratti Atoll. Except for January and October to December months, production obtained in the present study agreed with Qasim et al. (1972) and Wafar (1977).

Present study showed highly significant seasonal variation in gross production with a fall during monsoon. Though monsoon months are said to be the most productive season for phytoplankton in coastal waters (Gopinathan et al., 1984), it was not so in this oceanic lagoon. The present data is not large enough to predict whether this seasonal change would be consistent in every year.

Availability of nutrients is of major importance to phytoplankton production (Steeman-Nielsen and Jensen, 1957). Variation in one or more assimilable forms of nitrogen determines the rate of production (Wafar et al., 1986). He stated that Nitrogen in Lakshadweep sea limits phytoplankton

production. According to Droop (1983) and Parsons et al. (1984) a nutrient is said to be limited, when an increase in the flux of that nutrient increases a metabolic response, which might be gross productivity, net productivity, calcification growth and others as they described. The negative correlation between productivity and nitrate shows that it is available in required quantity so that fluctuation in that parameter is not influencing production. Phosphorous is unlikely to limit primary productivity at Lakshadweep waters (Wafar et al., 1986). Zooplankton regenerates an average 40% of it required for phytoplankton (Wafar et al., 1986). This is evident from the negative correlation between phytoplankton productivity and phosphate in the present study. Phytoplankton productivity correlated positively with all other parameters, of which it was significant only with salinity which has a direct influence on phytoplankton (Qasim, 1973).

Long term productivity studies on seagrasses and available literature on this is very few. Marine grass communities are highly productive (Odum, 1956). Qasim et al. (1972) reported a net production of 0.095 mg C/g/hr for Thalassia hemprichii and 0.034 mg C/g/hr for Cymodocea isoetifolium. In the present study gross production of Thalassia varied between 0.281±0.1 and 1.370±0.3 mg C/g/hr, and net production between 0.154±0.1 and 0.137±0.3 mg C/g/hr. Which were higher than those reported by Qasim et al. (1972). This may be due to the difference in methodology followed in the sense that the incubations of light and dark bottles were done in troughs by Qasim et al. (1972), which give more chance for temperature variations. Gross production of Syringodium varied between 0.255±0.1 and 0.812±0.1 mg C/g/hr and net production between 0.175±0.1 and 0.494±0.1 mg C/g/hr. As seen from the results, productivity of Thalassia was higher than Syringodium. Qasim et al. (1972) opined that since the experiments were conducted in small containers having stagnat water, the values may only give an approximation. When the per hour gross production was computed for 12 hours and the respiration for 24 hours the production was found to exceed respiration. that is, the P/R values were found to be more than 1 in almost all months for both the species.

The positive correlation of seagrasses productivity with most of the parameters shows that these parameters could limit production. Negative correlation with water temperature, pH and salinity indicates the independence of productivity over these parameters. Correlation with nitrite and silicate was also found to be significant.

Coral reefs are phytoplankton impoverished, and therefore if such ecosystem with its diverse fauna were to flourish, it must have pockets of high productivity, like the seagrasses beds, within itself. Wood et al. (1969) have discussed the role of seagrasses beds in the grazing food chain. Organic detritus derived from these communities serve as food for many organisms (Wood et al., 1969).

Hermatypic corals are known to produe morce oxygen than needed for their respiration during day, by the photosynthetic imprisoned algae (Odum and Odum, 1955). The imprisoned algae comprise symbiotic zooxanthellae in the animal tissue and the boring filamentous algae in the subsurface skeleton (Odum and Odum, 1955). Hence the gross production stands for the production from zooxanthellae and all other algae reside in corals that can photosynthesise, and net production means the total production minus the respiration of all plant components and the coral animal itself.

Among the three species studied, the seemingly smaller form Pocillopora damicornis showed highest gross and net production, followed by Acropora formosa and lowest by Porites cylindrica. Fast growing genera like Pocillopora and Acropora have comparatively higher rate of photosynthetic activity than that of the slow growing Porites (Pillai and Nair, 1972). Though Acropora and Pocillopra showed high rate gross production, their consumption was also high, resulting in lower net production, particularly during pre-monsoon period, which indicates a high metabolic rate (Pillai and Nair, 1972). Difference in rate of respiration is a result of difference in energy expenditure in biosynthesis (Davis, 1980). The present study showed a higher growth in Acropora formosa and Acropora aspera during pre-monsoon months (Table 27 - Chapter - III) which might require

increased metabolic activity resulting in high consumption rate. Despite for the slow growth rate of Porites (Pillai and Nair, 1972) and low gross production, the species exhibited high rate of consumption resulting in low net production, almost throughout the entire period of study, suggesting a high energy requirement in all times of the year.

Kanwisher and Wain wright (1967) showed in several species of Florida corals, that the photosynthesis is more than twice their respiration in dark (P/R is more than 1). However, in the present study, this was true only in some months for the three species, mainly during pre-and post-monsoon periods. This difference was probably because of the species specific factors (Goreau, 1961), regulation of production and consumption by quantity of imprisoned algal symbionts (Pillai and Nair, 1972; Smith and Muscatine, 1986) and physiological state of corals (Pillai, and Nair, 1972).

Productivity of corals show seasonal variations (Chalker and Dunlop, 1983). Production of Acropora and Pocillopora varied over seasons While Porites did not exhibit any statistically significant seasonality. The seasonal fluctuations may be due to the seasonal variation in ecological parameters.

Non -seasonality in Porites production may be due to the adaptability of some corals (Muscatine, 1980) or by the variation in zooxanthellae cell density (Smith and Muscatine, 1986). Nitrogen and phosphorous are major limiting factors for zooxanthellae (Yonge, 1963). The negative correlations with nitrate and phosphate show that production is independent of these parameters. Algae in corals may be deriving P from the coral animal metabolic products. Living corals are active sites of nitrification (Wafar et al., 1990). All this allow corals to live in sufficient supply of N and P. Other factors may also influence production. Acropora showed significant positive correlation with salinity and all the three species exhibited significant positive correlation with silicate, suggesting their possible influence on production. The variation in production cannot be attributed to a few causes alone, but may be due to the combined effect of many parameters.

Evidence as to the abundance of zooplankton near coral reef has been conflicting. Some authors have reported extremely low concentrations (Sargent and Austin, 1949; Odum and Odum, 1955 Johannes et al., 1970; Qasim et al., 1972), while others have found zooplankton in large quantities (Emery, 1968, Goswami, 1973; Sale et al., 1976). The present study clearly shows that the daytime numerical zooplankton density in Kavaratti atoll is low. Earlier observations by Tranter and George (1972), Qasim (1972), Madhu Pratap et al. (1977) and Goswami (1979) also showed that the day time zooplankton abundance in Kavaratti atoll is very low. But in sharp contrast to this, night samples showed higher density and richer in taxonomic groups. Nocturnal abund nce of zooplankton in coral reef has been reported by Emery (1968), Transter and George (1972), Glynn (1973a), Goswami (1973, 1979). The maximum nocturnal abundance recorded during the present study was 10,647/m^3, which shows the magnitude of abundance at night, even with the simple sampling methods. This nocturnal abundance has been attributed to many reasons. The transparency of water coupled with high incident radiation may be driving the plankton to take refuge in the grass bed, and come up during night (Goswami, 1979). In shallow water, zooplankton populations are epibenthic or demersal in nature during day time (Emery, 1968, Aldredge and King, 1977).

Madhu Pratap et al. (1977) observed domination of molluscan larvae in the zooplankton collected from Kavaratti. The present study also revealed fairly high representation of molluscan larvae, of which Gastropod larvae was found to be higher. They recorded poor representation of copepods in Kavaratti. This was true in day time samples of the present investigation, but night samples showed a uniformly high representation of copepods.

Except very few groups all others were found to be higher in density at night than daytime. Chaetognaths, Molluscs, and Siphonophors were lower in density at night. Goswami (1973, 1979) reported the lesser abundance of chaetognaths at night in Kavaratti Atoll. The very high percentage of Decapod larvae and Ostracods in the night samples kept the

percentages of all other groups low, despite for their actually high numerical abundance. Sengupta et al. (1979) attributed subsurface eddies and Goswami (1979) to breeding of prawns in this region for the abundance of decapod larvae in zooplankton samples. Spectacular Ostracod swarms have been reported from Kavaratti area at night by Tranter and George (1972) which was of the order of 1,000/m^3. Goswami (1979) also recorded swarms of Ostracods. The present observation recorded abundance of Ostracods at night, especially during late monsoon season, reaching a maximum average density of 1,986/m^3 in August. In the present study the lagoon-shore station (Station - 3) had lesser abundance than the reef station (station - 5). It appears that this difference may be because of zooplankton drifting into the lagoon over the reef is taking shelter in the extensive seagrass meadow in the extremely shallow lagoon. Luxurient growth of seagrass provide shelter for zooplankton (Goswami, 1973). Emery (1968) observed difference of zooplankton in sheltered areas from non sheltered areas and suggested that zooplankton take shelter in interstices of the reef caves and crevices. On area wise, the thickly growing seagrasses meadow in Kavaratti Atoll provide more area for shelter, than the coral dominated station - 6, this keep the density in this station higher than that of station - 3. Incidently, the highest zooplankton abundance at station - 2 is probably because of the lack of suitable areas of shelter as this area is characterised by sparse growth of seagrasses and algae intermixed by lagoon sand. So the zooplankton tend to drift and accumulate.

All the daytime stations and night station exhibited definite seasonal variation in total density as well as in individual groups. For all the daytime stations the lowest density was noted during monsoon. In sharp contrast to this, the night samples showed maximum abundance during monsoon, in more than double the abundance of pre-and post-monsoon seasons. This indicates the presence of a distinct noctural zooplankton from that of day time population. Reef associated zooplankton has a distinct composition (Johnson, 1954; Tranter and George; 1972). Coral reefs harbour resident zooplankton fauna with entirely distinct composition and behaviour (Emery, 1968; Aldredge and King, 1977). Reefs harbour demersal zooplankton which hide within reef sediments during the day, but emerge to swim freely over

the reef at night (Aldredge and King, 1977). Many of the reef zooplankton are capable of maintaining themselves within the reef habitat (Emery, 1968). If these are true in the case of Kavaratti Atoll, there will be two processes taking place. One is the continuous supply of energy in the form of zooplankton to the reef from the sea, and the other is reef produces its own zooplankton as its component. Goswami (1983) reported that some herpacticoid copepods are endemic to the Kavaratti lagoon.

Results of the diurnal studies showed very low zooplankton density during day time. From 2100 hr onwards the abundance sharply increased and reached a maximum at 0300 hrs. This high density declined sharply by 0900 hrs. Almost a same pattern of diurnal variation has been reported from Kavaratti by Goswami (1979). He suggested that this diurnal pattern may not be associated with the phenomenon of vertical migration as the lagoon is very shallow, instead, the shallowness and high light penetration might be driving them to take shelter in the reef substrata and come up during night. Goswami (1979) reported that zooplankton abundance and biomass values were higher during flood tide, when oceanic plankton were swept into the lagoon. But zooplankton density variation did not show any definite relation with tide in the present study. This also point towards the possibility that Kavaratti lagoon has its own zooplankton, as its component. Thus the nocturnal zooplankton may have the oceanic plus the lagoonal components, while most of the day time zooplankton in surface water is oceanic, which drifts into the lagoon and lagoonal zooplankton component may be contributing only to a minor fraction to the daytime abundance. To test whether Kavaratti Atoll has a resident zooplankton community distinct from the open ocean communities, a series of day and night sampling in the lagoon and outside at various stations has to be conducted simultaneously, and analysed for the abundance and species composition, supported by studies on demersal zooplankton.

The observations indicate that Kavaratti atoll has sufficiently abundant zooplankton content especially at night. The zooplankton must

be deriving nutrition from sources other than phytoplankton as the phytoplankton production is low. Organic matter exported from coral reefs serve as a significant food source in the lagoon (Qasim and Sankaranarayanan, 1970; Gerber and Marshall, 1982). Zooplankton feed on mucus aggregates, which dominate the particulate matter in reef water (Gerber and Marshall, 1974). Kavaratti Atoll can support abundant zooplankton fauna as its component with the alternate source of energy in the form of particulate organic matter.

