STUDIES ON ECOLOGY, CHEMICAL CONSTITUENTS AND CULTURE OF MARINE MACROALGAE OF MINICOY ISLAND, LAKSHADWEEP

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July 2000

Dedicated to

My Father

Peachiath Koya

Bava

Peachiath Sayed Mohammed Koya

and Bavebeeder

Chemmengath Kunhibi

CERTIFICATE

Certified that the thesis entitled **"STUDIES ON ECOLOGY, CHEMICAL CONSTITUENTS AND CULTURE OF MARINE MACROALGAE OF MINICOY ISLAND, LAKSHADWEEP."** is bonafide record of the work carried out by Haneefa Koya C.N. under my guidance and supervision and that no part thereof has been presented for the award of any other degree, diploma or any other similar title.

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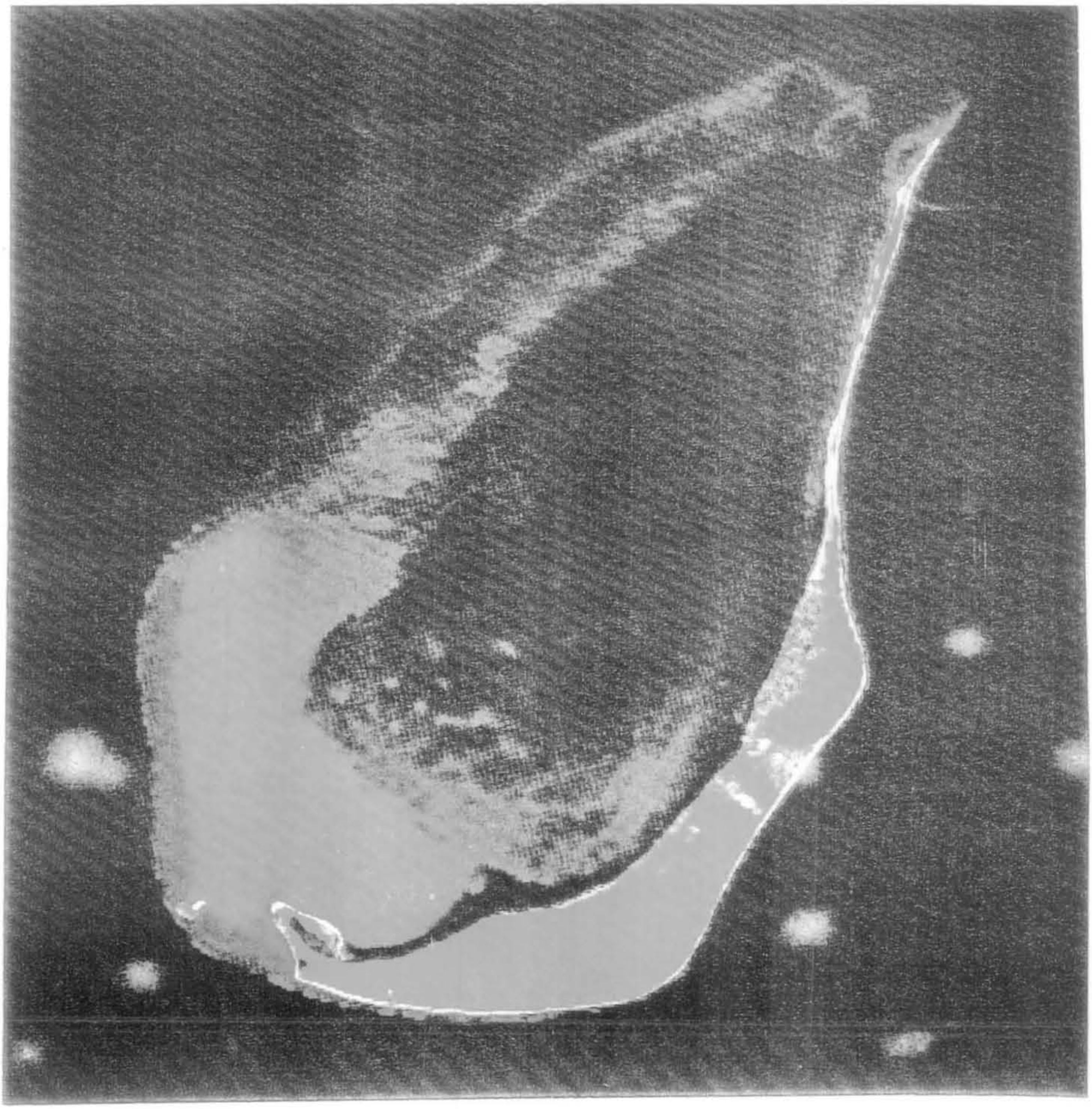

Satellite view of Minicoy, Lakshadweep

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PREFACE

Seaweeds are one of the most important and fascinating marine resources. They are used as human food, live stock feed, and fertilizer. They are used as food since they are rich in protein, carbohydrate and lipids. They possess many of the rare minerals which are essential for human body. They are considered as a delicacy in many parts of the world.

The plants of the sea that are called as "Seaweeds" belong to the simplest group of plants known as algae. They have no distinguishable roots, stems or leaves. The algae vary in size, from microscopic single cell forms (eg. diatoms) to the giant macrophytes (eg. *Macrocystis*). The algae are mainly divided into four groups by the colouring pigments in their cells. They are Chlorophyta (green), Rhodophyta (red), Phaeophyta (brown) and Cyanophyta (Blue- green). These groups of algae form very important living renewable resource of the oceans and lagoons. The economical importance of seaweeds are gaining momentum and it has become essential to have first hand knowledge about their availability, ecological distribution, seasonal fluctuations and their productivity. It will result in optimising the use of seaweeds and its conservation because of the ever increasing demand for them.

Seaweeds have been harvested and used as food, centuries back by many of the South East Asian countries. It is eaten raw or processed in many parts of the world. They contain more than 60 trace elements which are devoid in terrestrial plants. *Porphyra vietnamensis*, *Ulva faciata* and *U. lactuca* are some of the seaweeds commonly used as food in different countries. Chapman and Chapman (1980) reported that 100g of algae provide all that a human being needs in respect of Sodium, Potassium and Magnesium.

Phycocolloids such as agar and algin extracted from red and brown seaweeds respectively are put to use in many industries. Agar, algin and carrageenan obtained from seaweeds have multifarious use mostly as gelling, stabilizing and thickening agents. Agar is of great value as culture medium in microbiological studies. Agar yielding seaweeds are called agarophytes and some important species in Indian waters are *Gelidiella acerosa*, *Gracilaria edulis* and *G. crassa*. Algin is obtained from the cell walls of the brown algae. Algin yielding seaweeds are *Sargassum spp* and *Turbinaria spp*. Some of the red algae produce gel like extracts called agaroids. They differ in their properties and chemical nature from agar. Carrageenan comes under this category. The important species, which produce carageenan, are *Gigartina acicularis* and *Hypnea musciformis*. Mannitol, Laminarin, Iodine and Fucoidin are some other chemicals extracted from seaweeds. Seaweeds are a source of energy. Two third of the total solar energy which reaches the surface of the planet falls in oceans. Solar energy is used in photosynthesis by algae. The seaweeds can potentially be used as biomass for energy production

In this investigation, seasonal distribution, biomass of seaweeds, in addition to the study of the physicochemical parameters such as atmospheric temperature, surface water temperature, salinity, dissolved oxygen and nutrients were studied. Data were collected on biological and biochemical characteristics, total biomass of seaweeds, protein, carbohydrate, lipid, sodium alginate and agar. Culture of the macroalga *G .edulis* was conducted for the three main seasons. A statistical attempt was also made to study the inter-relationship between the independent (biomass) variable, and dependent variables (parameters) to find out any significant correlation.

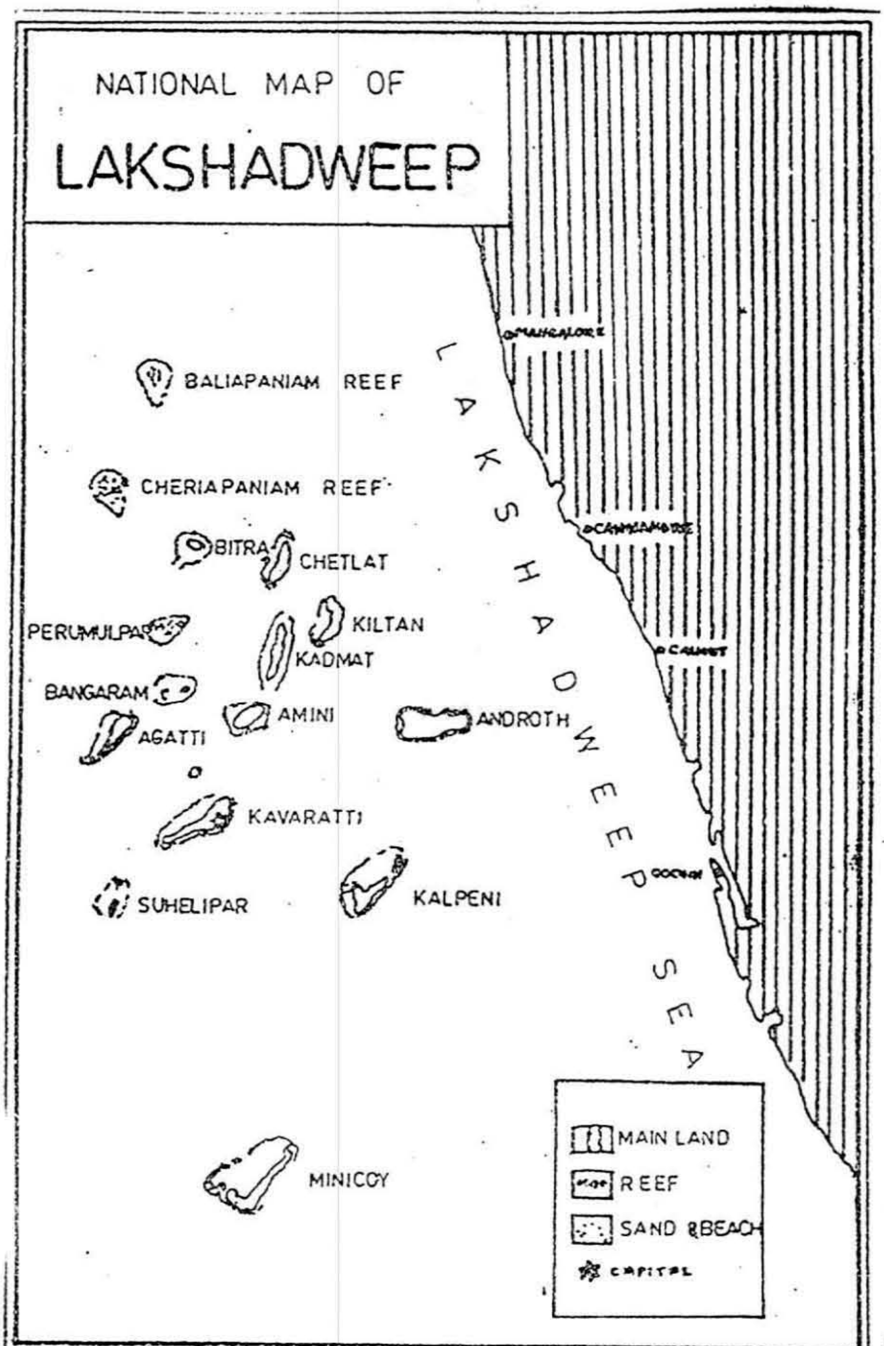
INTRODUCTION

The Union Territory of Lakshadweep is situated in the Arabian Sea about 200 to 400 km off the Kerala coast. This archipelago consists of 36 islands and five submerged banks with a total area of 32 sq. km .The islands lie between 08° 00 - 12° 30' N latitude and 71° 00 - 74° 00 E longitude. These islands consist of coral formation built on submerged ridge raising steeply from a depth of about 1500 to 4000 m in the Arabian Sea. The Lakshadweep, Maldives and Chagos archipelagos form an uninterrupted chain of coral atolls and reefs on a submarine bank covering a distance of over 2000 km. Most of these islands have sandy beaches with gentle slope on the lagoon side and on the seaward side there is a steep slope with boulders, coral rocks, living corals and debris. Corals cannot grow very deep in the oceans and what is seen at present depicts millennia of interaction between the submarine bank, tectonic activity and the level of the oceans, particularly during the Pleistocene period (Jones, 1986).

Coral reef ecosystems are the most diverse and colourful of any communities with the most complex interrelationship between species. Corals grow where the mean sea temperature is at least 20 ^{0}C throughout the year, preferably more than 23 ^{0}C. They also need clean sea water and are unable to grow where rivers dilute the sea or bring in mud. Coral reef communities may be very old and their formation is a result of persistent accumulation of calcareous deposits over long periods, extending from hundred to thousands of years (Qasim, 1998). Coral reefs are of three types: (1) Barrier reefs along continents (2) Fringing reefs around islands (3) Atolls, broken fringes of reef and islands around a central lagoon. The Indo-Pacific region is particularly rich in corals. The Australian Great Barrier Reef is an intermittent series of reefs stretching over 1900 km along the coast of Queensland. Other coastal reefs lie off East Africa and in the Red Sea. The Pacific and the Indian Oceans have thousands of atolls. In the West Atlantic, coastal reefs extend 200 km. southwards from Yucatan and many Caribbean islands are fringed with coral reefs. The corals are coelenterate polyp animals which extent their tentacles at night to feed on zooplankton washed over the reefs. Their tissues house symbiotic green algae (zooxanthillae). Zooxanthillae and other algae living in or on their calcareous skeleton conduct photosynthesis in the sunlight. Many reefs are in trade wind belts, the windward side being exposed to wave action, the leeward side being sheltered. Reef systems are often bioenergeticaly more or less self maintaining, complete ecosystem in themselves, beautifully adapted to use, hoard or recycle any inputs from the surroundings.

Minicoy Island ($8^{0}17^{I}$N and $73^{0}04^{I}$E) is a coral reef island among the Lakshadweep group of islands. It is about 10 km long and having a land area of 4.4 sq. km. (Fig. 1). The Minicoy Atoll have developed on the Chagos - Lakshadweep ridge during several sea level changes which caused colonisation of various coral communities belonging to different families. Minicoy lies in a NE-SW axis and is elevated only a few metres, above sea level. The lagoon with an area of about 25 sq. km. has two ecologically distinct habitats, the coral shoals that occupy 75 % of the area and the sand flats in the southern area of the lagoon. The average depth of the lagoon is 4 m. with tidal amplitude of 1.75 m. and with exposed reef of about 4 km long.