CHAPTER - III

GROWTH AND FACTORS INFLUENCING GROWTH OF CORALS

INTRODUCTION

Coral growth has been studied for various reasons. Beginning with Darwin's postulation of reef formation a great deal of work has been focussed on coral reefs all over the world. Some of these works have been bifurcated towards analysing the 'coral reef problem' that is, how could coral reefs reach the surface of the oceans in areas of great depth and once at the surface, how could they maintain themselves against the ravages of erosional forces exerted by waves. Stoddart (1969) has reviewed the history of this controversy. Darwin as early as 1842 and Dana (1875) advanced the thought that the main constructional elements of reefs are the coral polyps and colonies. For this reason many workers interested in "Coral reef problem" sought the answer in the study of rate of growth of coral colonies themselves. Recently, growth rate of corals has been cited as one of the best quantitative measure of assessing the status of reefs and stress due to environmental disturbance, because this parameter integrates a variety of physiological processes (Neudecker, 1983; Brown and Howard, 1985). Brown and Scoffin (1986) used coral growth rate measurement as an indication of the effect of pollution and environmental disturbance.

An understanding of coral growth rates, growth forms and longevity is basic to the study of coral reef ecosystems (Buddemeier and Kinzie, 1976) and awareness on the factors influence their growth and survival in reefs would help in assessing the environmental status and maintenance. There were reports on the deterioration of coral reef environment at Laksha-dweep (Pillai, 1983; 1985; James et al., 1989). Hence for the first time in India the present work attempted to study the rate of growth of corals and factors which possibly influence the growth, thereby providing information to assess the status of this ecosystem.

Buddemeir and Kinzie (1976) have reviewed the work on growth of corals and discussed the advantages and problems of various methods employed for growth study. Jacques et al. (1977) studied the growth of Astragia dana; Yap and Gomez (1981) Acropora pulchra; Charuchinda and Hylleberg (1984) and Oliver (1984) Acropora formosa; and Brown et al. (1985) On Acropora aspera.

Seasonality in growth and calcification of corals has been studied by Kinsey (1977), Barnes and Crossland (1980) and Crossland (1981). Effect of light on coral growth and calcification has been studied by Highsmith (1979), Crossland (1981), Hudson (1981), Schneider and Smith (1982), Gladfelter (1984). Jokiel and Coles (1990) investigated the effect of temperature on growth of corals.

Effect of nutrients on coral growth has been investigated by Lewis (1974), Dodge and Vaisnys (1975), Wellington and Glynn (1983). Johannes et al. (1970) studied the role of zooplankton in the nutrition of some scleractinian corals. Effect of availability of food on corals has been considered by Barnes (1973).

Dollar (1982) and Brown et al. (1985) discussed the influence of waves on coral growth. Important works on the effect of sedimentation on corals are those of Hubbard and Pocock (1972), Dodge et al. (1974) Jorge Cortes and Risk (1985). Rogers (1990) presented an extensive review on the response of coral reefs and reef organisms to sedimentation. Hodgson (1990) and Babcock and Davies (1991) have studied the effect of sedimentation on larval settlement of corals and stated that sedimentation reduces the overall substratum available for settlement.

MATERIALS AND METHODS

Growth studies on two species of branching corals Acropora formosa (Dana) and Acropora aspera (Dana) were carried out at station-6 (Figure 2-Chapter II) situated at the southern most part of Kavaratti lagoon, having a

depth of 1.5 to 2.5 m according to tidal amplitude. Growth was compared between seasons and between branch positions on the colony. Correlations were made between growth and important environmental variables to find out the possible factors which influence the growth.

Acropora formosa (Dana)

The study was carried out on a single colony of Acropora formosa (Dana), located about 40 m away from the shore on the lagoon flat. Study period was January, 1988 to November, 1989. Linear skeletal extension was measured by "tagging" method (Yap and Gomez 1981). Twenty branches each on "apical", "lateral" and "basal" positions of the colony were tagged, without causing any damage to the branches, at random lengths not more than 5 cm below from the tips, using plastic coated metal wire and numbered plastic tag tokens. Only those branches without any radial branches were used for tagging. Care was taken to see that all the branches were of same colour (Oliver, 1984), size and were without any damage. Each branch was measured 10 times from the wire tag to the tip with a flexible ruler to the nearest millimetre, and average of this was taken as length. Monthly growth was measured at an interval of 28 days during low tides. Average skeletal extension and standard deviations of branches on the three positions were calculated, and expressed in the results as linear skeletal extension in millimetres per month (mm/28 d).

After a period of growth, some tips developed radial branches, but only the axial branches were measured. However, measurement became increasingly difficult with time, because of the breakage of tips, overgrowing the wire by coral tissue, and fouling of the tags. The wire and tag were cleaned periodically using a small brush to prevent fouling. During the entire period of study, many branches had to be retagged and at the end of the study only 40% of the tagged branches were left intact.

Acropora aspera (Dana)

A large colony of Acropora aspera (Dana) located in the same area was used to study the monthly linear skeletal extension and $CaCO_3$

accretion (growth in weight). Studies were made between March, 1988 and November, 1989 using "Alizarin" staining method (Barnes, 1973; Lamberts, 1974; Gladfelter et al., 1978; Gladfetter, 1984; Brown and Scoffin 1986). The outline of the method is as following.

A clear, transparent polythene bag, with 20 mg Alizarin Red-S tied off in one corner, was filled with seawater and inverted on coral branches. Mouth of the bag was tied arround the branch with a rubber band, at about 4-8 cm below from the tip. Alizarin secured in the corner was released and allowed to diffuse slowly into the water inside the bag. Final concentration of the dye in the bag was kept at 10-15 mg/l (Dustan, 1975). The branches were left in the stain for 8 hours (Brown and Scoffin 1986) before removal of the bag. The dye incorporated into the skeleton and gave a pink colour to it.

Ten healthy unbranched tips, each on "apical", "lateral" and "basal" positions were stained. Each stained branch was labelled with plastic identifying tags. After an interval of 28 days, the branch tips, which had grown in this period, were collected carefully and taken to the field lab, placed in 1:1 solution (by volume) of fresh water and 5% "chlorox" (NaOCl) for 30 minutes (Gladfelter, 1982). They were them rinsed in freshwater, dried, covered in soft cotton cloth and kept in dessicator. The new skeletal portion added after staining was white in colour. Fresh branches were stained every month.

Linear skeletal extension: Linear skeletal extension was measured from the distal margin of the stained skeleton to the tip of the recent growth, using a dissection microscope equipped with an ocular micrometer, Mean and standard deviation of skeletal extension on the three positions of the colony were calculated and presented in the results as linear extension, in millimetre per month (mm/28 d).

$CaCO_3$ accretion: Using the same branch tips, weight of $CaCO_3$ added by growth was determined for each month. The newly grown white skeleton was carefully removed from above the stained skeleton using a junior hacksaw blade and file. This was dried at 105°C for 2 hours in an oven to remove moisture content and weighed on an electronic balance. Mean and standard deviation of $CaCO_3$ accretion on the three positions of the colony were calculated and expressed in milligram $CaCO_3$ accreted per month (mg/28d).

Environmental variables

Hydrobiological parameters: The place of growth study was situated at station-6 (Figure 2-Chapter II). Monthly growth was correlated with hydrobiological parameters like water temperature, pH, dissolved oxygen, salinity, silicate, phosphate, nitrite, nitrate, calcium and zooplankton abundance studied in this station.

Current velocity: Current velocity was measured along with measurement of other parameters at the site of growth study in seven days interval. Measurements were made by releasing "Fluorescin" dye on the water surface and simultaneously starting a stopwatch by one observer. When the Fluorescin marked water reached a second observer stationed excactly at 10 m distance along the direction of current, the watch was stopped and the time taken for the dye to travel 10 m distance was noted. Velocity was calculated as dividing distance travelled by time taken. Average of 10 observations were taken as velocity, and expressed as monthly average in centimetres per second (cm/sec).

Total suspended matter: Weight of total suspended matter in water was determined at seven days interval throughout the entire period of growth study. Four litres of water collected from the area of study was filtered through dried pre-weighed and pre-washed filter paper of pore size 0.45 /um using a specially designed field filteration unit working on pressure from a hand pump. The materials retained on the filter paper was thoroughly washed by filtering distilled water through it, poisoned it with 0.001 M sodium azide (Jorge Corts and Risk, 1985), dried at 105°C in an oven and

stored in dessicator. The samples were once again dried at 105°C for two hours in an oven and weighed to the nearest 0.001 g. The weight of suspended particles was found out by subtracting initial weight of filter paper from the final weight found on a "Metler" electronic balance. Monthly average values were used to express the results in milligram per litre (mg/l.)

Gross sedimentation: The gross sedimentation rate was calculated by collecting the "resuspended sediments" in traps. "Resuspended sediments" refer to that materials settling down on the reef surface, which will be collected in vertically oriented sediment traps. The flux of this material is a measure of gross sedimentation (Jorge Corts and Risk, 1985).

Glass cylinders with 21 cm^2 mouth area, having thin wall and height to diameter ratio 3:1, (a good ratio for estimating vertical fluxes according to Gardiner, 1980; 1980a), were fabricated. Four such traps were mounted on the corners of a 40 x 40 cm rectangular metal frame painted using anticorrosive paints, with mouth of the traps raised 40 cm above the lagoon bed (Charuchinda and Hyllberg, 1984). The metal frame with traps mounted on it was set at the place of growth study by planting the four legs of the frame into the lagoon bed. The traps were recovered at an interval of seven days after closing the mouth within the water, and replaced with fresh traps on the frame. The materials that settled in the traps were filtered in the field lab, washed with distilled water, poisoned with 0.001 M sodium azide, dried at 105°C and weighed accurately and expressed in terms of $mg/m^2/day$. This was considered as representative for the whole study area.

Total rainfall: Since Kavaratti island does not have a meteorological station, the rainfall data collected was that of the nearest island Agathi. Monthly average rainfall was calculated from the daily weather report of Trivandrum meteorological station, and expressed as cm/month.

Statistical analysis

The data were analysed with the help of a computer. Growth was compared between seasons and between positions of branch on the colony using 'ANOVA' test. For this purpose monthly average growth was pooled seasonwise into pre-monsoon, monsoon and post-monsoon, and into positions such as "apical", "lateral" and "basal". To find out the environmental factors that possibly influence the growth, the environmental variables were correlated with monthly average growth using "correlation matrix."

RESULTS

Results of the studies on the growth of corals are presented graphically. The graphs are drawn using the monthly mean values of growth. The vertical line at each mean point represents the standard deviation above and below the mean. In the text, the growth for 28 day is considered as a month and the year 1988 and 1989 as first and second year. For the convenience of expression the linear skeletal extension is regarded as growth in length and $CaCO_3$ accretion as growth in weight.

Acropora formosa (linear skeletal extension)

Monthly growth in length for the total colony and branches on basal, lateral and apical positions are given in Figure 18. Extension of individual branches varied considerably and large standard deviations were obtained for most of the months. It is seen from the figure that in January during the first year, the colony showed overall growth of 7.25±1.8 mm/28d. After reaching a growth rate of 7.45±2.7 mm/28d in April the growth decreased to a minimum in July (5.03±1.7 mm/28d), and again increased to a maximum in December (8.06±1.9 mm/28d). During the second year, the growth continued to increase from January and reached a maximum in March (8.68±2.3 mm/28d), then decreased to a minimum in July (4.9±1.3 mm/28d) and again the rate gradually increased till December (6.8±1.9 mm/28d).