The Lakshadweep group of islands became Union Territory in 1956 and progressed rapidly; but very few research work has been carried out in the context of its biodiversity. Seaweeds are not simple algae those live in the sea, but they are morphologically and physiologically distinct from both land plants and majority of fresh water algae. Man has been fascinated by the seashore with the ever-changing tides and multitude of organisms, which occupy the region between the tide level especially on rocky shores. Phycocolloids such as agar, algin and carageenan produced from red and brown seaweeds are used in many industries such as food, confectionery, pharmaceutical, textile, paint and varnish


NATIONAL MAP OF
LAKSHADWEEP
BALIAPANIAM REEF
CHERIAPANIAM REEF
BITRA
CHETLAT
PERUMULPAR
KILTAN
KADMAT
BANGARAM
AMINI
ANDROTH
AGATTI
KAVARATTI
SUHELIPAR
KALPENI
MINICOY
LAKSHADWEEP SEA
MAIN LAND
REEF
SAND &BEACH
CAPITAL

industries mostly as jelling, stabilizing and thickening agents. Agar is of great value as culture medium for microbiological laboratories of the world. Seaweeds are rich with a wide variety of chemicals, minerals, vitamins, essential amino acids, lipids, mannitol, laminarin, fucoidin and iodine. In recent years, economic importance of the seaweeds are gaining momentum in their wide range of utility. In this circumstance, it is essential to have a first hand knowledge about their availability, distribution, seasonal fluctuations in growth and productivity. It will enable us for proper utilisation of seaweeds as there is ever increasing demand for them. Moreover, seaweeds are a saviour of ecological balance in a highly diverse ecosystem by permitting to grow enormous number of epiphytes on them.

World seaweed production now exceeds 7 million tonnes (wet weight) a year according to FAO. China with over 4 million tonnes accounts for 60 % of the harvest and Asian countries produce 90 % of world's seaweed. Japan, China, South Korea and Philippines are the major seaweed producing countries. Since 1981 seaweed production has increased considerably. The brown algae comprise 70 % of the total harvested seaweeds.

The potential areas in India for luxuriant growth of seaweeds are south Tamil Nadu coast, Gujarat coast, Lakshadweep and Andaman and Nicobar Islands. The total standing crop from intertidal and shallow waters of all maritime states and Lakshadweep islands was estimated as 91333 tonnes (wet weight). The quantity of seaweeds growing in deep waters in Tamil Nadu was estimated as 75,372 tonnes (wet wt.). The quantity of agar yielding seaweeds *Gelidiella acerosa, Gracilaria edulis, G. crassa,* and *G. foliifera* exploited in a year varied from 248 to 1289 tonnes (dry wt), algin yielding seaweeds from 651 to 5537 tonnes (dry wt.) and edible and other seaweeds from 1177 to 6420 tonnes (dry wt.) (Kaliaperumal and Kalimuthu, 1997). In India agar and algin industries are getting their raw materials mainly from the natural seaweed beds of Tamil Nadu coast. It is essential that period of availability and harvestable quantity must be known before venturing for exploitation. The present work has been taken as a preliminary step to assess the distribution and standing crop of seaweeds in Minicoy.

The hydrological studies viz. physical, chemical and biological parameters of the marine environment are inevitable for the studies of the flora and fauna of any ecosystem. Some works on the above aspects nave been carried out in Lakshadweep. Jones (1959) reported the importance and special ecological conditions of the area. Cooper (1957) and Jayaraman *et al.* (1959 and 1960) have studied the oceanographic conditions of the sea. Sankaranarayanan (1973) studied the chemical characteristics of the Lakshadweep waters. Rao and

Jayaram (1966) and Girijavallaban *et al.,* (1989) reported the oceanographic conditions around Lakshadweep islands. The standing crop of seaweeds especially the commercial important species has to be assessed. Surveys of seaweed resources have been carried out from time to time to assess the standing crop in Tamil Nadu (Chako and Malu Pillai, 1958; Thivy, 1960; Varma and Krishna Rao, 1962; Desai, 1967; Umamaheswara Rao, 1973 and Anon (a), 1987), Kerala coast (Koshi and John, 1948) and Andaman and Nicobar islands (Gopinathan and Panigrahi, 1983). Anon (1979) and Kaliaperumal *et al* (1989) have reported the macro algae growing in Lakshadweep islands.

There are considerable works in the chemical aspects of Indian seaweeds. In the CMFRI, studies were carried out on the chemical composition of marine algae growing in the viscinity of Mandapam, (Pillai, 1955 (a). 1956, 1957a and 1957b). Twenty three species of green algae belonging to 12 genera collected from Mandapam coast were analysed for protein and carbohydrates (Reeta Jayasankar *et al.,* 1990).

The demand for seaweeds is much higher than the supply from the natural habitat. In order to overcome this situation, culture of seaweed has been attempted in many parts of the world and succeeded by developed countries and in some part of Latin America and South East Asian countries.

The seaweed based industries in India are increasing, but the seaweed production in the natural habitat is not yet increased proportionately. In India, mariculture of different species of seaweed has been attempted along the Tamil Nadu coast and Lakshadweep. Field cultivation of *G. edulis* has been carried out in Lakshadweep (Anon (a), 1990; Kaliaperumal *et al.,* 1992; Chennubhotla *et al* ; 1993; Kaladharan *et al.,* 1996). In the present study, culture of one of the most commercially important red seaweed *G. edulis* was attempted in four different sites along the lagoon side during premonsoon, monsoon and postmonsoon seasons.

CHAPTER - I

HYDROGRAPHY

INTRODUCTION

The earlier work on hydrology and productivity of coral reefs consisted of both field and experimental studies and concentrated on relationship between reef form and the environment with emphasis on critical factors such as temperature, exposure to sun, sedimentation and water turbulence. Reviews of the biology and ecology of coral reefs have been published by Wells (1957), Yonge (1963 and 1973), Stoddart (1969) and Lewis (1977).

The earlier studies involving hydrographic measurements have been the flow resperopmetery method where by changes in oxygen concentration have been monitored as the water flowing over a reef. This method measures community metabolism and depends on the flow of unidirectional currents across a reef. The first quantitative studies of this nature emerged from the work of Sargent and Austin (1949 and 1954). Their studies at Rongelat Atoll in the Pacific showed that the productivity on reefs was considerably higher than that of surrounding waters. The investigation of Sargent and Austin was followed by similar strategies of Odum and Odum (1955) and Kohn and Helfrich (1957). These studies were limited by the fluctuations in the concentration of dissolved gases due to roughness of water crossing the reef ; variations in tidal height and current velocity and changes in temperature. The above studies and those of

Gordon and Kelly (1962), Owens (1974) and Westlake (1974) suggest that the procedure of floor respirometary is correct and has considerable advantage over measurement of production in an enclosure.

The inorganic nutrients, phosphorous and nitrogen are essential to the primary products on all ecosystems. In most marine systems, nitrogen is considered to be the limiting nutrient and this is probably the case for coral reefs. Coral reef systems utilise dissolved nutrients and hence reduce the connection of these nutrients as water passes over them. The best coral reef development is always found on the driest and nutrient depleted poor oligotrophic waters as they are least tolerant of nutrients enrichment. The importance of nitrogen as a growth limiting element in the sea, nitrogen cycling and its availability have been well documented (Ryther and Dunstan, 1971; Dugdale, 1976; Carpenter and Copone, 1983 and Sathyanarayana *et al.,* 1992). Similarly nitrogen and its role in estuaries, mangrove swamps and other aquatic ecosystems have also received attention (Boto and Wellington, 1983; Ovalle *et al.,*1990, Gilbert and Garside; 1992, Caddy and Bakun, 1994; Sunitha Rao and Rama Sharma, 1995 and Stapel *et al.,* 1997). But the abundance and role of nitrogen in coral reefs have been discussed only in limited studies.

Nitrogen concentrations in tropical coral reef areas tend to be low except in locations in upwelling or terrestrial run off. Ground water seepage into the reef system also influences nutrient levels. (Marsh,1977; D'Elia *et al.,* 1981 and Lewis, 1985). Elevated nitrogen present in coral skeletons sediments results in a flex of dissolved nitrogen to the water column (Andrews and Muller, 1983 and Risk and Muller, 1983). High rate of nitrogen production in coral reefs has been attributed to fixation by reef communities (Wiebe, 1976; Cappone, 1977; Wilkisnson and Fay, 1979, Penhale and Cappone, 1981 and Pearl, 1984). However, the process of ammonification, nitrification and assimilation in coral reefs are not fully understood (D'Elia and Wiebe, 1990).

Phosphorous concentrations in tropical waters overlying most coral reefs are lower than in deep ocean, temperate or upwelling areas (D'Elia andWiebe, 1990). Reef communities are not limited by the supply of phosphorous and have evolved either internal (biochemical) or external (food chain) recycled loops to satisfy their need for phosphorous (Pilson and Betzer, 1973 and Pomeroy *et al.*, 1974). Studies on nutrient flux over coral reefs indicate that there is active recycling of phosphorous with minimum leakage to the overlying water (Johannes *et al.,* 1983). As in the case of nitrogen, phosphorous concentration in reefs is elevated by terrestrial run off, by ancient sea beds, Guano deposits or by ground water inputs (Marsh, 1977; Allaway and Ashford, 1984 and Lewis, 1987). Reef sediments contain a higher concentration of phosphorous and can provide soluble phosphorous to the algal community (Entsch *et al.,*1983). Biological regeneration of phosphorous from corals and microbial populations has also been reported (Geesey *et al.,* 1984 and Andrews and Muller, 1983).

Silicic acid concentration, in reef waters is also low. Smith and Jokiel (1978) have shown that there is a low utilisation of silicon in most reef environments. They also observed higher silica in areas of upwelling. A seasonal difference in the uptake and release of silicic acid has been reported (Johannes *et al.,* 1983b).

The early report on the hydrography of Lakshadweep waters is that of Jayaraman *et al.* (1959 and 1960) and Jones (1959). Patil and Ramamiratham (1963) observed circulatory patterns in Lakshadweep sea during winter and summer months and Rao and Jayaraman (1966) recorded upwelling in the Minicoy region and attributed it to divulging current systems. Physical characteristics of Lakshadweep sea have also been reported (Kesava Das *et al.,*1979 and Varkey *et al.,* 1979). Ansari, (1984), Jagtap and Untawale (1984), Wafar *et al.* (1986 and 1990) measured concentration of nitrogenous nutrients and primary production in oceanic waters of Lakshadweep. Suresh (1991) and Nasser (1993) described the hydrobiology of Kavaratti and Minicoy lagoon respectively.

The present study on the hydrography of the Mincoy lagoon was carried out to understand the variations between three major algal habitats, namely the lagoon, reef flat and shore reefs. Seasonal fluctuations in the various parameters in relation to the south west monsoon also form a part of the study.

MATERIAL AND METHODS

Study area

Minicoy, the southernmost island of Lakshadweep (Fig.2) is located 250 nautical miles off Kochi at Latitude of $8^{0}17'$ N and Longitude $73^{0}04'$ E with a land area of 4.4 sq.km. Minicoy Atoll has a lagoon area of about 25 sq. km. consisting of three ecologically distinct habitats. The coral shoals occupy about seventy five percent of the area and the sand flats in the southern region of the lagoon contribute the remaining twenty five percent. The average depth of the lagoon is approximately 4 m with the tidal amplitude of 1.57 m and an exposed reef area of about 4 km. Minicoy lies north east – south west and is elevated only a few meters over the sea level.

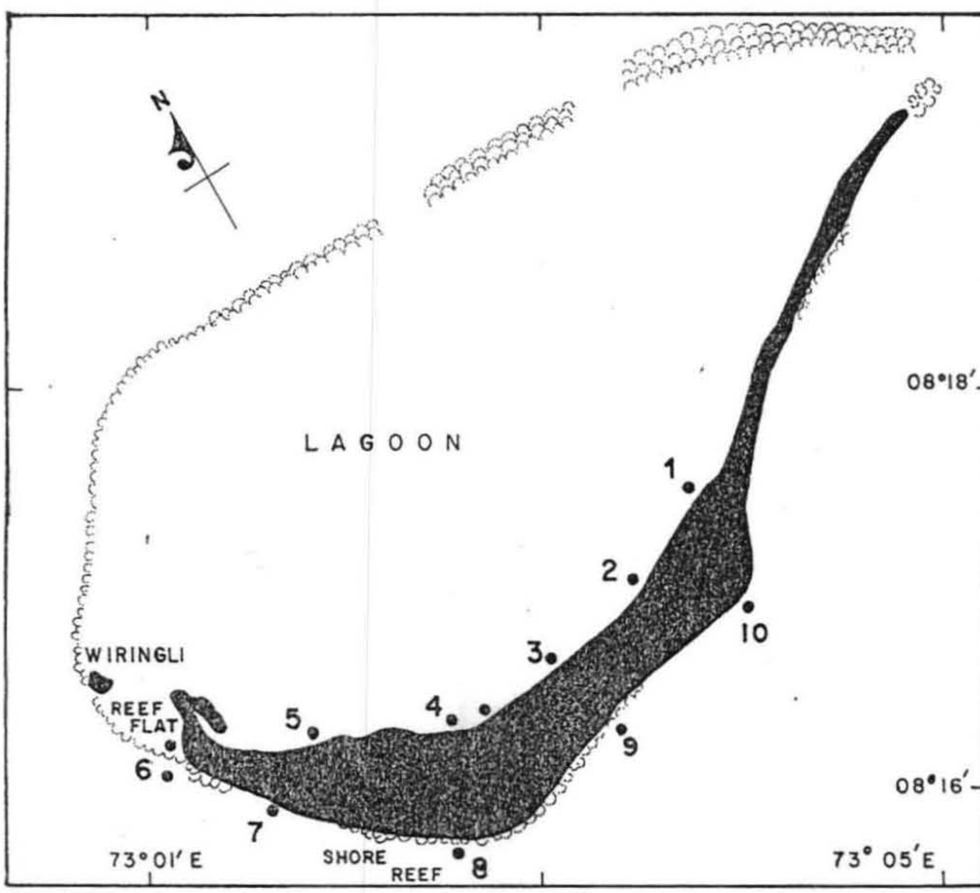


Fig. 2 : Map of Minicoy Island showing stations 1 — 10

The hydrobiological characteristics of the area, mainly the monsoon currents, the equatorial currents and equatorial counter current play an important role in the formation and ecology of the island. Air temperature does not show significant seasonal change with mean daily air temperature ranging from 24.5 ^{0} C in January to 33.5 ^{0} C in April. Total rainfall recorded for the year 1998 was 225.6 cm contributing sixty five percent during the monsoon months from May to September. Humidity varied between 80.5% (April) to 88.2% (October) . The winds are south westerly during south west monsoon and north easterly during north east monsoon. In general, the winds are stronger and steadier during the south west monsoon with speed reaching 45 to 55 knots. The southwest monsoon prevails during June-September and north east monsoon during November –February .The predominant wave periods and wave heights 5 – 6 sec and 0.5 to 1.5 m during fair weather season and 5-9 sec and 1-3 m respectively during the rough weather seasons (Kesava Das *et al.*,1979).

Sampling sites.

A reconnaissance survey was made in December 1997 to identify the important areas of algal growth and accessibility during the study period. Based on this survey, 10 representative stations (Fig.2) were fixed in the three major areas of Minicoy island. Station 1 to 5 was on the lagoon side of the island. Station 6 symbolised the exposed reef area and Stations 7 to 10 the shore reef areas on the eastern side of the island. Surface water samples were collected at fortnightly intervals from these stations for a period of one year from January to December 1998. Water samples were collected in 50 ml polythene bottles from the intertidal area at an average depth of 30 cm. Samples for dissolved oxygen analysis was carefully siphoned into 125 ml. BOD bottles and fixed with Winkler A and B solutions. These bottles were kept in dark, cool conditions in an ice box till the time of analysis on the same day. Water temperature was measured in the field using a calibrated thermometer. Data were classified as premonsoon (Jan-April), monsoon (May-Aug) and post monsoon (Sept- Dec) periods.

Methods

Salinity

Salinity was determined by the Mohr titration method (Strickland and Parsons, 1968).

Dissolved oxygen

Winkler method with modifications was used for the determination of dissolved oxygen content.

Nutrients

All nutrients except nitrates was analysed using the method outlined by (Strickland and Parson, 1968) and measured on Erma AE,11 photoelectric colorimeter. Nitrate was determined by a modified method of Mullin and Riley (1955).

Nitrite-nitrogen

The water sample was mixed with sulphanilamide solution. After 5 min NNED was also added and mixed thoroughly. The optical density was measured at 530 nm. Standard graph was prepared using standard nitrate solution and concentration is expressed in microgram per litre.

Nitrate-nitrogen

Nitrate in seawater was reduced to nitrite and then measured in the same way as described for nitrite. To the water sample a buffer reagent (Phenol + Sodium hydroxide) and reducing agent Copper sulphate + Hydrazine sulphate were added and kept in dark for 20 hrs. This reduced solution was treated with Sulphanilamide and intensity of colour developed was measured at 530 nm.

Phosphate-phosphorous

The phosphate in sea water was allowed to react with Ammonium molybdate forming a complex heteropholy acid. This acid was reduced by ascorbic acid to a blue coloured solution. After 5 min. the optical density was measured at 660 nm. For standard phosphorous different concentrations of Potassium dihyrogen phosphate was made and the graphs were plotted. Phosphate is expressed in microgram per atom per litre.

Silicate-silicon

The determination of the dissolved silicon compound was based on the formation of an yellow Silicomolybdic acid, when a more or less acidic sample was treated with a molybdate reagent. Since this acid was weak in colour, they were reduced by ascorbic acid to intensely coloured blue complexes. The absorbent of the sample was measured against distilled water at a wave length of 660 nm. Standard graph was prepared by using Sodium silico flouride and silicate is expressed in microgram atom per litre.

RESULTS

Mean values and standard deviation of various hydrological parameters during premonsoon, monsoon, and postmonsoon at Stations 1 to 10 are given in Table 1 & 2.

Water temperature was higher at Stations 3 and 4 of the lagoon side with maximum values during pre monsoon months. The salinity values were more or less uniform in all the stations. Dissolved oxygen values were high in seagrass dominated areas of Station 3,5 and in the wave beaten zones of Station 6 & 7. Among the nutrients nitrate had low values during monsoon and premonsoon, and high values during post monsoon. A similar trend was noticed in the case of phosphate with low values during premonsoon and in the case of silicate low values were noticed during post monsoon.

A 2 way ANOVA statistical analysis for the different hydrological parameters indicated that variations between stations were significant only in the case of water temperature while marked seasonal variations were noticed for all parameters except salinity (Table 3). The significant variations between stations observed for water temperature was due to the higher values noticed at Stations 2,3,4,5,7,8 & 9 (Table 4). Seasonal difference in dissolved oxygen was due to the increased values observed during monsoon. The low values of nitrites among pre monsoon and the high values of nitrate during post monsoon were responsible for the significant seasonal variations in these two nutrients. Similarly the low values of phosphate in pre monsoon and the low values of silicate

Table 1. Mean and standard deviation of various hydrological parameters at 1 to 5.

Parameter	Season	1	2	3	4	5
		M SD	M SD	M SD	M SD	M SD
Water temperature (^{o} C)	Pre	29.1 ± 1.52	29.9 ± 1.52	30.5 ± 1.38	30.6 ± 0.98	29.5 ± 1.55
	Mon	28.9 ± 1.15	29.3 ± 1.13	30.0 ± 1.13	29.9 ± 1.97	29.5 ± 1.54
	Post	28.3 ± 0.86	28.3 ± 0.92	29.6 ± 1.02	29.3 ± 0.89	29.1 ± 0.69
Salinity	Pre	33.0 ± 1.28	33.7 ± 0.94	33.8 ± 1.71	34.1 ± 1.12	33.2 ± 0.71
(ppt)	Mon	33.7 ± 1.39	33.5 ± 1.10	32.7 ± 0.95	33.1 ± 1.40	32.2 ± 1.12
	Post	34.5 ± 2.26	32.5 ± 1.18	32.1 ± 1.39	33.2 ± 2.73	32.8 ± 1.53
Dissolved oxygen (ml/ l)	Pre	4.13 ± 1.50	3.54 ± 0.79	6.54 ± 1.66	4.23 ± 1.69	4.24 ± 3.89
	Mon	5.45 ± 1.86	5.25 ± 1.55	4.74 ± 0.83	3.95 ± 1.02	7.15 ± 4.06
	Post	3.94 ± 1.45	4.19 ± 1.58	4.34 ± 1.34	4.70 ± 1.46	4.35 ± 1.96
Nitrite	Pre	0.46 ± 0.16	0.44 ± 0.17	0.38 ± 0.19	0.31 ± 0.20	0.39 ± 0.17
(μ g at./ l)	Mon	0.51 ± 0.11	0.49 ± 0.16	0.55 ± 0.08	0.50 ± 0.18	0.54 ± 0.09
	Post	0.41 ± 0.19	0.60 ± 0.16	0.50 ± 0.10	0.48 ± 0.11	0.51 ± 0.13
Nitrate	Pre	1.44 ± 0.60	1.63 ± 0.31	1.11 ± 0.55	1.26 ± 0.50	1.14 ± 0.37
(μ g at./l)	Mon	1.44 ± 0.60	1.44 ± 0.46	1.25 ± 0.46	1.18 ± 0.46	1.18 ± 0.46
	Post	1.10 ± 0.45	1.45 ± 0.55	1.51 ± 0.54	1.51 ± 0.55	1.51 ± 0.58
Phosphate	Pre	0.69 ± 0.15	0.78 ± 0.06	0.77 ± 0.14	0.75 ± 0.16	0.77 ± 0.17
(μ g at./ l)	Mon	0.77 ± 0.14	0.83 ± 0.12	0.83 ± 0.15	0.77 ± 0.17	0.74 ± 0.26
	Post	0.94 ± 0.07	0.98 ± 0.04	0.74 ± 0.32	0.97 ± 0.06	0.70 ± 0.06
Silicate	Pre	3.36 ± 3.57	1.98 ± 0.54	2.26 ± 0.62	2.79 ± 2.18	2.27 ± 1.04
(μ g at./ l)	Mon	2.02 ± 0.64	2.00 ± 0.57	2.44 ± 0.79	2.36 ± 0.75	2.96 ± 1.54
	Post	1.12 ± 0.29	1.40 ± 0.35	1.94 ± 0.61	1.83 ± 0.23	1.79 ± 0.19

Pre = Premonsoon Mon = Monsoon Post = Postmonsoon

M = Mean SD = Standard deviation

Table 2. Mean and standard deviation of various hydrological parameters at Station 6 to 10.

Parameter	Season	6	7	8	9	10
		M SD	M SD	M SD	M SD	M SD
Water Temperature (° C)	Pre	29.5 ± 1.75	29.9 ± 1.78	30.3 ± 1.20	30.3 ± 0.92	30.2 ± 1.12
	Mon	29.1 ± 0.39	29.5 ± 0.78	29.3 ± 1.63	30.1 ± 0.99	30.3 ± 0.60
	Post	28.0 ± 0.64	29.4 ± 0.89	29.8 ± 0.97	29.9 ± 0.99	29.2 ± 0.99
Salinity (ppt)	Pre	33.1 ± 0.95	33.6 ± 0 .71	33.7 ± 0.96	33.8 ± 1.08	34.2 ± 1.45
	Mon	33.4 ± 0.71	33.3 ± 0.75	33.3 ± 0.86	33.3 ± 0.87	33.1 ± 0.51
	Post	33.2 ± 0.78	33.6 ± 1.77	33.4 ± 2.33	33.5 ± 1.98	33.9 ± 1.66
Dissolved Oxygen (ml / l)	Pre	5.10 ± 3.16	4.47 ± 1.30	4.97 ± 1.19	4.69 ± 1.40	5.32 ± 1.32
	Mon	6.36 ± 2.46	6.20 ± 2.41	5.19 ± 1.84	5.58 ± 1.78	5.18 ± 1.71
	Post	4.60 ± 0.70	5.00 ± 0.74	4.79 ± 1.71	5.05 ± 1.35	5.51 ± 1.02
Nitrite (µ g at. /l)	Pre	0.37 ± 0.13	0.28 ± 0.11	0.27 ± 0.09	0.23 ± 0.06	0.43 ±0.16
	Mon	0.47 ± 0.11	0.47 ± 0.13	0.46 ± 0.10	0.49 ± 0.11	0.51 ± 0.08
	Post	0.54 ± 0.12	0.49 ± 0.08	0.44 ± 0.09	0.45 ± 0.10	0.54 ± 0.09
Nitrate (µ g at. / l)	Pre	1.39 ± 0.48	1.35 ± 0.58	0.98 ± 0.52	0.98 ± 0.52	1.44 ± 0.43
	Mon	1.13 ± 0.63	1.06 ± 0.65	1.24 ± 0.61	1.00 ± 0.55	1.36 ± 0.62
	Post	1.65 ± 0.57	1.56 ± 0.49	1.41 ± 0.46	1.43 ± 0.40	1.40 ± 0.52
Phosphate (µ g at. / l)	Pre	0.69 ± 0.09	0.67 ± 0.20	0.67 ± 0.16	0.71 ± 0.15	0.66 ± 0.25
	Mon	0.84 ± 0.16	0.81 ± 0.13	0.92 ± 0.21	0.78 ± 0.22	0.83 ± 0.20
	Post	0.86 ± 0.11	0.84 ± 0.13	0. 95 ± 0.10	0.88 ± 0.12	1.40 ±0.52
Silicate (µ g at. / l)	Pre	2.69 ± 2.36	2.02 ± 0.78	2.34 ± 0.83	2.96 ± 1.80	3.69 ± 2.56
	Mon	2.55 ± 0.61	3.00 ± 1.56	2.42 ± 0.63	2.31 ± 1.70	3.10 ± 1.44
	Post	1.92 ± 0.49	1.81 ± 0.44	1.33 ± 0.12	1.46 ± 0.26	2.21 ± 0.89

Pre = Premonsoon   Mon = Monsoon   Post = Postmonsoon

M = Mean   SD = Standard deviation

Table 3. Two way ANOVA between stations (treatment) and between (replicate) for the various hydrological parameters.

Parameter	Source	DF	SS	MSS	F	P
Water temperature	Treatment	9	6.363	0.707	7.46	P < 0.01
	Replicate	2	3.980	1.990	20.99	P < 0.01
	Error	18	1.707	0.095		
Salinity	Treatment	9	3.191	0.355	1.46	P > 0.05
	Replicate	2	1.098	0.549	2.26	P > 0.05
	Error	18	4.379	0.243		
Dissolved oxygen	Treatment	9	4.746	0.527	0.90	P > 0.01
	Replicate	2	4.512	2.256	3.85	P < 0.05
	Error	18	10.558	0.587		
Nitrite	Treatment	9	0.480	0.005	2.21	P > 0.05
	Replicate	2	0.136	0.068	22.08	P < 0.01
	Error	18	0.340	0.002		
Nitrate	Treatment	9	0.285	0.320	1.08	P > 0.05
	Replicate	2	0.292	0.146	4.98	P < 0.05
	Error	18	0.520	0.029		
Phosphate	Treatment	9	0.480	0.005	0.99	P > 0.05
	Replicate	2	0.102	0.510	9.47	P < 0.01
	Error	18	0.097	0.005		
Silicate	Treatment	9	2.548	6.283	1.88	P > 0.05
	Replicate	2	5.329	2.665	17.72	P < 0.01
	Error	18	2.706	0.150		

Table 4. Stations and seasons comparison based on ANOVA tables.

STATION COMPARISON

Parameters	Station	2	3	4	5	6	7	8	9	10
Water temperature	1	NS	SIG	SIG	SIG	NS	SIG	SIG	SIG	SIG
	2	-	SIG	SIG	NS	NS	NS	SIG	SIG	SIG
	3	-	-	NS	SIG	SIG	NS	NS	NS	NS
	4	-	-	-	SIG	SIG	NS	NS	NS	NS
	5	-	-	-	-	NS	NS	NS	SIG	NS
	6	-	-	-	-	-	SIG	SIG	SIG	SIG
	7	-	-	-	-	-	-	NS	NS	NS
	8	-	-	-	-	-	-	-	NS	NS
	9	-	-	-	-	-	-	-	-	NS

SEASON COMPARISON

Parameters	**Season**	**Monsoon**	**Postmonsoon**
Water temperature	Premonsoon	SIG	SIG
	Monsoon	-	SIG
Dissolved oxygen	Premonsoon	SIG	SIG
	Monsoon	-	SIG
Nitrite	Premonsoon	SIG	SIG
	Monsoon	-	NS
Nitrate	Premonsoon	NS	SIG
	Monsoon	-	SIG
Phosphate	Premonsoon	SIG	SIG
	Monsoon	-	NS
Silicate	Premonsoon	NS	SIG
	Monsoon	-	SIG

NS - Not significant SIG - Significant

during post monsoon contributed to the significant variations.