In the first year, the maximum skeletal extension observed for basal branches was 8.20±1.6 mm/28d in December. Whereas for the lateral

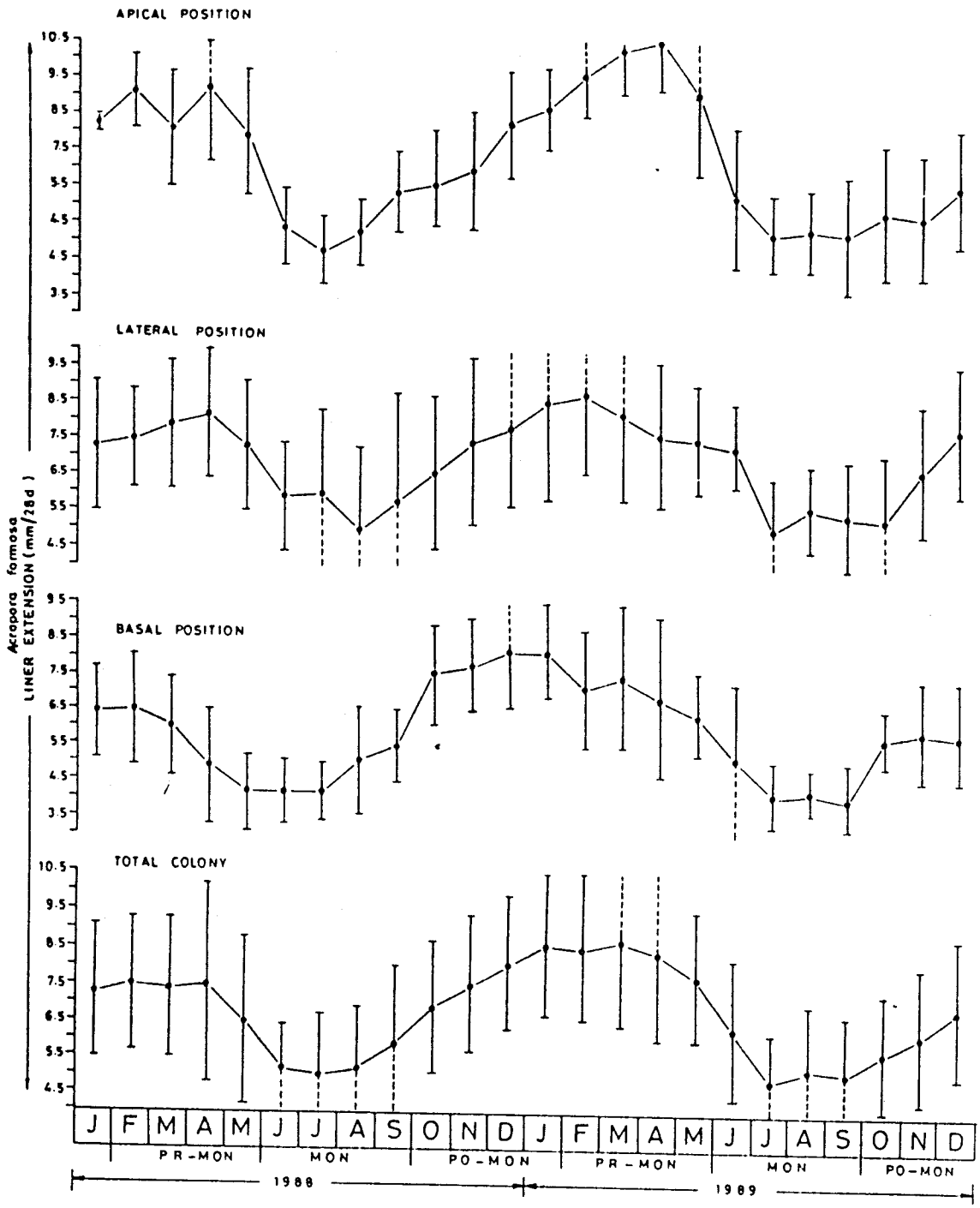

Figure 18. Monthly average skeletal extension of Acropora formosa colony and branches on the basal, lateral and apical positions.

and apical branches the maximum growth was in April (8.18±1.8 and 9.22±2.3 mm/28d respectively). The minimum extension was 4.20±0.8 and 4.80±0.9 mm/28d in July for basal and apical branches whereas the lateral branches showed minimum growth in August (5.00±2.3mm/28d). At the end of first year, the apical branches have extended upto 8.63 cm, lateral branches 8.28 cm and basal branches upto 7.1 cm.

During second year, the basal branches showed maximum growth rate in January (8.20±1.3 mm/28d). Lateral and apical branches showed maximum growth in February, the values being 8.82±2.2 and 9.55±1.1 mm/28d. Minimum rate of growth was 4.11±0.9mm/28d in September for basal branches and 5.10±1.4 and 5.30±1.0 mm/28d in July for lateral and apical branches. During second year the apical branches showed an extension of 8.8 cm, lateral branches 8.5 cm and 7.2 cm by basal branches.

Highly significant seasonal variations ($P < 0.01$) were observed in total average colony extension and extension on basal, lateral and apical positions of the colony (Table 24), seasonal average growth in length of the entire colony and branches of the three positions are given in Table 27. Maximum rate of growth was observed during pre-monsoon season, it decreased during monsoon and again increased during post-monsoon.

On a comparison, the growth rate of branches on the three positions showed highly significant variations ($P < 0.01$) (Table 28). The apical branches showed maximum average growth per month (7.30 mm), lateral branches 6.98 mm/month and basal branches showed the lowest rate of growth (5.93 mm/month) (Table 29).

Acropora aspera

Linear skeletal extension: Figure 19 gives the monthly average linear skeletal extension (mm/28d) for the entire colony and branches on basal, lateral and apical positions of Acropora aspera. As in the case of Acropora formosa, this species also showed considerable variations in growth of

Table 24. Analysis of variance (ANOVA) showing the seasonal variation in linear skeletal extensions of the total colony, and branches on apical, lateral and basal positions of Acropora formosa

Total Colony growth

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	25.004	12.502	22.71	HI.SIG(1%)
ERROR	21	12.209	0.581		

Apical branches

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	55.045	27.522	33.84	HI.SIG(%)
ERROR	21	17.078	0.813		

Lateral branches

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	18.728	9.364	16.11	HI.SIG(1%)
ERROR	21	12.209	0.581		

Basal branches

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	23.458	11.729	12.82	HI.SIG(1%)
ERROR	21	19.210	0.915		

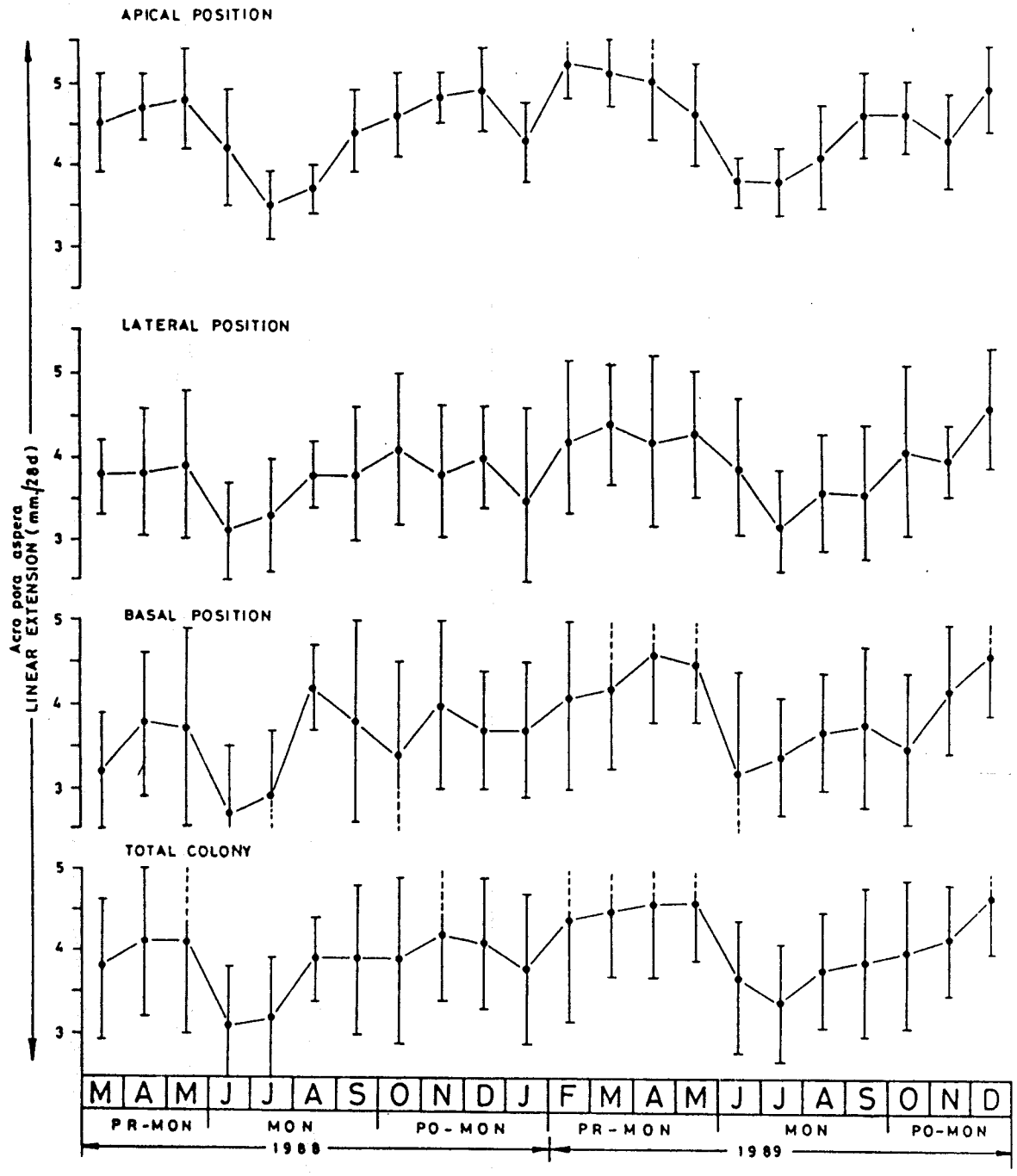

Figure 19. Monthly average skeletal extension of Acropora aspera colony and branches on the basal, lateral and apical positions.

individual branches and large standard deviations in most of the months.

During first year, the total average colony growth in March was 3.77±0.8 mm/28d. The rate of growth increased up to 4.08±1.1 mm/28d in May and dropped to a minimum of 3.08±0.7 mm/28d in August. From there on it showed a steady rate upto October (3.95±1.0 mm/28) and increased to the highest rate in November (4.17±0.9 mm/28d). Thereafter the rate of growth showed a fall up to January in the second year,and again increased to the maximum of second year (4.56±0.9 mm/28d) in April. Then it decreased to 3.42±0.7 mm/28d in July, and again increased steadily to the highest growth of 4.69±0.69 mm/28d in December.

As inferred from Figure 19 that,branches of the basal, lateral and apical positions showed highest rate of growth of 4.20±0.5, 4.10±0.9 and 4.80±0.6 mm/28d in August, October and May respectively and minimum of 2.70±0.8, 3.10±0.6 mm/28d in June for basal and lateral branches and 3.51±0.4 mm/28d for apical branches in July during first year. At the end of first year the apical branches have extended upto 4.4 cm, lateral branches 3.7 cm and basal branches 3.5 cm.

During the second year, maximum growth of basal branches showed two peaks, one in April (4.60±0.8 mm/28d) and other in December (4.60±0.7 mm/28d). Lateral branches showed maximum growth in December (4.60 ±0.7 mm/28d) and apical branches in February (5.16±0.4 mm/28d). The lowest growth observed for basal and apical branches was in June, the rates being 3.20±1.2 and 3.84±0.3 mm/28d respectively, and lateral branches in July (3.20±0.6 mm/28d). During second year the apical branches extended to 5.4 cm, lateral branches 4.8 cm and 4.8 cm by basal branches.

The rate of growth showed almost the same pattern in first and second year. Table 25 shows that there was no significant seasonal variation in growth of the total colony and branches of the basal position of the colony, whereas apical and lateral branches showed highly significant seasonal variation ($P < 0.01$). The rate of growth was almost same in pre-monsoon

Table 25. Analysis of variance (ANOVA) showing the seasonal variation in linear skeletal extension of the total colony, and branches on apical, lateral and basal positions of Acropora aspera

Total Colony

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	1.202	0.601	4.07	N.S.
ERROR	21	3.099	0.148		

Apical branches

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	2.599	1.299	13.92	HI.SIG(1%)
ERROR	21	1.960	0.093		

Lateral branches

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	1.183	0.591	6.26	HI.SIG(1%)
ERROR	21	1.984	0.094		

Basal branches

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	0.964	0.482	2.06	N.S.
ERROR	21	4.901	0.233		

and post-monsoon, whereas monsoon season showed a considerable drop in the rate of growth. Average seasonal skeletal extension and standard deviations of the entire colony, and for the branches an the three positions are shown in Table 27.