The monthly values for the different hydrological parameters are depicted in Figure 3 - 9. Seawater temperature (Fig. 3) showed variations from 27 ^{0}C to 32^{0}C with a decreasing trend observed till March and then an increasing trend with a peak in May. Further a decrease in temperature was noticed in the monsoon months with the lowest values in September. The post monsoon months in general showed an increase in seawater temperature (Fig. 3). Salinity was more or less similar ranging between 32 and 34 ppt. with values above 35 ppt in January and November (Fig. 4). Dissolved oxygen values (Fig. 5) indicated an increasing trend from January to May with values of 10 ml/l at reef flat during the month of May. A sharp decline in the case of dissolved oxygen was noticed in June and it was steady in the monsoon and post monsoon months. Any definite pattern was not observed in the case of nitrite (Fig. 6) with almost similar values at lagoon, reef flat and shore reef regions of Minicoy in May and July. The fluctuations in post monsoon months is less erratic than the pre monsoon and monsoon periods. Definite peaks were observed for the values of nitrates at the three regions (Fig. 7) in April, August and November and

SEA WATER TEMPERATURE

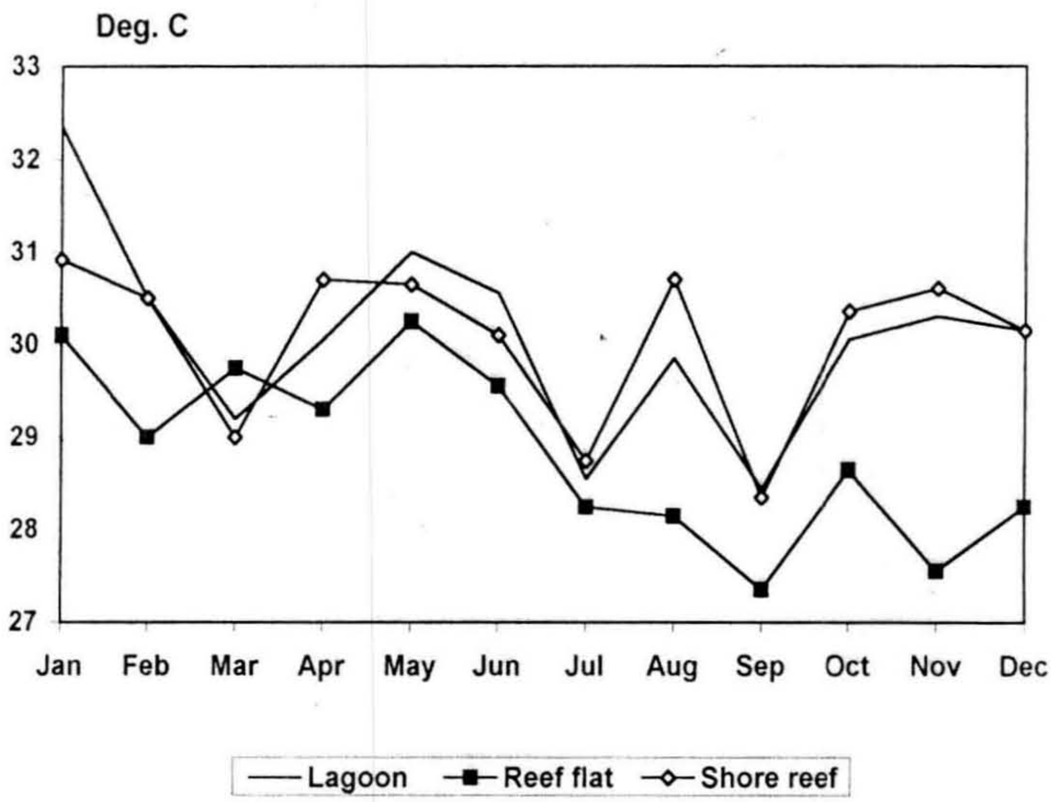


Fig. 3. Monthly variations in sea water temperature at the three regions of Minicoy

SALINITY

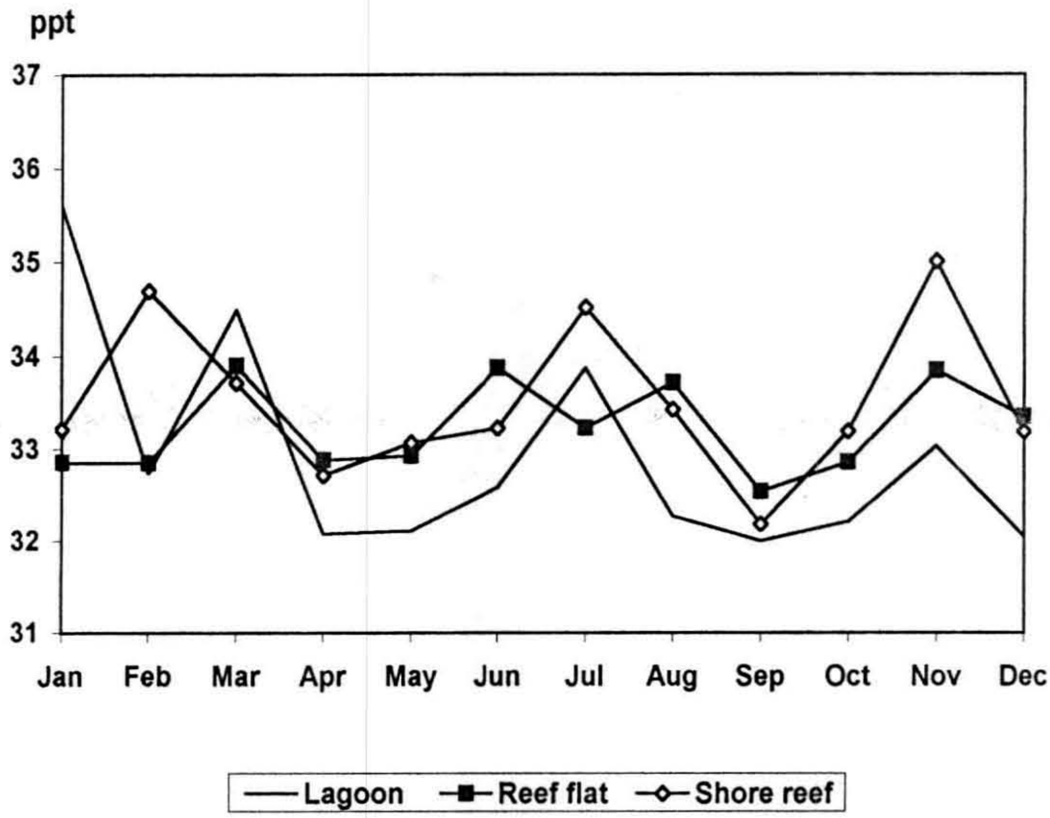


Fig. 4. Monthly variations in salinity at the three regions at Minicoy island

DISSOLVED OXYGEN

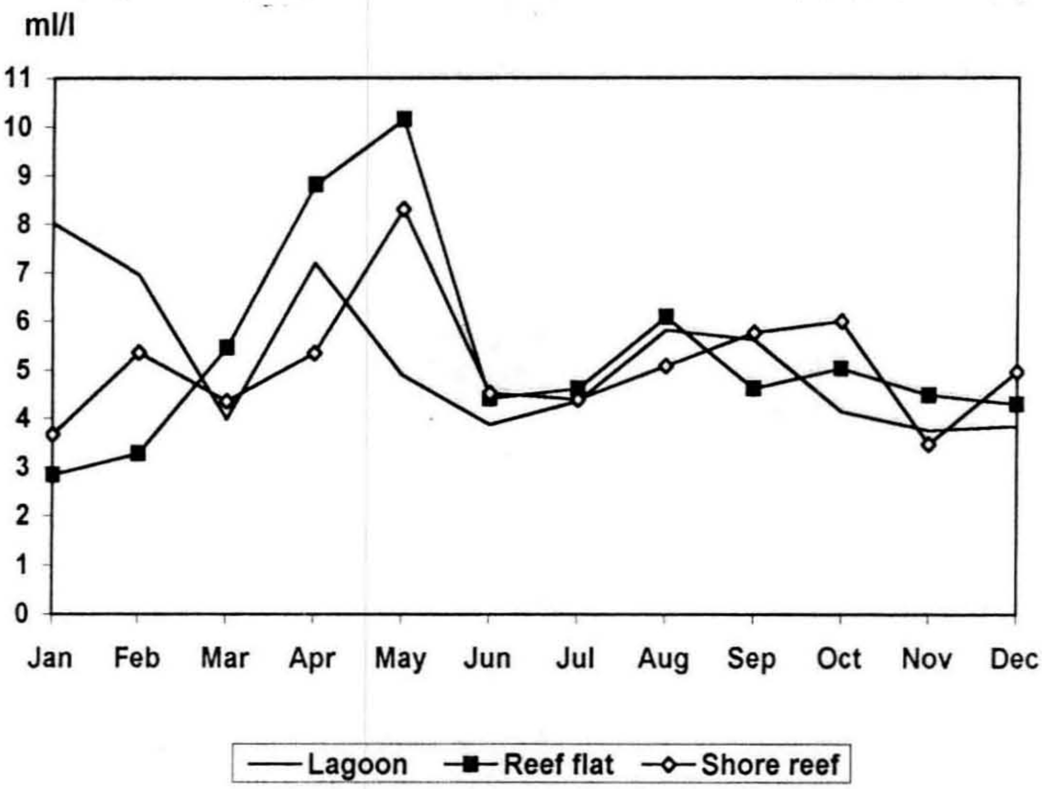


Fig. 5. Monthly variations in dissolved oxygen at the three regions of Minicoy

NITRITE

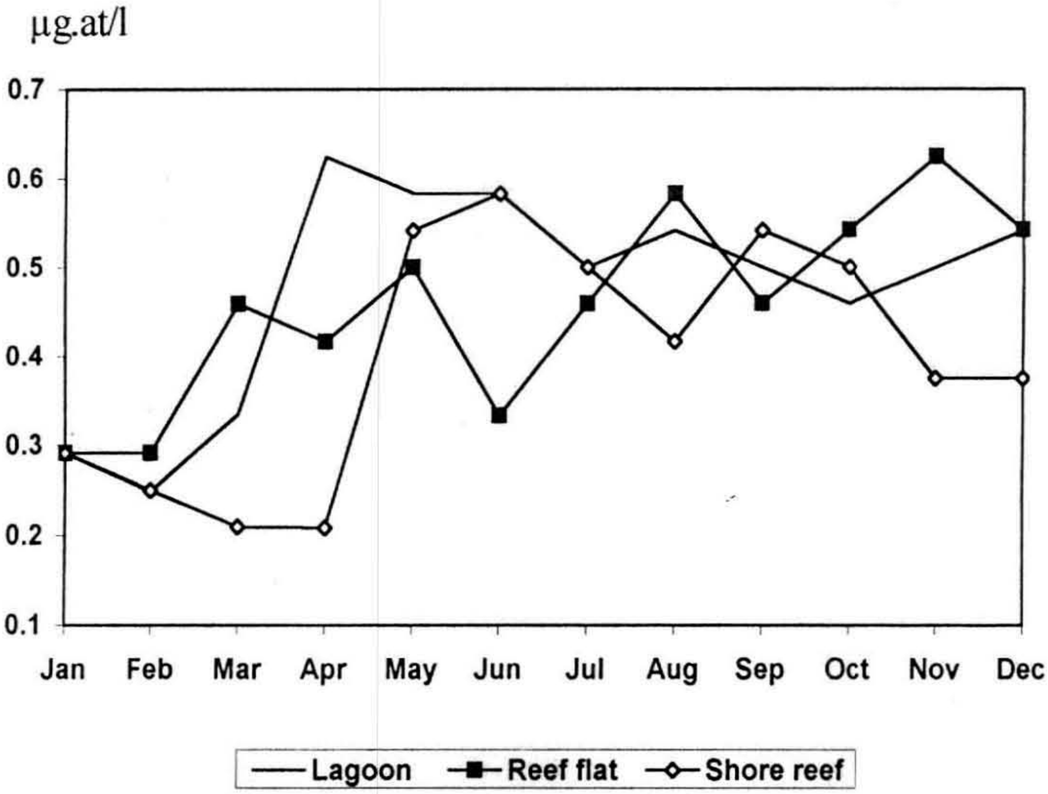


Fig. 6. Monthly variations in nitrite at the three regions of Minicoy

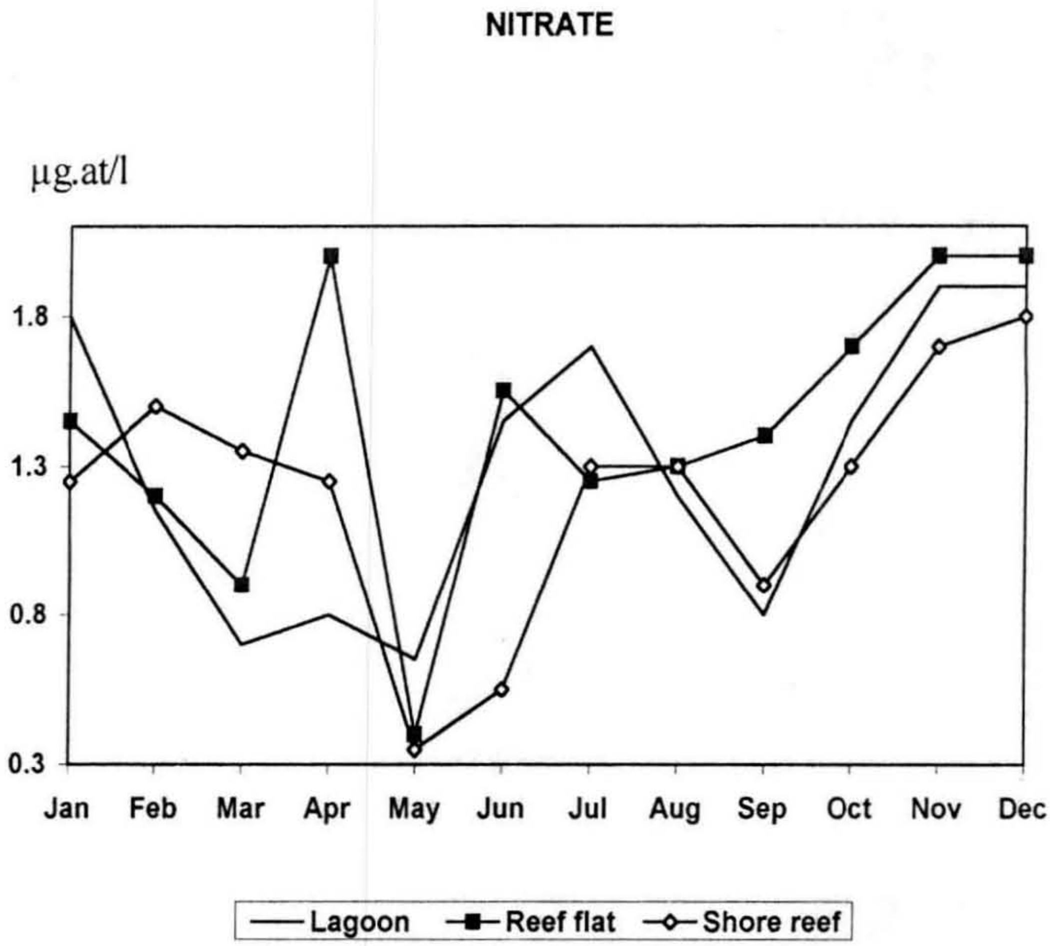


Fig. 7. Monthly variations in nitrate at the three regions of Minicoy

PHOSPHATE

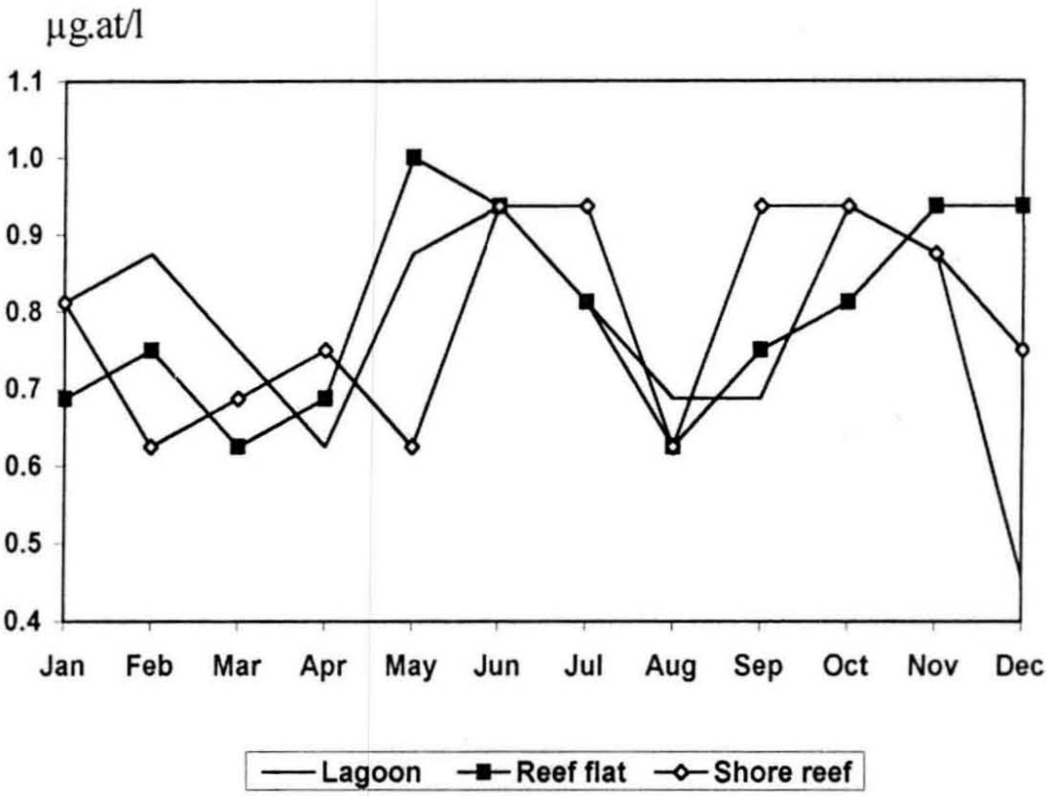


Fig. 8. Monthly variations in phosphate at the three regions of Minicoy

SILICATE

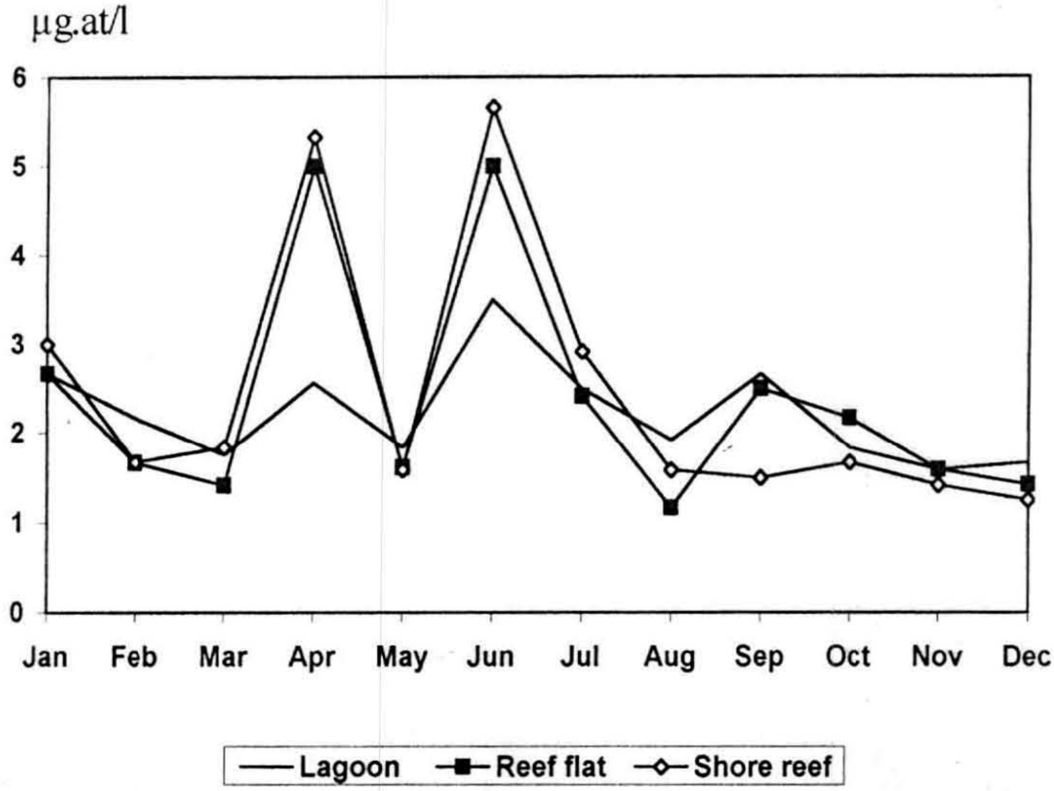


Fig. 9. Monthly variations in silicate at the three regions of Minicoy

low values were recorded in May and September. Monsoon months recorded maximum values of phosphates (Fig.8) and the values were lowest in February and August. As in the case of nitrate, silicate values (Fig. 9) also indicated definite peaks with high values in April and June and low values in March, May and August.

DISCUSSION

The water mass structure in the reefs and lagoons are determined by factors such as seasonality, regional precipitation and net radiation resulting in surface heating and cooling (Andrews and Pickard, 1990). Strong winds during the south west monsoon, the abundant light energy available in clear waters of the lagoon and complex current patterns around the islands of Lakshadweep will therefore have a strong influence on the water bodies. Water temperature during the present study showed only a narrow range in variation of only 2.6 ^{0}C. The temperature patterns of the three areas, i.e. lagoon, reef flat and shore reef indicate that they are more or less homogenous. It also indicates that the reef flat and shore reefs are not inundated by cool, nutritionally rich waters from the surrounding areas. The mean seasonal variations in temperature is also not large, the difference being only 0.89 ^{0} C. This lack of marked seasonality may indicate that the sustained precipitation during monsoon has no significant effects on the coral waters of Minicoy islands. Andrews and Gentien (1982) proposed three reasons for the unstratification of the lagoon waters.

Firstly, the nature of the shelf slope induces tidal mixing and wind stirring in areas away from the shore. Secondly, the shoreward speed of the cold waters may be such that they cannot penetrate well into the lagoon. Thirdly, the low frequency currents in the lagoons tend to mix the waters horizontally. There is virtually no information on the currents and on the circulation pattern of the lagoons of the Lakshadweep. Water circulation in the lagoon has been indicated as a source of variation for many hydrophysical parameters and their stratification (Von Arx, 1954 and Atkinson, 1981).

The anomaly of the existance of highly productive coral reef ecosystem in a nutrient poor ocean has long been a topic in the literature. Hatcher and Hatcher (1981) found that the reef is not dependent on the surrounding oceans for input of organic nitrogen, rather, it generates and retains available nitrogen in a manner which is dependent on its structure, the season and which is influenced by its benthic algal communities. At Minicoy, the nutrient showed distinct seasonal pattern although variations in space were insignificant. Nutrients of coral reefs have received considerable attention but they are restricted to reef systems such as Barrier reefs (Great Barrier Reef) and fringing reefs (Caribbean reefs). Although some concepts of these reefs apply to atoll, they have completely different characteristics and structure.

Inorganic phosphorous less than 0.4 μg at/ l is common in reef areas and at times so low that it approached the limit of detection (D'Elia and Wiebe, 1990). The range of phosphorous observed at Minicoy compares well with the values reported from other areas of the Indian Ocean (Johannes *et al.,* 1983 b; Rayner and Drew, 1984 and Wafar *et al.*, 1985). The phosphorous cycle, in general is effected both by chemical and biological processes (Webb, 1981). Phosphate concentration at different locations seems to show an increasing trend from premonsoon to postmonsoon months. Increase or decrease of phosphorous in the water in relation to depth and also the time of the day has been reported (Pilson and Betzer, 1973 and Atkinson, 1981). But major changes in nutrient levels were not observed during the present study. Johannes *et al.* (1983 b) observed that dissolved inorganic nutrient concentrations varied with season. They reported three patterns of nutrient flux: (1) Concentration dependent fluxes, (2) Fluxes variable over the diet cycle and (3) Neither.

Silicon dynamics of coral reefs have received less attention than nitrogen and phosphorous, primarily because, coral reef organisms are calcareous and not siliceous and silicon is not an essential element for most reef flora and fauna. As in the case of nitrogen and phosphorous, terrestrial run off or ground water may be a source of silicic acid. According to Johannes *et al.* (1983 a), nutrient uptake patterns in phytoplankton and benthic macroalgae is related to the dissolved nutrient concentrations. When community metabolism advances to a stage where there is no diet rhythm, silicate is always super abundant relative to community metabolism.

The results of the present study indicate that environmental variables such as temperature, salinity, dissolved oxygen and nutrients do not have a limiting role in the coral reef ecosystem. Although significant variations between seasons were observed for most of the parameters studied, these variations were minimal when compared to those in estuarine or coastal systems. The different regions of Minicoy lagoon and reef appear to be homogenous without distinct differences between them. The important nutrients such as nitrogen and phosphorous are not related to other environmental variables such as salinity or temperature indicating an in-situ production.

CHAPTER – II

DISTRIBUTION AND BIOMASS OF MACROALGAE

INTRODUCTION

The seaweeds comprise of four main groups of algae, each distinguished by the predominant colouring pigments in their cells. They are, Chlorophyta (green), Rhodophyta (red), and Pheophyta (brown) and Cyanophyta (blue-green algae). The economically important marine seaweeds belong to the red, brown and green algae.

For centuries various kinds of seaweeds have been put into use in the south and the south east Asian countries. The development of seaweed utility is favoured by their ready availability and proximity to centres of human population characteristically settled in coastal areas. The seaweeds that could be used for food were the first to be identified. Later other species were found to yield industrial, medicinal, pharmaceutical and cosmetic products.

The coastline and wide coastal shelves of many countries provide suitable environment for seaweed growth. The extensive shallow base coral reefs and lagoons characterised by slow to moderately strong currents and sandy coralline bottoms are ideal habitats for many economically important seaweeds (Rabanal and Trono Jr., 1983).

The economically most important seaweeds abound in habitats characterised by true marine waters where the salinity is uniformly high (32 - 35 ppt), although some species grow well in slightly brackish waters, such as the genus *Gracilaria* (red alga) and *Cheatomorpha, Cladophora* and *Enteromorpha* (green algae). Under both levels of salinity, clear seawater with moderate currents and good nutrient loading will be favourable (Rabanal and Trono Jr, 1983).

Shepherd and Womersley (1981) found that changes in biomass, coverage, species richness, percentage similarity and dominance with the communities were related to the degree of water movement and depth. Water movement is a major factor determining the local distribution and abundance of marine organisms (Gessner, 1955; Gurjanova, 1968 and Riedl, 1971). Schewenke (1971) lists four types of water motion that affect benthic algae. Wave action and tidal currents are probably the most important in determining the local distribution of seaweeds population (Mathieson *et al.,* 1977)

An understanding of the occurrence of seasonal changes in seaweed population is an important aspect of their biology. In the case of economic seaweeds such as *Hypnea,* which is in industrial demand as a carrageenan producer (Lerving *et al.,* 1969, Mshigeni,1974), such knowledge can be used as a basis for deciding period of commercial harvesting with maximum profit. Data on macro-algal biomass in seagrass communities, particularly coastal lagoons are limited despite recognition of their importance by several investigators (McRoy and Mac Millan, 1977) and (Den Hartog , 1979).The algae typical of these communities world wide include forms which can anchor in the sediments (e.g. *Chara*) and unattached entanglements of green and red algae, especially *Cheatomorpha* , *Cladophora* , *Enteromorpha* , *Gracilaria* and *Spyridia* (Hedgepath, 1957; Grontved, 1958; Dillon, 1971; Edwards, 1978; Den Hartog, 1979; Wallentinus, 1979 and Congdon and Mc Comb , 1981). Thorn- Miller *et al.* (1983) and Wittick, *et al.* (1989) have reported that many species show distinct latitudinal distribution in the north west Atlantic . In this region temperature has a strong latitudinal relationship. It has been suggested that environmental parameters influence the seasonal abundance of benthic algae in the tropics (De Wreede, 1976). Light and water temperature, especially temperature in the warmer months are most important in determining the seasonal changes in algal vegetation in Texas lagoon (Conover, 1964) and subtidal algal communities in Florida (Earle, 1969). Santelices (1977) stressed the importance of water movement as a seasonally significant factor in the tropics. Shallow vegetations were generally dominated by *Thalassia* and *Halimeda opuntia* (Kueaneu and Dibrot, 1995). Stephenson and Stephenson (1972) described the tropical and subtropical shores by its sea surface temperature which does not fall below 20° C and commonly exceeds 23.5° C. The study on the population of Tiahura reef (Moorea island, French Polynesia) showed that the environment effects the morphology and biology of the individual. Density and biomass as well as the abundance of the holdfast increased in the exposed sites while on the contrary, branching, plant size and individual species biomass decreased (Pyari, 1984). Banaimoon (1988) studied the marine algal flora of Khalf, P.D.R.Yemen and found that the growth of algae is most active from July to September. He also observed that the rocks appeared naked in May and June but covered with thick algal coverage in August and September. (Edward Drew 1995). Macroalgae were generally inconspicuous throughout the Chagos Archipelago. Anon, (1986) described that two year intervals between successive harvests are sufficient to yield plant of the desired commercial properties. It is observed in Antigua by John and Price (1979) that the vertical distribution patterns of the principal shore organisms observed around Antigua are similar to those recorded elsewhere in the Caribbean. Many of the same characteristic band zones forming organisms occur consistently on littoral rocks, despite very different degrees of exposure to wave action. During the five year study in Edward Islands, Canada McLachlan *et al.* (1987) estimated the standing stocks and observed little annual variation of either total biomass or individual components. The studies of Richard McCurt (1984) revealed that *Sargassum spp* are most abundant during winter in tropical regions and during summer months in Temperate Zone. The ecological studies in the inter-tidal rock pools at the isles of Shoals (USA) showed that the degree of exposure to wave action appeared to determine competition between individual species and grazing (Sze . 1980).