Table 28 shows that, as in the case of Acropora formosa, Acropora aspera also showed highly significant variation ($P < 0.01$) in skeletal extension between branches of the basal, lateral and apical positions. Their averages are shown in Table 29. Maximum growth was observed on apical position and minimum on basal position.

$CaCO_3$ accretion: The monthly average growth of the entire colony and the branches of basal, lateral and apical positions are shown in Figure 20. As with skeletal extension, monthly $CaCO_3$ accretion of individual branches also showed considerable variations and large standard deviations.

$CaCO_3$ accretion for the whole colony in March, during the first year, when observations were started, was 11.39±1.7 mg/28d, it increased upto the highest rate of 11.97±1.5 mg/28d in May and decreased to a minimum in July (9.76±1.3 mg/28d), again increased to 10.86±0.9 mg/28d and fluctuated. During second year from January (10.82±1.6 mg/28d) the growth rate increased upto 12.39±1.73 mg/28d in May and declined to the lowest 10.39±1.4 mg/28d in August. The rate again increased to a maximum of 13.38±1.9 mg/28d in December. The rate of growth over the entire two years showed similar pattern.

In the first year, the basal branches showed maximum rate of growth in April (12.30±2.1 mg/28d) lateral and apical branches in May (11.70± 1.2 and 13.08±0.6 mg/28d) and minimum in July (8.50±0.8, 10.10±0.8, and 10.06±0.9 mg/28d respectively for basal, lateral and apical branches).

During the second year, the maximum growth rates for basal, lateral and apical branches were 11.53±0.7, 13.6±0.9 and 15.73±1.1 mg/28d respectively in December, the minimum being 9.04±1.3 mg/28d for basal

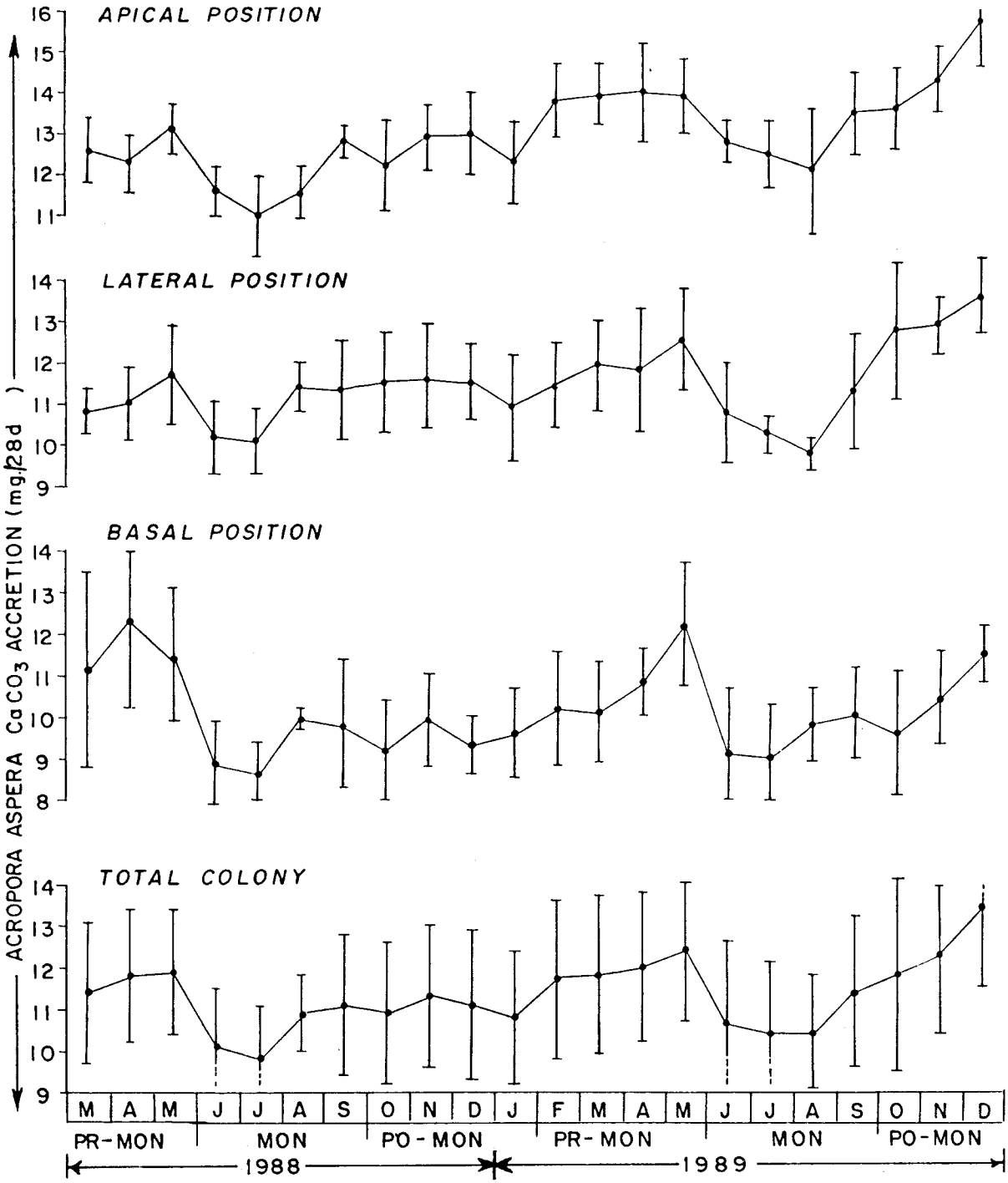

Figure 20. Monthly average $CaCO_3$ accretion of Acropora aspera colony and branches on the basal, lateral and apical position.

branches in July, 9.79±0.4 and 12.07±1.5 mg/28d for lateral and apical branches in August. The pattern of growth was almost similar in both first and second year.

The ANOVA Table 26 shows that, the average $CaCO_3$ accretion for the whole colony and branches on the lateral and apical positions exhibited highly significant variations over seasons ($P < 0.01$), whereas the basal branches did not exhibit any significant seasonal fluctuation. $CaCO_3$ accretion was almost similar during pre-monsoon and post-monsoon seasons. A decreased accretion was observed during the monsoon. Seasonal average of growth in weight is given in Table 27.

$CaCO_3$ accretion also showed highly significant variation ($P < 0.01$) between branches of basal, lateral and apical positions on the colony (Table 28). The apical branches showed highest rate of growth and basal branches the lowest. Average growth rate of branches on the three positions are shown in Table 29.

Environmental variables

Hydrobiological parameters: Hydrographical parameters studied in station-6 along with growth studies are shown in the results of the Chapter-II Figures 3 to 11. Highly significant seasonal fluctuations ($P < 0.01$) were observed in water temperature, pH, salinity, silicate, phosphate, nitrite, and calcium. Dissolved oxygen and nitrate did not show any seasonal variations. The seasonal averages of the parameters are given in Table 8 in Chapter-II

Figure 21 shows the monthly average total count of zooplankton in station-6, during the period of growth study. During first year, the highest zooplankton count obtained was in March (576 nos/m^3) and the lowest in May (180 nos/m^3) during the pre-monsoon. During the monsoon the maximum count was in July (200 nos/m^3) and minimum in September (80 nos/m^3). During the post monsoon, the maximum count was in January

Table 26. Analysis of variance (ANOVA) showing the seasonal variation in $CaCO_3$ accretion of the total colony and branches on apical, lateral and basal positions of Acropora aspera

Total colony

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	6.559	3.279	7.89	HI.SIG(1%)
ERROR	21	8.731	0.416		

Apical branches

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	2.599	1.299	13.92	HI.SIG(1%)
ERROR	21	1.960	0.093		

Lateral branches

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	1.18	0.591	6.26	HI.SIG(1%)
ERROR	21	1.984	0.094		

Basal branches

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	0.963	0.482	2.06	N.S.
ERROR	21	4.901	0.233		

Table 27. Seasonal averages and standard deviation in growth of Acropora formosa and Acropora aspera

PR.MON - Pre-Monsoon, MON - Monsoon, PO-MON. Post-Monsoon.

	Total colony growth	Aplical branches	Lateral branches	Basal branches
Acropora formosa				
(Linear Extension)				
PR.MON	7.77±0.7	9.23±0.9	7.90±0.5	6.20±1.1
MON	5.35±0.5	5.53±0.6	5.79±0.7	4.61±0.6
PO.MON	7.21±0.9	7.14±1.1	7.24±0.9	6.99±1.1
Acropora aspera				
(Linear Extension)				
PR.MON	4.21±0.3	4.81±0.3	4.06±0.2	3.91±0.5
MON	3.62±0.4	4.02±0.4	3.54±0.3	3.46±0.5
PO.MON	4.09±0.3	4.58±0.3	3.97±0.4	3.86±0.3
Acropora aspera				
($CaCO_3$ Accretion)				
PR.MON	11.80±0.3	13.28±0.7	11.49±0.6	11.03±0.7
MON	10.59±0.5	12.23±0.8	10.63±0.6	9.42±0.6
PO.MON	11.54±0.9	13.28±1.2	12.12±0.9	9.89±0.7

Table 28. Analysis of variance (ANOVA) showing variation in growth between branches of apical, basal and lateral possition of Acropora formosa and Acropora aspera colony

Acropora fromosa

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	24.580	12.290	5.82	HI.SIG(1%)
ERROR	69	145.729	2.112		

Acropora aspera (linear extension)

SOURCE	D.F.	SUM. SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	6.402	3.201	15.40	HI.SIG(1%)
ERROR	63	13.095	0.208		

Acropora aspera ($CaCO_3$ accretion)

SOURCE	D.F.	SUM SQR	MEAN SQR	F-VAL	REMARKS
TREAT	2	95.320	47.660	48.66	HI.SIG(1%)
ERROR	63	61.699	0.979		

Table 29. Average rate of growth of branches on apical, lateral and basal positions of Acropora formosa and Acropora aspera colony

	Apical branches	Lateral branches	Basal branches
Acropora formosa (linear extension)	7.30	6.98	5.93
Acropora aspera (linear extension)	4.47	3.87	3.77
Acropora aspera ($CaCO_3$ accretion)	12.97	11.42	10.04

(1041 nos/m^3) and minimum in October (79 nos/m^3). The highest zooplankton count observed was during post-monsoon season and lowest during monsoon season. The same trend was followed in the second year, with maximum and minimum counts during pre-monsoon being 480 nos/m^3 in March and 173 nos/m^3 in May. The maximum count during monsoon was 170 nos/m^3 in July and minimum in September (64 nos/m^3). During the post monsoon, December showed highest count (780 nos/m^3) and lowest in October (68 nos/m^3).

Current velocity: Monthly average current velocity observed in the study area is given in Figure 21. The pre-monsoon period, upto May, showed a very low velocity, between 3.5 and 6.5 cm/sec. From May it increased sharply to the maximum of 15.0 cm/sec in June during monsoon and gradually decreased to 5.8 cm/sec in October, and thereafter increased to 8.0 cm/sec in December. The velocity dropped to 4.5 cm/sec in January. The same trend was repeated in the second year also by pre-monsoon velocity fluctuating between 4.0 and 5.0 cm/sec. During the monsoon it increased to 15.0 cm/sec in June, and dropped to a minimum of 9.35 cm/sec in October during the post monsoon season.

Total suspended matter: Figure 21 shows the amount of total suspended particles in seawater over the study area. First year, during pre-monsoon season the amount of suspended matter fluctuated between 2.50 mg/l in March and 3.00 mg/l in May. During monsoon it reached a peak in June (9.95 mg/l), then decreased to 3.20 mg/l in October, and fluctuated upto January (6.45 mg/l) during post-monsoon. This trend is followed in the second year also. During the pre-monsoon, it fluctuated between 4.10 mg/l in February and 3.60 mg/l in May. During the monsoon it increased to a peak of 14.65 mg/l in July and decreased to a minimum of 1.95 mg/l in November during post-monsoon.