The major seaweed growing region in India are the coastal areas of Gujarat State from Veraval to Okha and Dwaraka and Tamil Nadu State from Mandapam to Kanyakumari and Gulf of Mannar Islands where many of the economically important seaweeds occur in harvestable quantities. In addition to these places the littoral and sublittoral rocky stretches in the vicinity of Mumbai, Karwar, Cannanore, Kovalam, Madras and Vishakapatanam are rich with of seaweeds growth (Umamaheswara Rao and Sreeramulu (1968).

Ecological studies have been carried out on the marine algal vegetation of the Mahabalipuram coast (Srinivasan, 1946), salt marshes at Madras (Krishnamurthy, 1954),Chilka Lake (Parija and Parija 1946),Okha, Porbander, Veraval, Mumbai areas (Misra, 1960),Vishakapatanam coast (Umamaheswara Rao and Sreeramulu 1964) and Okha (Gopalakrishnan, 1970) and Murthy *et al.,* 1978). The distribution pattern of marine algae on the shores of Pamban was given by Subbaramaiah *et al.* (1977). The changes on the tidal emergence and submergence, topography of the coast, surf action, levels at which the plants grow contribute much to the fluctuations in the growth behaviour of the algae (Chennubhota *et al.,* 1987). Gopinathan and Panigrahi (1983) surveyed the Andaman Nicobar Islands from Digilpur in the north to Campel Bay in the south.

The studies in Okha for intertidal algae revealed that environmental factors which influence accumulation of biomass and consequently primary production are temperature and dissolved oxygen (Murthy *et al.,* 1978). The study was to assess the zonation pattern, monthly variations in biomass of intertidal algae and to assess the effects of some ecological factors of the marine environment on the macroalgae. Kaliaperumal and Chennubhotla (1997) surveyed the Kerala coast to study the distribution and resource of seaweeds during May – June, 1988. They recorded 35 species belonging to 28 genera and 18 families from 15 localities of the Kerala coast. Jayachandran and Ramaswamy (1997) surveyed the Pondichery coast. Untawale *et al.* (1989) studied the ecology of intertidal benthic algae of northern Karnataka coast. Reddy et *al.* (1982) studied the beach stability along the coast from Ullal to Thannirbhavi near Mangalore and found that wind has direct and indirect effect since it makes the waves which in turn effect the fauna of the shore.

Seaweed resources of Lakshadweep islands have been assessed partially during 1977-1979 by the combined effort of Central Salt and Marine Chemical Research Institute and Department of Fisheries Lakshadweep. The survey was conducted in some of the inhabited islands covering a total area of 3570 ha both in the lagoon and the reef .The islands surveyed were Kavaratti, Agatti, Bangaram, Amini, Kadamat, Chetlat, Kiltan, Androth, Kalpeni and Minicoy. The survey revealed the biomass of standing crop for all the Lakshadweep islands covering a potential area of 1334 ha (Anon, 1979). Seaweed and seagrass resources of Lakshadweep group of islands viz. Chetlat, Kiltan, Kadamat, Amini, Bitra, Bangaram, Agatti, Androth, Kavaratti, Kalpeni, Suheli and Minicoy were reported by Kaliaperumal *et al.*, (1989).

In India seaweeds are used at present only for the production of agar and alginate. The seaweed industries offer employment to hundreds of people living in coastal villages. Agar and alginate are exported to earn good foreign exchange, (Kaliaperumal and Kalimuthu, 1997).

Studies on seaweeds have not been carried out in the islands for long periods. The present study was made with a view to estimate the abundance of algae in space and time and to provide information on the seasonal availability and its quantity for harvest of economically important species.

MATERIAL AND METHODS

Minicoy Island consists of the main island and an islet called Viringili in the southern reef flat area. It consists of a large lagoon of about 25 sq km area.

TOPOGRAPHY OF STATIONS

The study carried out from January to December 1998. Ten stations were selected along the coast of Minicoy with five stations in the lagoon side, one station in reef flat and four stations in shore reef at the eastern side. The island was mainly divided into 3 areas- (i) lagoon area in the western side (ii) reef flat area in the southern tip where the wave action is more and the water mixes from lagoon and outer sea. (iii) shore reef in the eastern side of the island near to the shore area (Plate - 1 to 3). Most of the areas are rocky except few places of sandy bottom. Open sea is on an average 30-60 m away from the shore. (Table 5).

Station 1: The place is locally known as Navodaya since Navodaya Vidyalaya is located nearby. The seagrass *Thalassia hemprichii* bed is on the north west side of the island. This area is partly protected by heavy wave action and currents by 80-100 m wide zone of large coral conglomerates. The substrate consisted mainly of corals and calcareous algal forms.

Station 2: The area is near to the village side from north and in the western side. The area is little deeper and *T.hemprichii* beds in two patches are available. Seaweed vegetation is present in this locality. The substratum is sandy and with calcareous algal vegetation.

Station 3: This station is situated in the lagoon side near to the fisheries jetty and with thick growth of seagrass *Cymodocea serrulata*. The substratum is sandy with algal populations. The fish waste and sewage from the Tuna canning factory are let out near this site.

Plate – 1

a. Aerial view of Minicoy lagoon side.

b. Close up view of Station No. 3

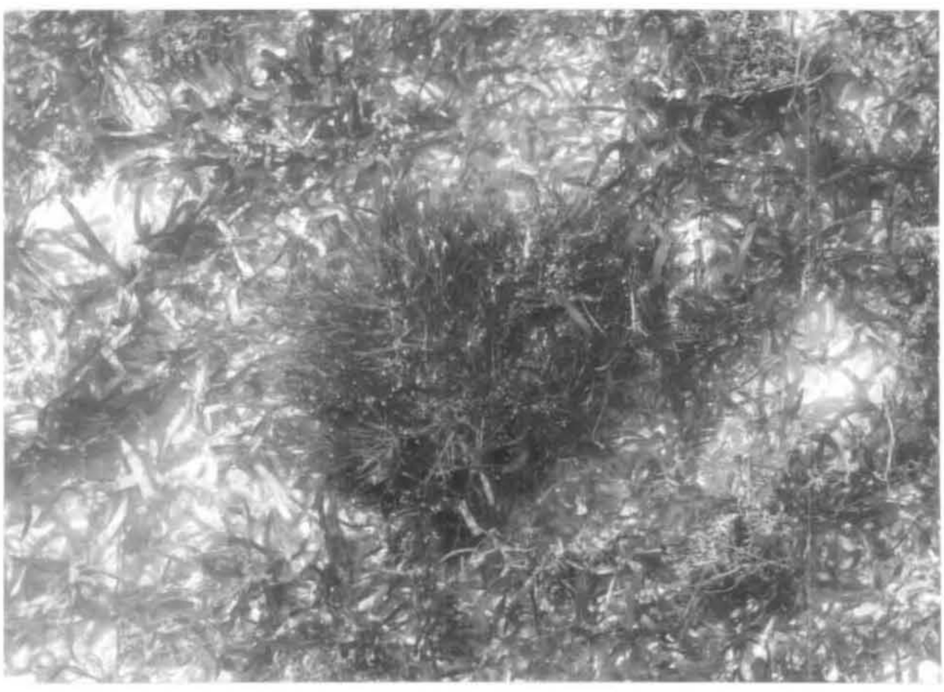


Plate – 2

a. Reef flat region of Minicoy

b. Close up view of Station No. 6

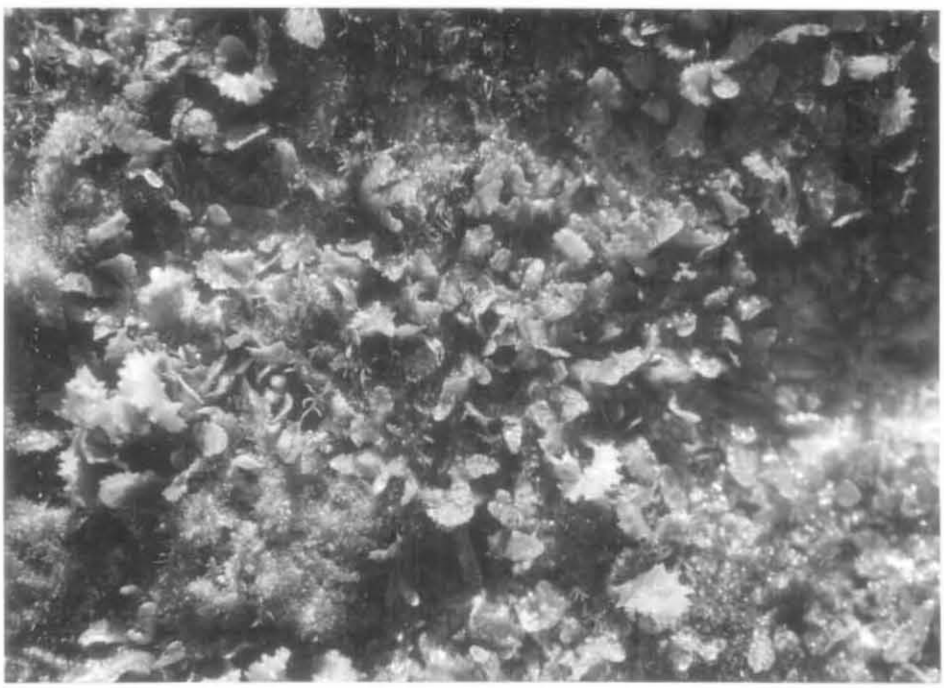


Table 5: A compilation of the characteristic of different algal communities (Stations 1 - 10) in 1998.

Parameters	1	2	3	4	5	6	7	8	9	10
Substratum										
Coral sand	+	+	+	+	+	–	+	+	–	–
Coral rubble	–	–	–	–	–	+	+	+	+	+
Coral boulders	–	–	–	–	–	+	+	+	+	+
Sea grass bed	+	+	+	–	+	–	–	–	–	–
Calcareous algal fragments	+	–	+	–	–	+	–	–	–	–
Muddy	–	–	–	+	+	–	–	–	–	–
Macroalgae										
Mean monthly number of species	5.58	2.67	4.08	2.91	4.5	2.92	5.0	4.8	5.8	9.0
Total number of species	16	13	10	10	13	4	15	15	18	19

+ present - absent

Station 4: This station is also in the western lagoon side towards the south of the island. Seagrasses occur in small quantities. The area is muddy in nature when compared to most of the other stations which are sandy with corals.

Station 5: This site is near to the lighthouse. The sea bottom at this locality is muddy with coral sand and *Cymodocea serrulata* vegetation. The area is protected with an extension of land but the currents during tides have more effect on this seagrass bed.

Station 6: This station is in reef flat area where there is no seagrass growth. The substratum is rocky with little quantity of algae. The area is near to the southern tip and Viringili Island is near to this station.

Station 7: It is located in the shore reef where direct wave action is prevalent. Most of the eastern side is rocky except some patches of sandy bottom with seagrass *Cymodocea serrulata* along with other seaweeds.The substratum is with coral boulders, rubbles and calcareous algal growth.

Station 8: This station is on the south-eastern side of the island with a smaller patch of seagrass (*Thallasia*) bed bordered by a sandy area with coral boulders. The substratum consists of coral sand and exposed during low tides.

Station 9: This station is situated in the middle of the island on the eastern side. The substratum is rocky with coral boulders of big size. The wave action is more, as the width of the shore reef area is less. Calcareous algae and seagrass are absent. Coral rubbles are present during monsoon period.

Station 10: This site is near the eastern side jetty of the island. The substratum is rocky with very large coral boulders. The wave action is comparatively more since the width here also is less. Coral rubbles are also present. The algal species are found to be abundant in this region.

In the present study observations were made in all stations at fortnightly intervals. Seaweed samples were collected by random sampling method. Quadrat of 25x25 cm size was randomly placed and seaweeds were collected from 5 qudrats at each station. In the laboratory samples from each quadrat was thoroughly cleaned to remove the fauna, stones, debris etc. Then the species were sorted out and the fresh weight of individual species was taken. The samples were preserved in 4 % seawater formalin for detailed examination in the laboratory.

RESULTS

A total number of 38 algal species were recorded during the present study. This included 14 species of *Chlorophyceae*, 5 species of *Phaeopyceae,* 18 species of *Rhodophyceae and* one species of *Cyanophyceae.*

The percentage occurrences of individual algal species in terms of wet weight in different stations were presented in (Table 6 to 15) and monthly distribution of species in maximum quantity in each station is shown in (Figures 10 to 19).

Totally sixteen species were recorded from Station 1 during the period of the study. The dominant algae occurring in most of the months were *Gracilaria edulis, Acanthophora spicifera, Laurencia papillosa, Lyngbya confervoides* and *Caulerpa recemosa.* (Fig.10). *Gracilaria edulis* was observed throughout the year except in May. *Acanthophora spicifera* occurred for seven months with maximum percentage in January and October. *Laurencia papillosa* was found throughout the year except in November. The peak occurrence was in July (55.6%). *Lyngbya confervoides* was more in quantity during April to June. *Caulerpa recemosa* was observed for only 6 months and it was not

Table 6 : Percentage occurrence of algae (g wet weight) at Station 1.