Gross sedimentation: Figure 22 shows the monthly average gross sedimentation. During pre-monsoon, the resuspended sediments fluctuated between 6.45 mg/cm^2/day (February) and 2.69 mg/cm^2/day (May). During

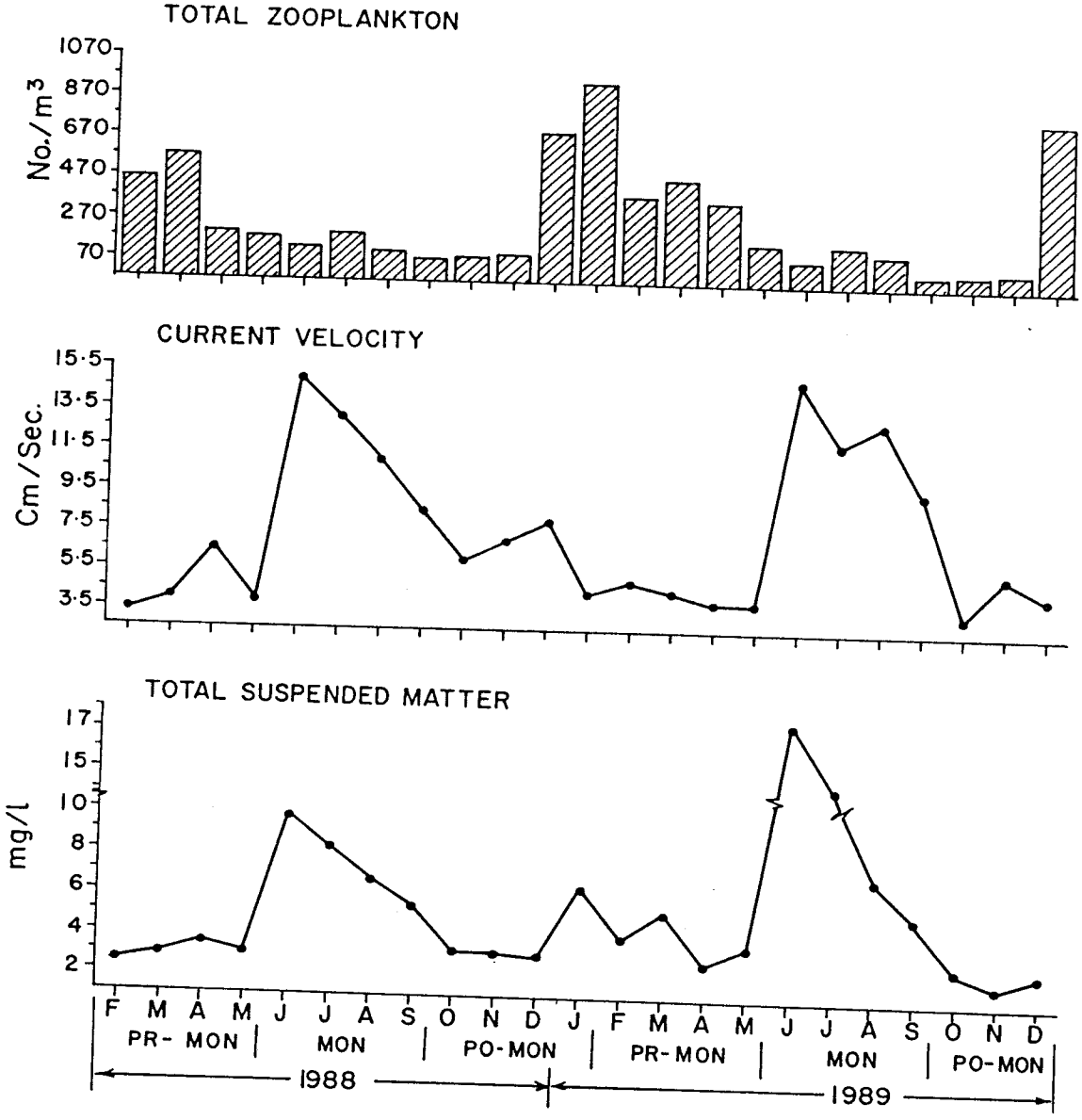

Figure 21. Monthly variation of total suspended matter, current velocity and total zooplankton.

monsoon it reached the highest rate in July (103.36 mg/cm^2/day), and decreased towards post-monsoon. During postmonsoon it fluctuated between 15.32 mg/cm^2/day and 2.26 mg/cm^2/day. This trend was repeated in the second year, with pre-monsoon having maximum rate in February (6.39 mg/cm^2/day) and minimum in April (2.69 mg/cm^2/day). During monsoon the maximum and minimum values were 124.49 mg/cm^2/day (July) and 58.44 mg/cm^2/day (September). Maximum and minimum rates in post-monsoon were 20.29 mg/cm^2/day (October) and 3.31 mg/cm^2/day (December).

Total rain fall: Figure 22 shows the monthly total rainfall for the entire period of study. First year during pre-monsoon, only the month of May received rainfall (50 cm). Maximum rain fall during monsoon was in June (430 cm) and minimum in July (220 cm). Rainfall declined during post-monsoon, receiving maximum in November (40 cm) and minimum in January (2 cm). During second year, the rains started as early as April (34 cm), and declined to 13 cm in May. June received maximum rainfall (518 cm) and minimum in August (126 cm) during monsoon. During post monsoon the rainfall decreased to 50 cm in November and December received no rain. The results indicated that monsoon months received good rain and pre-monsoon and post-monsoon received very little rain.

Factors influencing rate of growth

Estimates of correlation coefficients of coral growth with environmental parameters are given in Table 30. Only significant relationships are considered in the text. Skeletal extension of Acropora formosa showed significant positive correlations with silicate, nitrite and zooplankton abundance ($r = 796$, $P \leq 0.01$; 0.456, $P \leq 0.05$ and 0.612, $P \leq 0.01$ respectively). Significant negative relationships were observed with current velocity, gross sedimentation and total rainfall ($r = \bar{}.682$, $P \leq 0.01$; $\bar{}.791$, $P \leq 0.01$ and $\bar{}.715$, $P \leq 0.01$).

Skeletal extension of Acropora aspera showed significant positive correlation with silicate and nitrite ($r = 0.813$, $P \leq 0.01$ and 0.643, $P \leq 0.01$) and significant negative correlation with calcium, current velocity, total

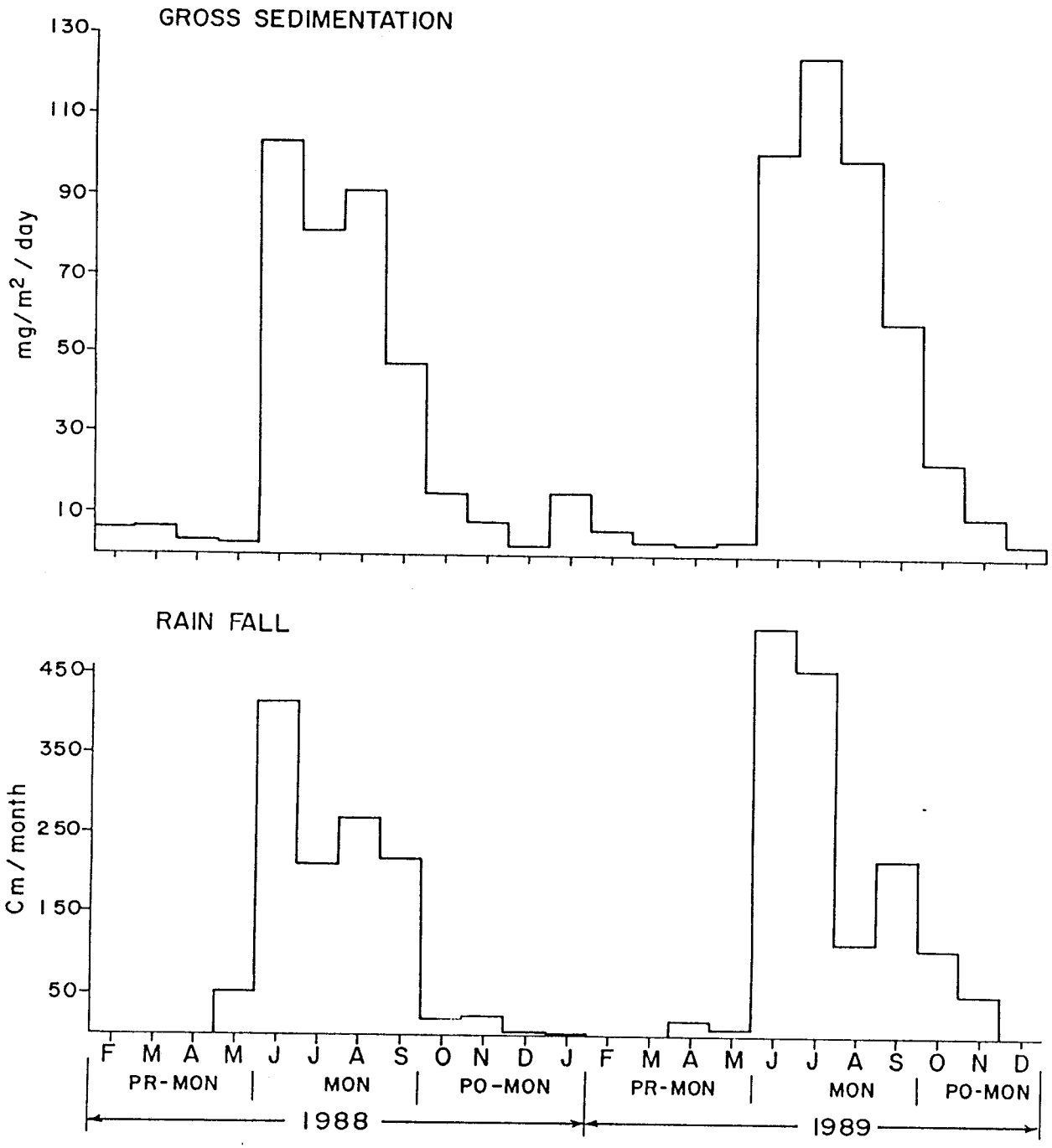

Figure 22. Total monthly rainfall and rate of Gross sedimentation.

Table 30. Estimates of correlation coefficients of coral growth with environmental variables

A. formosa (length)	A. aspera (length)	A. aspera (weight)	Environmental variables
0.181	0.028	0.182	Water temperature
-.328	-.120	0.033	H^+ion concentration (P^H)
0.304	0.387	0.249	Dissolved Oxygen
0.240	0.338	0.404*	Salinity
0.796**	0.813**	0.656**	Silicate
-.306	-.308	-.231	Phosphate
0.456*	0.643*	0.614*	Nitrite
-.118	0.130	0.035	Nitrate
-.289	-.557	-.590	Calcium
n-2=22, *p ≤ 0.05, **p ≤ 0.01			
0.612**	0.265	0.226	Zooplankton
-.682**	-.722**	-.735**	Current velocity
-.380	-.649**	-.627**	Total suspended matter
-.791**	-.750**	-.714**	Gross sedimentation
-.715**	-.677**	-.581**	Total rainfall
n-2=22, *p ≤ 0.05, **p ≤ 0.01			

suspended matter, gross sedimentation and total rainfall. Their "r" values were $^{-}.557$, $P \leq 0.05$; $^{-}.722$, $P \leq 0.01$; $^{-}.649$, $P \leq 0.01$; $^{-}.750$, $P \leq 0.01$; and $^{-}.677$, $P \leq 0.01$).

$CaCO_3$ accretion of Acropora aspera exhibited significant positive correlations with salinity ($r = 0.404$, $P \leq 0.05$), Silicate ($r = 0.656$, $P \leq 0.01$) and nitrite ($r = 0.614$, $P \leq 0.01$). Significant negative correlations were observed with calcium ($r = ^{-}.590$, $P \leq 0.01$), current velocity ($r = ^{-}.735$, $P \leq 0.01$), total suspended matter ($r = ^{-}.627$, $P \leq 0.01$) gross sedimentation ($r = ^{-}.714$, $P \leq 0.01$) and with total rainfall ($r = ^{-}.581$, $P \leq 0.01$).