Alga	Jan	Feb	Mar	Apr	May	Jun	Jun	Aug	Sep	Oct	Nov	Dec
Chaetomorpha linoides	29.6		7.8	14.2	-	-	-	-	-	-	-	-
Chaetomorpha aerea	-	31.4	-	-	-	-	-	-	-	-	-	-
Ulva lactuca	0.3	-	-	-	-	-	-	-	-	-	-	-
Caulerpa recemosa	0.1	10.0	-	-	-	-	-	-	36.7	15.2	38.1	24.5
Caulerpa peltata	-	-	-	-	-	-	-	-	5.0	-	-	20.4
Enteromorpha compressa		-	-	-	-	-	-	4.4	-	-	-	-
Dictyota dichotoma	-	2.4	-	-	-	-	-	-	-	-	-	-
Padina boergesenii	-	-	-	-	-	-	-	-	4.0	-	-	-
Gracilaria edulis	36.2	24.0	81.2	9.1	-	1.8	37.0	53.3	37.6	44.7	43.5	32.7
Gracilaria corticata	1.9	1.3	-	-	-	-	-	13.3	-	-	-	-
Acanthophora spicifera	24.5	1.6	-	-	-	10.6	-	-	9.9	23.9	16.3	10.2
Laurencia papillosa	3.6	18.0	6.6	6.9	4.8	14.1	55.6	20.3	7.0	15.2	-	12.3
Hypnea valentia	3.0	3.7	1.0	-	-	-	-	-	-	-	-	-
Hypnea musciformis	0.8	3.1	-	-	-	-	-	-	-	-	-	-
Jania capillacea	-	-	-	-	-	-	-	-	-	-	2.2	-
Lyngbya confervoides	-	2.3	3.3	69.9	95.2	73.6	7.4	6.7	-	-	-	-

Table 7 : Percentage occurrence of algae (g wet weight) at Station 2.

Alga	Jan	Feb	Mar	Apr	Ma	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chaetomorpha. linoides	-	-	4.0	21.3	-	-	-	-	-	-	-	-
Chaetomorpha aerea	53.1	2.6	-	-	-	-	-	-	-	-	-	-
Ulva lactuca	0.4	1.8	-	-	-	-	-	-	-	-	-	-
Caulerpa recemosa	0.4	-	-	-	-	-	-	57.1	100	-	-	-
C. peltata	0.5	-	-	-	-	-	-	-	-	-	-	-
Boergesenii forbesii	2.1	-	-	-	-	-	-	-	-	-	-	-
Gracilaria edulis	40.0	83.5	51.8	-	-	-	-	-	-	-	-	-
Gracilaria corticata	0.3	-	-	-	-	-	-	-	-	-	-	-
Acanthophora spicifera	1.4	-	-	-	-	-	-	-	-	-	-	-
Laurencia papillosa	1.53	1.1	5.7	10.7	-	-	-	-	-	-	-	-
Hypnea valentiae	2.8	1.9	2.9	-	-	-	-	-	-	-	-	-
Hypnea musciformis	0.2	2.6	-	-	-	-	-	-	-	-	-	-
Lyngbya confervoides	-	4.1	35.7	68.1	100	100	100	42.9	-	-	-	-

Table 8 : Percentage occurrence of algae (g wet weight) at Station 3.

Alga	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ulva lactuca	0.1	-	-	-	-	-	-	-	-	-	-	-
Enteromorpha compressa	-	-	-	-	-	-	8.5	2.7	-	3.5	-	-
Chaetomorpha antennina	-	-	-	-	-	-	10.3	-	12.1	-	9.3	8.8
Chaetomorpha linoides	-	-	-	-	-	-	-	-	-	7.0	3.7	-
Chaetomorpha recemosa	-	0.9	-	-	-	-	-	-	-	-	-	-
Halimeda gracilis	24.0	51.8	31.6	25.7	20.5	28.7	69.8	24.3	-	26.3	24.1	31.6
Gracilaria edulis	9.4	2.8	1.8	-	-	-	-	-	-	-	-	8.8
Gracilaria corticata	8.5	3.3	-	-	-	-	-	-	-	-	-	3.5
Gracilaria crassa	43.3	33.1	50.2	31.1	12.4	56.2	19.4	73.0	87.9	63.2	63.0	47.4
Laurencia papillosa	0.2	-	-	-	-	-	-	-	-	-	-	-
Lyngbya confervoides	14.8	8.2	16.0	41.5	67.2	15.2	-	-	-	-	-	-

Table 9 : Percentage occurrence of algae (g wet weight) at Station 4.

Alga	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chaetomorpha aerea	38.5	5.3	-	-	-	-	-	-	-	-	-	-
Chaetomorpha antennina	-	6.7	-	-	-	-	-	-	-	-	-	-
Chaetomorpha linoides	-	-	21.0	11.1	1.7	46.9	-	28.6	-	-	-	59.5
Cladophora fascicularis	38.5	34.6	21.0	4.8	2.4	-	14.3	42.9	81.6	-	-	35.7
Halimeda gracilis	-	-	-	-	-	-	-	-	-	-	-	-
Turbinaria ornata	0.5	9.4	-	-	-	-	-	-	-	-	-	-
Acanthophora spicifera	7.6	-	-	-	-	-	-	-	-	-	-	-
Hypnea. valentia	5.1	-	-	-	0.9	-	-	-	18.4	-	-	-
Gracilaria edulis	-	20.0	-	-	-	-	-	-	-	-	-	-
Tolypocladia.. glomerulata	-	-	-	-	-	-	-	-	-	-	-	4.8
Lyngbya confervoides	9.8	20.0	58.0	84.1	95.1	53.2	85.7	28.7	-	-	-	-

Table 10 : Percentage occurrence of algae (g wet weight) at Station 5.

Alga	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chaetomorpha linoides	57.3	31.6	34.3	27.9	-	-	47.6	100	0.3	35.7	42.9	50.0
Chaetomorpha aerea	0.9	-	-	-	-	-	-	-	17.4	-	-	-
Chaetomorpha antennina	-	0.7	2.81	-	39.9	-	-	-	-	-	-	-
Caulerpa taxifolia	0.4	-	-	-	-	-	-	-	-	-	-	-
Caulerpa fasciculari	2.1	4.2	-	-	0.6	-	28.6	-	5.7	64.3	28.6	30.0
Enteromorpha compressa	-	1.8	-	-	-	-	-	-	-	-	-	-
Halimeda gracilis	12.8	17.3	21.0	-	2.7	-	-	-	-	-	-	-
Turbinaria ornata	5.8	13.1	6.3	-	-	-	-	-	-	-	-	-
Acanthophora spicifera	4.8	7.7	6.0	-	-	-	-	-	28.4	-	-	-
Laurencia papillosa	14.8	-	-	15.5	3.8	100	23.8	-	47.3	-	14.3	20
Gracilaria edulis	-	12.5	11.7	-	-	-	-	-	-	-	-	-
Hypnea valentia	-	-	-	-	1.4	-	-	-	1.0	-	14.3	-
Lyngbya confervoides	1.6	11.3	17.9	56.7	51.6	-	-	-	-	-	-	-

Table 11. Percentage occurrence of algae (g wet weight) at Station 6.

Alga	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Halimeda gracilis	81.5	68.9	67.8	80.7	90.7	63.2	24.6	7.9	16.0	15.2	24.1	42.9
Turbinaria ornata	8.8	31.1	31.2	19.3	-	16.3	69.2	86.9	83.9	78.3	69.0	42.9
Sargassum duplicatum	-	-	-	-	0.5	0.3	1.5	-	-	-	-	-
Gelidiella acerosa	9.7	-	-	-	0.8	20.2	4.6	5.3	0.1	6.5	6.9	14.3

Table 12 : Percentage occurrence of algae (g wet weight) at Station 7

Alga	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chaetomorpha antennina	-	5.8	13.3	4.68	13.7	2.7	-	-	-	-	-	-
Cladophora fascicularis	3.8	-	-	-	-	-	-	-	-	-	-	-
Caulerpa cupresoides	-	-	-	-	-	11.4	-	-	-	-	-	-
Caulerpa sertulariodes	-	-	-	-	-	-	3.2	3.2		2.8	-	-
Enteromorpha compressa	-	-	-	-	-	-	1.3	9.5	-	-	-	-
Halimeda gracilis	79.3	85.0	68.4	62.2	90.6	69.8	23.9	6.4	25.0	22.2	76.9	33.3
Padina boergesenii	6.2	-	-	-	-	-	-	-	0.3	5.6	7.7	-
Sargassum duplicatum	0.4	2.1	-	-	-	-	-	4.8	-	-	-	-
Turbinaria ornata	-	-	-	-	-	-	22.5	11.1	70.4	-	-	-
Acanthophora spicifera	4.6	-	-	-	-	2.5	4.0	15.9	-	-	-	2.6
Gelidiella acerosa	1.6	7.1	22.4	24.4	4.7	2.5	9.9	19.1	1.0	11.1	15.4	10.3
Laurencia papillosa	4.2	-	-	-	-	-	-	-	-	-	-	-
Laurencia obtusa	-	-	-	-	-	-	2.7	6.4	-	-	-	-
Laurencia ceylanica	-	-	-	-	-	-	26.5	23.8	3.3	58.3	-	53.9
Jania capillaceae	-	-	-	-	-	-	6.6	-	-	-	-	-

Table 13 : Percentage occurrence of algae (g wet weight) at Station 8

Alga	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chaetomorpha linoides	-	-	-	-	-	6.0	-	-	-	-	-	-
Chaetomorpha antennina	-	-	-	-	1.4	-	-	2.6	-	-	-	-
Enteromorpha compressa	-	-	-	-	-	-	-	1.7	-	-	-	-
Cladophoropsis zollingeri	-	-	-	-	-	6.0	-	-	-	-	-	-
Halimeda gracilis	70.5	76.1	72.1	67.8	88.2	30.1	1.3	6.1	55.8	25.0	10.5	5.2
Rosenbingea intricata	-	3.0	-	-	-	-	-	-	-	-	-	-
Turbinaria ornata	-	-	-	-	-	-	51.5	34.5	-	-	18.4	32.8
Padina boergesenii	0.4	-	-	-	-	11.8	14.2	12.9	-	-	5.3	1.7
Sargassum duplicatum	-	-	-	-	0.9	-	-	5.2	-	-	-	-
Acanthophora spicifera	25.1	-	-	-	-	-	-	7.8	-	-	-	-
Laurencia papillosa	4.0	6.1	6.6	15.5	-	-	8.6	-	-	-	-	-
Gelidiella acerosa	-	14.8	21.3	16.6	9.6	-	23.8	-	4.3	4.6	5.3	3.5
Laurencia ceylanica	-	-	-	-	-	-	-	29.3	25.3	45.5	47.4	43.1
Laurencia obtuse						46.2	-	-	13.6	11.4	7.9	8.6
Asparogopsis taxiformis	-	-	-	-	-	-	-	-	1.0	13.6	5.3	5.2

Table 14 : Percentage occurrence of algae (g wet weight) at Station 9

Alga	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Enteromorpha compressa	-	-	-	-	-	-	-	1.8	-	-	-	-
Cladophoropsis zollingeri	-	-	-	-	-	-	1.7	2.9	-	-	-	-
Sargassum duplicatum	-	0.9	11.0	-	-	-	11.1	15.9	54.9	14.0	16.7	15.1
Amphiroa fragilissima	-	-	-	-	-	6.0						
Chaetomorpha aerea	-	-	-	-	-	13.8	-	-	-	-	-	-
Halimeda gracilis	-	0.9	-	-	7.8	-	-	-	-	-	-	-
Padina boergesenii	14.8	6.5	27.5	32.3	11.7	5.2	14.1	4.7	-	2.0	1.5	3.8
Rosenvingea intricata	-	1.6	0.9	-	-	-	-	-	-	-	-	-
Turbinaria. ornata	51.6	6.9	-	8.1	-	3.5	13.3	33.6	32.3	22.7	30.3	18.9
Gelidiopsis variabilis	-	-	-	-	-	-	1.7	5.9	-	-	-	-
Gelidiella acerosa	24.6	83.9	61.0	59.7	80.5	30.9	28.1	3.5	5.7	-	10.6	1.9
Acanthophora spicifera	7.4	-	-	-	-	18.0	14.7	3.5	-	-	-	-
Jania capillacea	-	-	-	-	-	13.2	-	-	-	-	-	-
Asparogopsis taxiformis	-	-	-	-	-	-	-	-	-	4.7	9.1	3.8
Gelidium pusillum	-	-	-	-	-	6.0	-	-	-	-	-	-
Centroceros clavulatum	-	-	-	-	-	-	11.9	2.4	-	-	-	-
Laurencia ceylanica	-	-	-	-	-	-	3.4	25.9	-	40.0	31.8	56.6
Laurencia obtusa	-	-	-	-	-	-	-	-	7.1	16.7	-	-

Table 15 : Percentage occurrence of algae (g wet weight) at Station 10

Alga	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chaetomorpha aerea	49.3	20.6	-	-	-	-	-	-	6.3	-	-	-
Chaetomorpha antennina	-	9.9	-	-	-	-	-	-	-	-	-	-
Chaetomorpha linoides	-	-	9.3	15.4	-	-	-	-	0.7	12.5	5.4	2.0
Cladophoropsis zollingeri	-	-	-	9.0	-	13.6	1.2	6.5	1.2	8.0	1.8	-
Ulva lactuca	-	2.8	2.7	1.3	0.9	1.1	-	-	3.3	0.5	-	2.0
Enteromorpha compressa	-	0.7	-	-	-	6.2	2.4	5.6	-	-	-	-
Padina boergesenii	-	0.7	-	-	-	-	-	-	9.6	-	-	-
Acanthophora spicifera	31.2	-	-	-	-	-	1.4	10.3	3.9	9.5	14.3	6.1
Gelidiella acerosa	19.4	62.4	36.0	19.4	77.5	15.7	5.97	4.7	-	13.2	8.9	6.1
Laurencia papillosa	0.53	3.6	9.3	9.7	-	20.2	4.3	3.7	0.2	10.7	10.7	6.1
Laurencia obtuse	-	-	13.3	9.0	7.9	3.6	-	-	10.4	7.5	5.4	8.2
Laurencia ceylanica	-	-	-	-	-	-	7.5	14.0	-	25.0	24.8	53.1
Hypnea valentia	-	-	-	-	-	-	0.5	4.3	-	-	-	-
Gelidiopsis variabilis	-	-	10.6	11.6	1.7	5.4	5.3	11.4	7.1	5.0	3.6	-
Asparogopsis taxiformis	-	-	-	-	-	3.1	9.6	17.7	17.8	9.99	10.7	10.2
Champia sp	-	-	-	-	-	19.1	6.6	4.7	29.6	2.1	10.7	6.1
Jania capillaceae	-	-	18.7	24.5	12.1	2.7	27.4	13.1	9.9	7.5	3.6	-
Gracilaria corticata	-	-	-	-	-	-	27.2	4.1	-	-	-	-
Amphiroa fragilissima	-	-	-	-	-	9.4	-	-	-	-	-	-