Though growth rate showed various degrees of correlation with other parameters as given in Table 30, none of these were found to be statistically significant.

DISCUSSION

Skeletal extension and $CaCO_3$ accretion of individual branches in A. formosa and A. aspera varied considerably and very wide standard deviations were observed in every month. Average growth of branches on 'apical', 'lateral' and 'basal' positions of the same colony also showed variation in rate of growth. This intracolony growth variation has been reported by Rogers (1979) and Brown and Howard (1985). Skeletal growth is a function of linear extension, bulk density and calcification, which can vary independently (Barnes and Crossland, 1982; Gladfelter, 1983; Dodge and Brass, 1984). This variability has been variously attributed to differences in physical factors (Houck et al., 1977), seasonality (Shinn, 1966) endogenous zooxanthellar rhythms (Chalker and Taylor, 1978) and difference in age or size (Barnes, 1973; Isedale, 1977). Experimental methodology can also cause variation in measured growth (Buddemeier and Kinsie, 1976; Barnes and Crossland, 1977). This variability led to the conclusion that the use of averages be preferred to individual measurements for growth study.

Skeletal extension and calcification rate were found to be highest on 'apical' branches, and lowest on 'basal' branches. Considerable variation may occur between individual branch tips in a colony (Goreau, 1959). Apical branches of A. formosa calcify rapidly than the basal branches (Goreau and Goreau, 1959; Pearse and Muscatine, 1971). UNESCO (1986) reported variation in extension and calcification rate in A. aspera, with most rapid growth on apex. The presence or absence of zooxanthellae near the tips of A. formosa branches correlated with apical skeletal extension rates (Patzold, 1984). Light and zooxanthellar photosynthesis directly enhance calcification rates (Kawaguti and Sakamoto, 1948; Vandermeulen et al., 1972). Apical branches receive more direct light incidence than the lateral and basal branches, which facilitates an increased photosynthetic rate in apical branches. Patzold (1984) suggested that the growth variation may be due to the influence of exogenous and endogenous factors or a combination of both. The translocated carbon from the algal symbionts in corals can meet the animal carbon demand for growth (Muscatine et al., 1985). Photosynthetically fixed carbon translocated towards the apical corallite in A. cervicornis branches (Pearse and Muscatine, 1971). The difference in the amount of zooxanthellae supplying translocate to each tip causes difference in growth (Oliver et al., 1983).

The monthly and seasonal skeletal extension rate of A. formosa obtained in this study was comparable with the observations of Charuchinda and Hylleberg (1984) in Phuket Island (8 cm in one year) and that of A. aspera were also comparable with the results of UNESCO (1986) in some months. Apical position 4.7±1.6 mm/28d in length, lateral branches 2.7±0.5 mm and for basal branches 1.4±0.3 mm/28 d. $CaCO_3$ accretion was 12.50±2.6 mg/28d on apical position, 7.46±0.3 mg on lateral, position and 4.51±1.9 mg/28d on basal position.

Seasonal cycle at the study area was characterised by the heavy south-west monsoon, marked by cloudy sky, reduced sunshine, heavy rain,

strong wind and turbulent water conditions, during June to September period. The north-east monsoon was characterised by good sunshine calm water conditions and less forceful rain throughout October to January. The February to May period was depicted by clear sky, abundant sunshine, and calm water (pre-monsoon).

Total average colony extension and skeletal extension on the three positions in A. formosa showed seasonal variations, with a decline during monsoon season. In A. aspera the average growth for the colony and basal branches did not show any specific seasonal pattern in skeletal extension but the apical and lateral branch extension showed variation over seasons. Their $CaCO_3$ accretion exhibited seasonality, with a drop during monsoon except in basal branches. These variations may be a reflection of the seasonal variation of influencing environmental parameters. Many of the environmental variables showed clear seasonal variation, Temperature, pH, salinity, silicate, phosphate, nitrite, and zooplankton abundance decreased during monsoon, current velocity, total suspended matter, gross sedimentation and rain fall were highest during monsoon, Dissolved oxygen and nitrate did not vary over seasons.

Calcification is strongly light dependent (Crossland and Barnes, 1977; Schneider and Smith, 1982; Gladfelter, 1984. Calcification on cloudy days can be only 50% of that on sunny days (Goreau, 1959). It is observed in the present study that faster growth rate was obtained in times of the year with clear sky and high light intensity (Pre-monsoon). Cloud cover and rainfall were maximum during monsoon, when skeletal extension and accretion rates were lowest.

Temperature affect coral growth (Highsmith, 1979; Schneider and Smith, 1982). Though the present study showed a positive correlation with temperature, it was not significant suggesting that the temperature fluctuations may be within the optimal range. $CaCO_3$ accretion exhibited significant correlation with salinity and pH in that an increase of both favour the deposition of $CaCO_3$.

An increase in coral growth was observed with increasing levels of silicate and nitrite through significant positive correlations. Nitrogen enrichment has been implicated in more rapid growth (Meyer and Schultz 1985) and laboratory studies demonstrated an increased calcification with enrichment of NH_4^+ (Crossland and Barnes, 1974, Taylor, 1978). Simkiss (1964), Lamberts (1974) and Kinsey and Davis (1979) have reported that higher phosphate level can decrease coral growth. Present study showed a negative correlation with phosphate, however, the relation was not significant. Significant negative correlation was observed with calcium in skeletal extension and accretion rates in A. aspera, whereas in A. formosa it was not significant. Saturation state of $CaCO_3$ in the water may affect calcification rates Smith and Pesert (1974). This also shows that the increase in level of calcium beyond certain level may be supressing calcification.

Food source may be another factor which can influence growth in A. formosa (Barnes, 1973, Lewis, 1974, Oliver et al., 1983). Corals are specialized carnivores depending primarily upon zooplankton (Coles, 1969). Skeletal extension of A. formosa exhibited highly significant positive correlation with zooplankton density. Zooplankton density fluctuations can cause seasonal changes in linear growth rates (Buddemeier and Kinzie, 1975). Calcification also increased with zooplankton supplements (Lewis, 1974, Jacques and Pilson, 1980). A. aspera did not show any significant relation with zooplankton. This may be due to species specificity in food and feeding.

Current velocity was found to exert highly significant negative influence on growth. Wave energy affected skeletal extension rates in A. aspera, which was also found to affect skeletal accretion (Dustan, 1975; Brown et al., 1985). Strong currents cause coral polyps to retract which restricts their feeding (Hubbard, 1974).

Normal suspended matter concentrations and sedimentation rate for coral reefs appear to be in the order of 10 mg/l and 10 $mg/m^2/day$ or less (Rogers, 1990). But it is still not known, what is the minimum

level to evoke a response in growth. Total suspended matter was found to exhibit a highly significant inverse relation with extension and accretion rate in A. aspera whereas it was not significant with A. formosa, showing its high tolerence, as pointed out by Yap and Gomez (1981) that certain species of corals can adapt silty conditions. Studies of Charuchinda and Hylleberg (1984) has shown that A. formosa is capable of branch extension during periods of high water turbidity, nevertheless higher rates were in low turbidity levels. Particles in suspension can alter both intensity and spectral composition of light, there by affecting the metabolism of organisms (Rogers, 1990). In the modern reefs, sedimentation is a controling factor of reef growth (Hubbard, 1986). Acroporid corals have limited ability to reject sediments (Bak and Elgershuizen, 1976). Corals use ciliary action, muscus secretion (Lewis and Price, 1976; Charuchinda and Hylleberg, 1984) and hydrostatic pumping (Hubbard and Pocock, 1972) to rid themselves off sediment. This process require expense of energy, which otherwise would have been available for growth, which causes a growth reduction (Bak and Elgershuizen, 1976; Lewis and Price, 1976; Hubbard and Pocock, 1972, Crossland, 1980). Coral growth is reduced in areas of high sediment resuspension rates (Dodge et al., 1974; Loya, 1976; Jorge Corts and Risk, 1985).

During the southwest monsoon, heavy rainfall and reduced sunlight create less favourable condition for zooxanthellar photosynthesis, and a decrease in the level of many parameters which support growth also occurre. Heavy monsoon wind generate turbulent water conditions which agitate sediment. Erosion of reef and beach due to removal of coral rocks and boulders by people also increases the total suspended matter and gross sedimentation rate. This sediment settle on coral colonies. The strong current sweeps away a major fraction of it, which does not allow in all cases, the death of corals. But the strong current hinders feeding activity of corals and some energy gets diverted to sediment rejection process. These coupled with reduced light and other factors cause reduction in growth. Post-monsoon, and pre-monsoon seasons have a reversal of this situation,

which facilitate good coral growth. Kavaratti though an oceanic atoll, the rate of gross sedimentation observed during monsoon equals the level at Cahuita (Jorge Corts and Risk, 1985) affected by large scale coastal sedimentation. This is a matter of concern to the stability of Kavaratti Atoll. Every monsoon, thus leave a trauma, which heals in the post-monsoon, and regains vitality through pre-monsoon season, only to get trampled again during monsoon.

CHAPTER - IV

CORAL REEFS IN LAKSHADWEEP - THEIR STATUS AND MANAGEMENT

INTRODUCTION

Of all marine ecosystems, coral reefs have the highest productivity and sustain heaviest human use (Wells, 1989). The "International Union for Conservation of Nature and Natural Resources" identified coral reefs as one of the essential life supporting systems, necessary for human survivial and sustainable development (IUCN/UNEP/WWF, 1980). Research on reefs have shown in the 1960s and early 1970s that they are fragile and delicate ecosystems, extremely vulnerable to human activities, and slow in recovery if damaged (Johannes, 1975). Many of the world coral reefs are under the threat of natural and manmade damages. Lakshadweep coral reefs are no exception to this (Pillai, 1983, 1985; 1986; Wafar, 1986; James et al., 1989). The atoll environment in general is a relatively restricted ecosystem, where the impact of natural as well as manmade assualts will manifest heavily within short span of time. Realising the urgent necessity for the protection of this ecosystem, attempts have been made during the present study through prolonged observations, to evaluate the present status of the coral reefs and to locate the sources of damage in same of these islands. In the light of these, suggestions are made for the management and conservation of this ecosystem.

PRESENT STATUS OF THE CORAL REEFS OF LAKSHADWEEP

Lakshadweep Atolls are famous for their rich resources and flourishing reef fauna, but the threat of deterioration from various forces are gripping almost all the atolls of this area. At present healthy and untouched fauna exist only in those islands which are not inhabited by man, like Suheli and Bangaram. There are good growth of corals and associated fauna in some isolated areas in the human inhabited islands like Kalpeni, Agatti and Chetlat also, but the coverage is patchy and localized to deeper

areas which are beyond the easy reach of man. This gives an impression that the major cause of reef deterioration at Lakshadweep is related to human activities. Developed islands like Kavaratti, Minicoy (Pillai, 1983) and Agathi are the worst affected areas.

Bangaram and Suheli islands have vast, spacious lagoons, surrounded by well defined and strong reef frame. These islands are not permanently inhabited by man, which coupled with the deep lagoon and healthy reef frame provide calm environment, supporting growth of rich reef fauna and flora. Ramose and tabular acroporid corals exist in deeper areas of the lagoon, the shallower areas are dominated by massive Porites, Goniopora and Heliopora genera. Bangaram lagoon has several coral knolls rising from deep bottom, around which exists good growth of corals. In general the life in Bangaram and Suheli lagoons look healthy and harbour thick assemblage of reef fauna. Mild erosional effects were observed in these islands, especially in Suheli, however, these did not look serious.

Kalpeni lagoon harbours rich growth of corals and associated fauna at the central and northern areas where the lagoon is deep and to some extent protected from excessive human use. Near 'Cheriyam' and 'Kodithala' islets thick assemblage of coral exists, which seemed untouched by man. This area is dominated by ramose Acroporid corals. Tabular Acropora species are rich in the deeper areas, some of them have grown even to a diameter of 1 m. Shallow areas toward the beach have profuse growth of Acropora aspera. Toward the reef, the lagoon is dominated by massive Porites and Heliopora corals. But the shallower southern area of the lagoon is practically denuded of live coral cover and associated organisms. A major portion of this area gets exposed during low tides, and receive excessive human activity. Erosional elements are severe in this island. Some of the small islets at the southern end of the main island are shrinking due to large scale erosion (Plate 9a). According to local people, one islet (Tilakam) has already disappeared in erosion. Erosion is rampant on the main island also, where loss of coconut palms and land property was observed (Plate 9b).

The lagoon of Kavaratti gives a denuded look. Reasonable growth of corals is restricted only to the southernmost tip of the lagoon. This area is dominated by branching Acropora and Porites forms, intermixed by large massive Porites and Heliopora corals. The central and northern areas of the lagoon have only isolated colonies of massive species. The lagoon has, toward the beach, all along the length, a luxurient growth of seagrasses. At the lagoon entrance, all the coral structures are dead and covered with sediment and debris. Excessive colonization of hard rocky reef substratum with filamentous green algae was observed in the present study. This is spreading all along the lagoon at an alarming rate, which could prevent new settlement and growth of corals. Cyclic beach displacement was observed at the northern tip of the lagoon with seasonal change in wave direction. Land erosion is severe in this island, which is more on the seaward side of the island. At the northern tip of the island, even the seawall has been broken in wave action, and the whole beach is getting eroded (Plate 9c).

Amini Island has a very shallow lagoon. During low tides, a major portion of the lagoon gets exposed. All along the lagoon, isolated branching Acropora coral colonies are observed. The dominant forms are porites. Shallow intertidal areas of the lagoon is characterised by thick growth of seagrasses. Toward the northern side of the lagoon there is good growth of corals, mainly massive forms. The lagoon flat looks heavily sedimented, and gives an impression that the lagoon is fast getting filled up. The seaward side of the island is subjected to heavy land erosion. (Plate 9d). Continuous dredging has been reported from this island (James et al., 1989).

Kadmat Island is long and narrow, having a vast lagoon with many coral shoals, but most of which are dead and live coral cover is less. Coral growth in the lagoon bottom looked rich, with ramose Acropora, Porites and massive forms. The inner reef flat and lagoon flat harbour rich assemblage of life and the lagoon in general gives a rich appearance. Northern half of the lagoon is richer in reef life than the southern half.

The seaward side of this island is facing the threat of erosion, but comparatively lesser in magnitude.

A rich coral and reef associated fauna exist in the lagoon of Chetlat Island. The northern areas get exposed during low tides, and live coral coverage is less, but toward the deeper areas good growth of corals exists. Acropora, Porites and Heliopora are the dominant forms. Profuse distribution of smaller forms like Psammocora was observed in the lagoon flat, and reef flat. In general the lagoon harbours a fairly good assemblage of corals. Beach erosion and filling up of the lagoon with sediments and excessive sediment depositions were visible in many areas. Human activities in the lagoon and removal of corals are less in this island.

Agatti being a fast developing island, the increased interference on the ecosystem is well reflected on the present status of the reef. This island has fairly good growth of corals at the central and southern areas of the lagoon. Lagoon bottom toward the beach has thick growth of seagrasses. Northern area of the lagoon is characterised by massive and encrusting forms, but most of these are dead and colonized by algae. Excessive colonisation of the reef substratum with a green filamentous algae was observed in this island also. Central and southern areas of the reef and lagoon flat harbour good growth of corals. Human activity in the lagoon is very high, especially during low tides. Erosion is rampant in this island. At many places, coconut palms and vast areas of land have been lost in erosion (Plate 9e). The northern end where the lagoon entrance is situated, faces severe cyclic beach displacement and land loss.

CAUSES OF DAMAGE

Causes of damage and deterioration of coral and coral reefs at Lakshadweep are many. It is impossible of single out any one particular reason, but because of a combination of various natural and man made causes.

Natural damage

At present natural damage due to biological agents are not in a noticable scale. The notorious "crown of thorns" starfish Acanthaster planci, which devastated many world coral reefs (Glynn, 1973; Endean, 1973; Seymour, 1989; Wilkinsen, 1990) has been reported from Lakshadweep, in Minicoy Atoll (Murty et al., 1979) and in Kavaratti Atoll (Sivadas, 1977). The present study recorded this species from Kalpeni Atoll (Plate 9f). Though their actual population density is not known, it appeared that they are not in any dangerous scale.

It was observed in the present study that in many of these islands the rocky substratum is getting covered with a filamentous green algae, which is excessive in Kavaratti and Agatti lagoons. Bio-fouling and bio-erosion of live and dead corals have been reported from Lakshadweep, but no specified study has so far been made on these aspects, except for the works of Appukuttan (1973) on oral boring bivalves and Thomas (1988) on boring sponges. Destruction due to natural calamities at Lakshadweep has been documented by Jones (1986). As described earlier, erosion is a menace in the present day Lakshadweep. Though the process is natural, the major cause is man's modification of the environment, which can be effectively prevented.

Human interferences

At Lakshadweep, human interferences pose more serious threat than natural forces. Major problem is from the removal of live corals. Though this has been banned, the process is on the increase. The removal is mainly by visitors and local people themselves. Local people sell cleaned corals to tourists and visitors or present to guests as souvenirs. Tourists and visitors do their best to take atleast a small bit of coral with them. The process is severe in Kavaratti, Minicoy, Agatti and Kadmat islands. In Kavaratti atleast 4 families are involved in clandestine selling of cleaned corals to tourists and visitors. Branching Acropora, Pocillopora and solitry coral like Fungia are the most exploited forms.

During the lowest low tides, when the reefs get exposed, they undergo heavy trampling by people. Fishing, octopus hunting, shell picking and walking on the exposed areas of coral cover cause extensive breakage and destruction. These processes are more in islands like Kavaratti and Agatti, where there are always large number of visitors. Pressure of exploitation on ornamental shells like Cypraea, Lambis, Conus, Turbo etc. is very high, that many of them are becoming rare.

Lagoon based fishing activity using large nets and rope lines cause excessive damage to branching forms. Fishermen in the fishing frenzy pock and beat on corals with spears and sticks which cause severe damage. In shallow areas the activity stirs up settled sediment and cause resuspension. Mooring and anchoring of fishing boats and cruising in shallow areas of coral cover also cause considerable damage.

Localized removal of coral boulders from the reef and beach results in large scale erosion of shore line and land property. This is severe in Kavaratti, Kalpeni and Agatti islands. The removal is mainly for the construction of houses, buildings and compound walls (Plate 10a). The increasing population density and the way of living as independent families demand construction of more and more houses and compound walls. The removal of coral rocks for making lime and collecting coral shingles for making concrete, by people and administrative departments are also on the increase. All these processes expose large areas of land to savage waves resulting in erosion, which create sedimentation in water, destroying vast areas of coral life (Plate 10e,f). Removal of coral boulders from the reef, which otherwise have been forming an effective barrier to heavy waves, results in large scale disappearance of land, as seen in Kavaratti, Kalpeni and Agatti Islands.

Dredging and deepening of boat channels and jetty have been reported from Lakshadweep since very long time. It is still in practice in Kavaratti, Agatti, and Amini Islands. Cutting and deepening of reef to facilitate boat entry into the lagoon allows waves to pound on the land,

which is the cause for the cyclic beach movement in Kavaratti and Agatti Islands. Kavaratti, island is facing severe threat from deepening of jetty (Plate 10b). Vast areas of seagrass beds and lagoon substratum have already been dredged. The deleterious effects of dredging of coral reefs have been summarised by Rogers (1990). Pillai (1983) reported that the large scale killing of corals in Minicoy was due to the effect of dredging and sedimentation. Good coral cover support multitude of other organisms, especially the valuable fishes (Plate 10c, d). Death and detruction of live coral force these associated fauna to move away or die, making the environment barren and invite algal colonisation (Plate 10e,f).

The problems of pollution in Lakshadweep have been dealt with by James et al. (1989). At present the major source of pollution is by oil. The increasing number of mechanised fishing boats and large vessels pose threat in the near future, because all these vessels are anchored in the lagoon. Aged engine oil and diesel waste are dumped on the lagoon beach. All these cause localised oil spill. During lowtides these pollutants get deposited on seagrasses and corals. This was observed in Agatti and Kavaratti lagoons.

Construction of an airstrip at Agatti Island resulted in large scale destruction of reef life, when the slaughtered coconut palm trunks and stumps were dumped into the lagoon. This crumpled many coral colonies at the southern tip of the lagoon (local people, personal communication). The candidate personally observed palm stumps entangled among coral formations.

MANAGEMENT ASPECTS AND RECOMMENDATIONS

Research has shown that reefs can regenerate, but the time scale, the mechanism involved and the extent to which new reef will resemble the old one are still poorly understood (Wells, 1989). Hence it is extremely difficult to suggest control measures, and reef management tend to be largely a matter of common sense (Wells, 1989) dependent on the local conditions.

The present observations could bring forth only a qualitative picture of the damage occured, but a more deep and quantitative study to assess the magnitude of damage is an urgent necessity before formulating any protective measures. This requires a team of specialized personnel Since the islands are just specks of land surrounded by high seas, and their very existence depends on the continuous growth and maintenance of calcarious organisms, mainly corals, something has to be done immediately.

Realising the urgency for protecting these islands, the following suggestions are made.

1. Removal of live corals may be prevented through strict implimentation of the already existing rules. The existing ban on this is largely overlooked, and seemingly there is no interest from the authorities to strictly impose the regulations. People are unaware of the ban or the delicateness of the system. Hence these should be informed properly to people, and visitors who seek entry into this territory. Tourist activity must be strictly managed by trained guides who can brief them of the vulnerability of the environment. Distributing pamphlets and erecting notice boards, large enough to be noticed by visitors, would be of great benefit.

2. Social and economic development is a must for all society, but in such societies where land and resources are limited as in Lakshadweep, the developmental activities should be properly controlled to keep pace and harmony with nature. The existing practice of removing coral rocks for housing should be controlled by providing the people with burned bricks and granite stones at subsidised rates through government bodies.

3. Fishing activity in the lagoon should be properly managed. Using large nets and cruising boats in shallow areas of coral cover should be banned. The lagoon based capture fishery could be modified by the introduction of culture and farming by designing suitable methods which will not interfere in the ecosystem.

4. Dredging should be completely stopped. Proper sea-walls and barriers should be errected in areas of erosion and cyclic beach movement.

5. Creation of marine park and sanctuaries would provide protection from direct assualt on reef fauna and environment. Detailed suggestions in this line have been made by James and Pillai (1989). Any motion for the creation of marine parks should be properly negotiated with fishermen. Suheli, Bangaram and some areas of Kalpeni Atoll have the potential to be declared as marine parks. Establishment of 'artificial reefs' in denuded areas of the lagoons can attract fishes and other reef fauna into the lagoon.

6. Research and studies on the elements which deteriorate the system, and socioeconomic problems that directly or indirectly interfere with environment, should be activiated.

7. Educating people about the urgent need for population control in this tiny territory, benefits of family planning and imparting training to local volunteers for managing the environment would generate good results towards conservation of coral reefs in the long run. Formal education for island children from lower school levels and informal education for youth and adults about the need for conservation can make drastic signs of awareness about the delicatenessand fragility of this coral habitat.

Conservation and management of this area is not easy, specially because the main-stay of people lies in the coral habitat. So the management measures should come from a greater public awareness, and integrated wide-ranging conservational policies, a difficult, but not an impossible one.

SUMMARY

Lakshadweep is a group of coral islands situated in the Arabian Sea between 08°00' and 12°30'N Latitude and between 71°00' and 74°00' Longitude. The archipelago consists of 27 islands and a number of sunken banks and open reefs. Of these, 10 islands are inhabited by man. Our knowledge on the distribution and availability of living marine resources, dynamics of the important physical, chemical and biological parameters in the lagoons, growth of corals, maintenance of the system and status of the environment is meagre. The present study, hence, attempted to widen our knowledge on the above aspects and results of which are summarised below.

Results of the faunistic survey conducted at Kavaratti, Kalpeni, Agatti, Bangaram, Amini, Kadmat and Chetlat Islands for corals and reef associated echinoderms, crustaceans, molluscs, and fishes revealed the presence of a large number of species.

A total of 110 species of corals divided among 40 genera and 15 families have been recorded; out of this 22 species are new records to Lakshadweep. Genera like Herpolitha, Leptoseris, Oulophyllia, and Pachyseris have not previously been recorded from Lakshadweep. Maximum number of species were recorded from Kavaratti,and minimum from Kadmat . Though certain islands harbour good number of species, their distribution is patchy, and area of live coral cover was found to be less. Twenty two species were found to be common to all the islands surveyed.

Altogether 50 species of crustaceans, divided among 32 genera and 18 families have been recorded. Out of these, 41 species were crabs, 2 species were lobsters and 7 species were prawns. Kavaratti Island has the highest number of species (37) and lowest in Amini (20). Eight species were found to be common to all the islands surveyed. These islands were not found to possess any substantial resource of crustaceans which could

be exploited on a commercial level. Sea ranching and culture programmes could improve the stock of lobsters and edible crabs.

Fourty six species of echinoderms divided among 31 genera and 19 families were noted in the survey. Out of these the species Mithrodia clavigera is a new record from Lakshadweep. Holothurioidea showed domination with 16 species. Maximum number of species were recorded from Kavaratti (42) and minimum from Bangaram (18). The starfish-Acanthaster planci was found to occur in Kalpeni lagoon. Thirteen species were found to be common to all the islands surveyed. Of all echinoderms, the commercially important forms from Lakshadweep are holothurians used in beche-de-mer industry. Four species of these were found to be available in substantial quantity. Since the exploitable area is limited, these islands may not withstand large scale commercial exploitation. There is possibility for culture and farming of holothurians, which could be tried to increase the production.

There were 230 species of molluscs divided among 87 genera and 60 families in the present survey, of this 37 species come under bivalves, 5 species under cephalopods and 188 species under gastropods. Total number of species was highest in Kavaratti (190) and lowest in Amini (70). Thirty five species were found to be common to all the islands surveyed. Gastropods ranked highest in all the islands. Micromolluscs and deep water forms were not covered, and many more species are likely to occur. The survey indicated a remote possibility for large scale commercial exploitation. However, some species of gastropods, cephalopods and bivalves have potential for commercial farming.

There found to be 120 species of lagoon and reef associated fishes, belonging to 67 genera and 35 families. Out of this, two species - Forcipiger flavissimus and Pygoplites diacanthus- were recorded for the first time from Lakshadweep. The family Labridae with 13 species was found to be dominating. Species abundance was highest in Kalpeni (105) and lowest in Amini (57). Fourty two species were found to be common to the islands

surveyed. The survey indicated the availability of a large number of species of ornamental value.

Hydrobiological studies were carried out in Kavaratti Atoll, which is a perfect atoll, situated along Lat. 10°33'N and Long 72°38'E. The lagoon is 4,500 m long and 1,200 m wide, having a maximum depth of 1.8 m at low tide and 3.5 m at high tide.

Samples were collected from 5 stations inside the lagoon and one station outside the lagoon on fortnightly intervel for the studies on the hydrographical conditions. Productivity of phytoplankton, and seagrasses was studied for one year and production from three species of corals for two years. Zooplankton samples were collected from 4 stations at day and one station at night for the entire period of study. Diurnal studies on hydrographical parameters and on the occurence and abundance of zooplankton were carried out in one station.

Variation in water temperature between stations were insignificant. Between stations the temperature variation was within 29.32 and 29.63°C. Temperature decreased during monsoon due to the seasonal variation in atmospheric temperature. Temperature increased during day and decreased at night.

There was no variation in pH and salinity with location of stations. Average variation in pH was between 8.12 and 8.18 and that of salinity between 34.26 and 34.5‰. Both these parameters exhibited seasonal variation by a decrease during monsoon. Temperature, pH and salinity were positively correlated, which explains the diurnal variation in pH, and salinity.

Dissolved oxygen concentration was high in lagoon stations than the open sea station. The variation between stations was from 4.58 to 5.37 ml/l. The high photosynthetic activity in the lagoon by the benthic and symbiotic plant community accounts for this. High photosynthetic activity during day increases oxygen concentration, and intense respiration at night decreases the dissolved oxygen concentration.

Concentration of silicate, phosphate, nitrite and nitrate was very low. Except nitrate, all other parameters showed highest concentration in open sea, indicating their uptake in the lagoon. Nitrate was slightly higher in the lagoon due to the high rate of fixation in the form of nitrate by nitrogen fixing agents in the lagoon. Average variation in silicate between stations was from 3.50 to 4.54 /ug at/l, phosphate 0.26 to 0.35 /ug at/l, nitrite 0.54 to 0.71 /ug at/l and that of nitrate from 0.11 to 0.13 /ug at/l. Except silicate, all other parameters showed definite diurnal variation with an increase at night and decrease during day indicating the relation between light and photosynthesis related utilization of these nutrients in the lagoon. This suggests the role of seagrasses and algal communities in the recycling of nutrients within the lagoon community. Except nitrate all these parameters decreased during monsoon, which may be due to the relation between light, photosynthesis, assimilation and fixation.

The lower concentration of calcium in all the lagoon stations than the open sea station indicated the high rate of precipitation by calcifying organisms. The average range of variation between stations was within 422.56 to 433.97 mg/l. Since calcification is strongly light dependent, the lower light intensity during monsoon reduced precipitation of calcium which increased the concentration of calcium during monsoon. The day time decrease and increase at night of calcium also suggests the role of light in precipitation.

Temperature, pH, salinity and dissolved oxygen increased with decreasing tide and phosphate, nitrite, nitrate and calcium showed a reverse trend, whereas silicate did not show any relation with tide.

Gross primary productivity of phytoplankton varied between 0.62±0.01 to 6.09±2.48 $mgC/m^3/hr$ and net production between 0.20±0.13 to 1.46±0.85 $mgC/m^3/hr$. Highest production was during post-monsoon which amounted to 4.75±0.93 $mgC/m^3/hr$ (gross) and 0.593±0.49 $mgC/m^3/hr$ (net). The lowest was during monsoon, the values being 1.03±0.33 $mgC/m^3/hr$ (gross) and 0.405±0.21 $mgC/m^3/hr$ (net).

Productivity of the seagrass Thalassia hemprichii ranged between 0.281±0.10 and 1.370±0.29 mgC/g/hr (gross), and 0.154±0.10 and 0.769 ±0.26 mgC/g/hr (net). Production was maximum during pre-monsoon 0.902±0.44 mgC/g/hr (gross) and 0.556±0.26 mgC/g/hr (net) and minimum during monsoon 0.405±0.11 mgC/g/hr (gross)and 0.225±0.06 mgC/g/hr (net).

Minimum and maximum gross and net production of Syringodium isoetifolium was 0.255 ±0.10 and 0.812 ±0.10 mgC/g/hr (gross) and 0.175±0.13 and 0.494±0.10 mgC/g/hr (net) Highest production was during pre-monsoon (0.575±0.16 mgC/g/hr (gross) and 0.321±0.11mgC/g/hr (net) and lowest during monsoon (0.368±0.10mgC/g/hr(gross)and 0.246±0.07 mgC/g/hr(net).

Production from corals was found to be maximum during post-monsoon, the values being 0.045±0.01 mgC/g/hr (gross) and 0.020±0.003 mgC/g/hr (net) from Porites cylindrica, 0.052±0.01 mgC/g/hr (gross) and 0.025±0.01 mgC/g/hr(net) from Acropora formosa and 0.081±0.02 mgC/g/hr (gross) and 0.048±0.01 mgC/g/hr (net) from Pocillopora damicornis. Lowest production observed was during monsoon and highest during post-monsoon season.

Productivity of phytoplankton was found to be limited by all parameters except nitrite and silicate in which the relation with salinity was significant ($r = 0.677$, $P \leq 0.05$). Productivity of Thalassia and Syringodium was limited by all parameters except temperature, pH and salinity. The significant correlations were with silicate and nitrite ($r = 0.677$, $P \leq 0.05$ for Thalassia and $r = 0.640$, $P \leq 0.05$ for Syringodium). Productivity of corals correlated positively with nitrite, silicate, dissolved oxygen, temperature and salinity, indicating the possible influence of these parameters on production. Significant relations were that of Acropora with salinity ($r = 0.486$, $P \leq 0.05$) and Porites, Acropora and Pocillopora with silicate ($r = 0.453$, $P \leq 0.05$; $r = 0.581$, $P \leq 0.01$ and $r = 0.512$, $P \leq 0.453$, $P \leq 0.05$, respectively). However, the relation with silicate is expected to be more of insidental because silicate is mainly metabolised by diatoms.

Major zooplankton groups observed in daytime samples were copepods the eggs, zoea, decapod larvae, ostracods, bivalve larvae, gastroped larvae and foraminiferans Night samples, in addition to the above groups, contained doliolum, salps, euphausiids, tunicates and tanidaceae. Numerical abundance varied with location of stations, as well as over seasons. Nocturnal abundance was very high than that of day time abundance. Average density were 581.9/m^3 for station-2, 222.8/m^3, for station-3, 387.1/m^3 for station-5, 317.2/m^3 to station-6 and 2,622.3/m^3 for night station. Nocturnal zooplankton was distinct in their occurrence and seasonal variation, suggesting the presence of resident zooplankton as a component of the lagoon fauna. The sharp increase to very high density after 1800 hrs and the independence of abundance on tide also support this view.

Growth of corals was studied by tagging and 'Alizarin' staining methods in respect of monthly skeletal extension and weight of $CaCo_3$ accretion in a period of 28 days.

The average colony extension of Acropora formosa during first year was between 5.03±1.72 and 8.06±1.88 mm/28d and during second year it was 4.90±1.27 to 8.68±2.3 mm/28d. Since light and zooxanthellar photosynthesis directly enhance calcification rates, the apical branches which receive more light grew faster (7.30 mm/28d) than the lateral (6.98mm/28d) and basal (5.95 mm/28d) branches.

Skeletal extension of Acropora aspera colony was between 3.08±0.69 and 4.17±0.96 mm/28d for the first year and between 3.42±0.71 and 4.69±0.69 mm/28d for the second year. Extension rate was highest on apical branches (4.47mm/28d) and lowest on basal branches (3.77 mm/28d).

$CaCO_3$ accretion of Acropora aspera colony during the first year was between 9.76±1.33 and 11.97±1.52 mg/28d and during the second year it was between 10.39±1.144 and 13.38±1.95 mg/28d. Average accretion rate was highest on apical branches (12.97 mg/28d) and lowest on basal branches (10.04 mg/28d).

Total average colony growth and growth on the three positions of the colony also exhibited seasonal variation with a decrease during monsoon season. The low light intensity, drop in many environmental factors, high current velocity (15.06 cm/sec), high amount of total suspended matter (9.95 to 14.65 mg/l) and very high rate of sediment resuspension (103.3 to 124 $mg/m^2/day$) create less favourable conditions for growth of coral during monsoon. Heavy monsoon wind induces extreme turbulence which agitate the settled sediment and the removal of coral boulders and rocks by people create land and beach erosion which also enhance sediment resuspension rate during monsoon.

Lakshadweep coral reefs are under the threat of deterioration due to natural and manmade causes. Healthy and apparently untouched reef fauna exist only in islands which are not inhabited by man, like Suheli and Bangaram and in some deeper areas of inhabited islands like Kalpeni, Agatti and Chetlat where man cannot easily reach.

Natural damage is not in any large scale at present. The presence of Acanthaster planci, does not cause threat at present because the population is thin.

Human interferences pose more serious threat than natural damages. This is mainly by the removal of live corals by local people and visitors, excessive human activity during low tides, destructive methods of fishing, removal of coral stones and boulders from the reef and beach for construction activities, dredging and deepening of jetty, ever increasing developmental activities, housing to accommodate the teeming population and oil pollution from mechanised vessels.

Imposing strict ban on removal of corals, supplying the people with alternate materials for construction, scientific management of reef fishery, restriction on dredging, construction of proper seawalls, establishment of marine parks, creation of artificial reefs, advanced research on the environmental problems and educating people about the fragility of these ecosystem have to be initiated immediately, which would help protecting these island ecosystems.

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