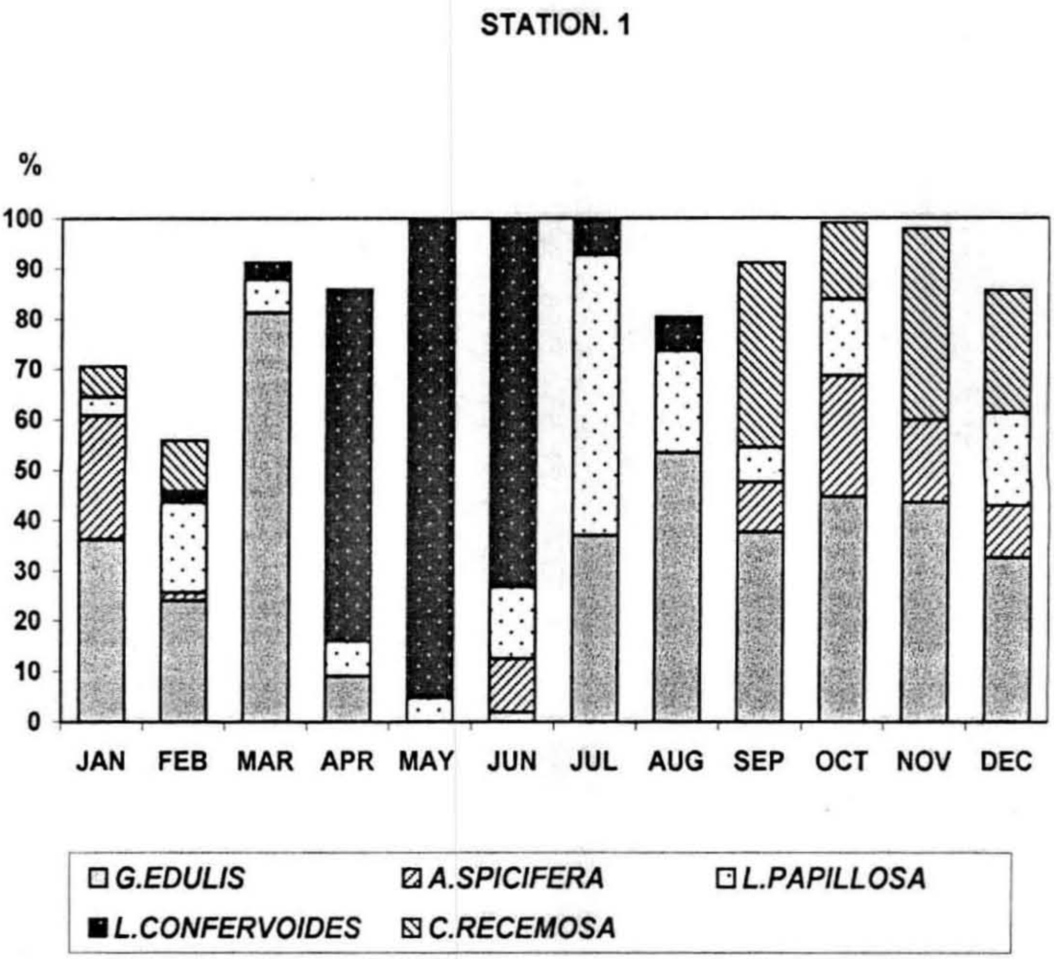


Fig. 10 Monthwise percentage availability of dominant macro algae in Station 1 at Minicoy

STATION. 2

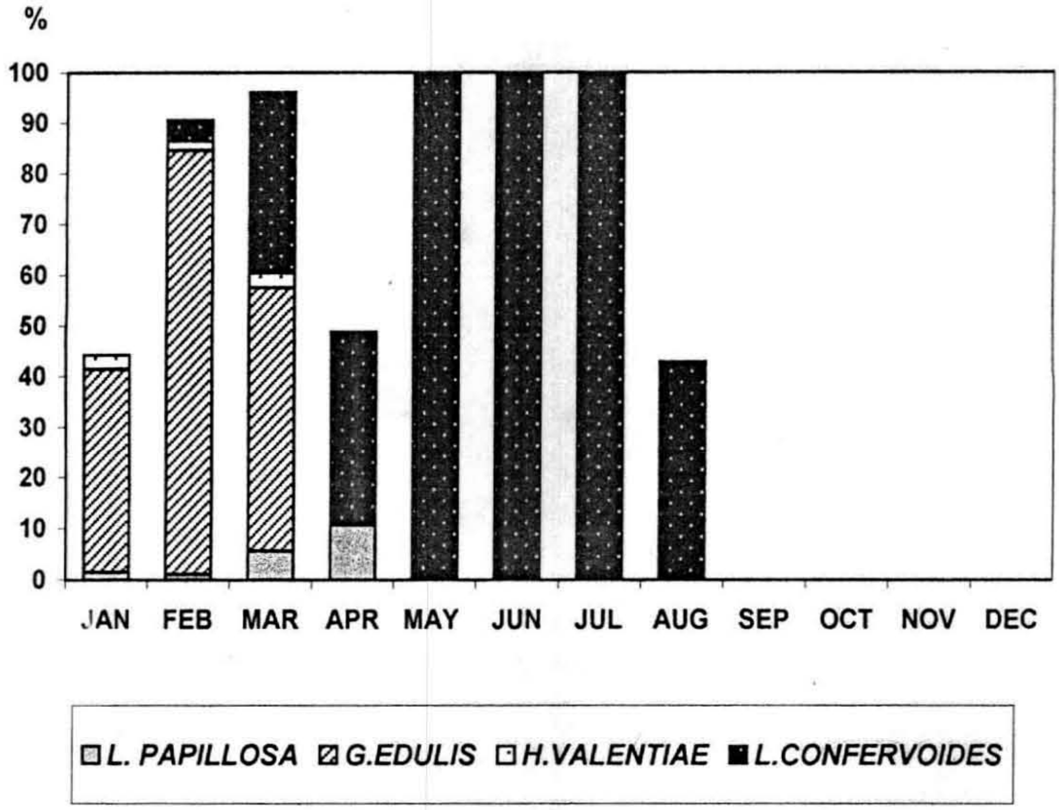


Fig. 11 Monthwise percentage availability of dominant macro algae in Station 2 at Minicoy

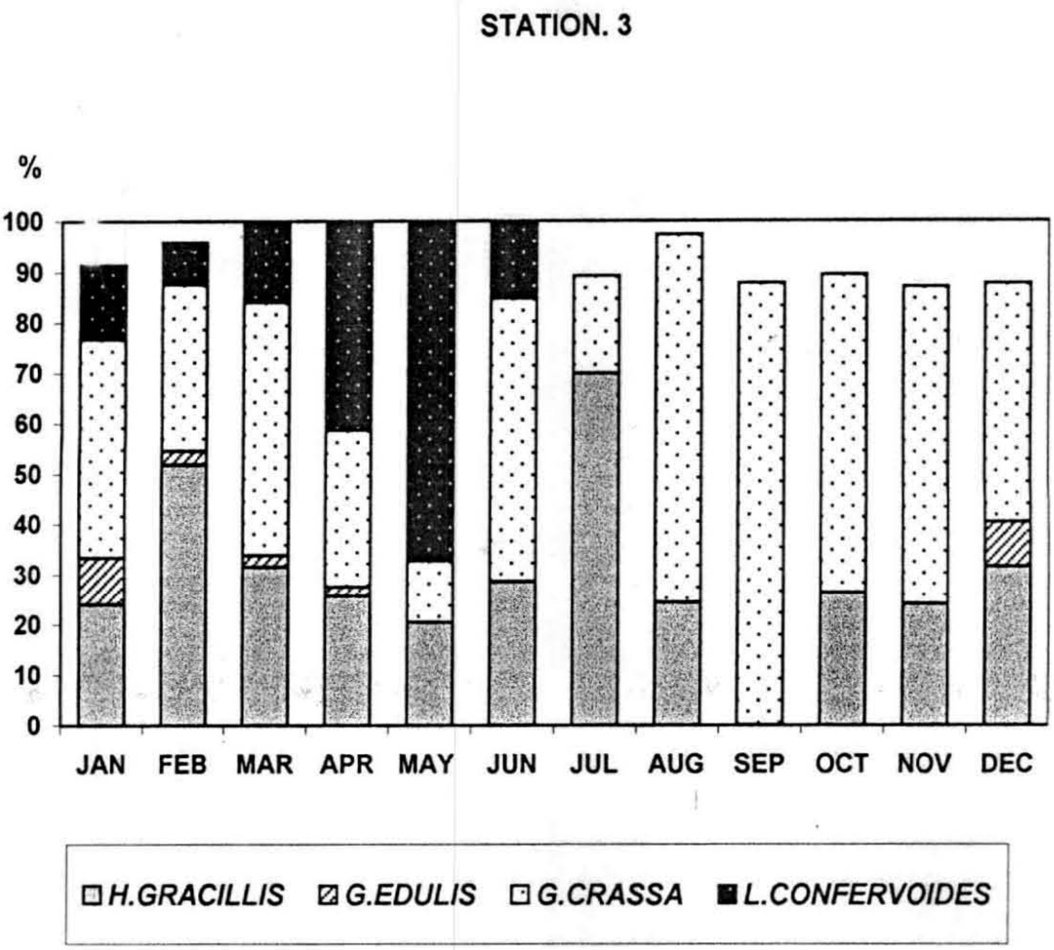


Fig. 12 Monthwise percentage availability of dominant macro algae in Station 3 at Minicoy

STATION. 4

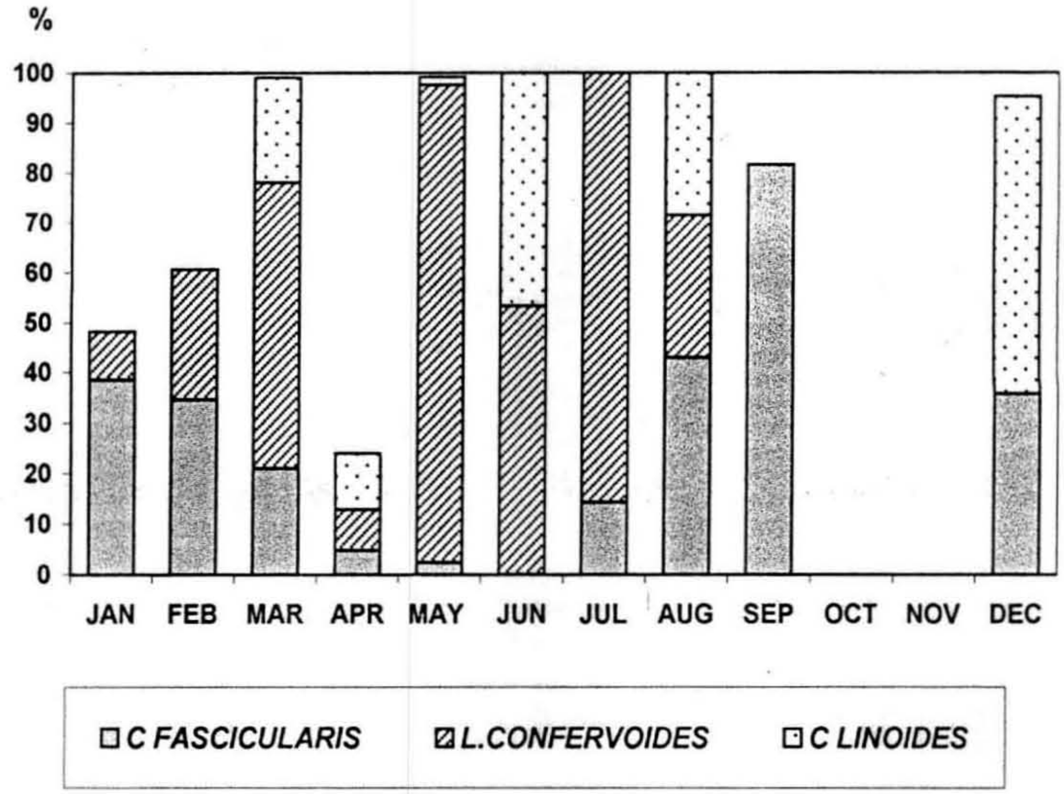


Fig. 13 Monthwise percentage availability of dominant macro algae in Station 4 at Minicoy

STATION. 5

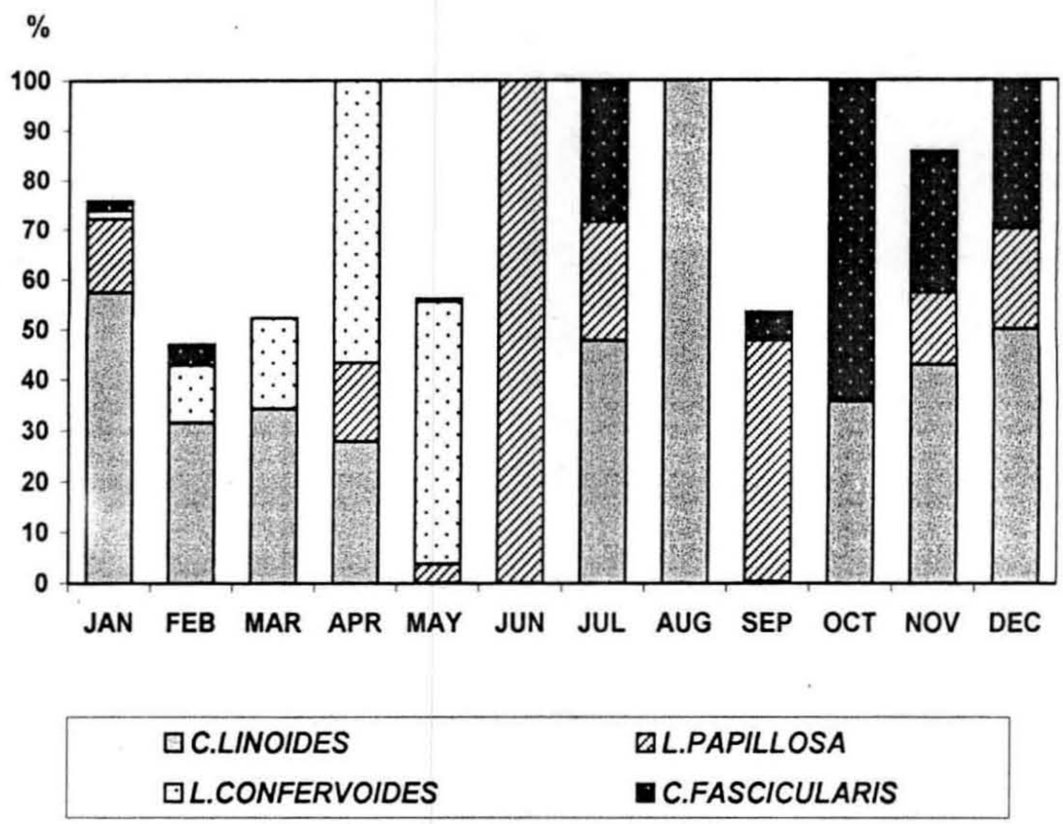


Fig. 14 Monthwise percentage availability of dominant macro algae in Station 5 at Minicoy

STATION. 6

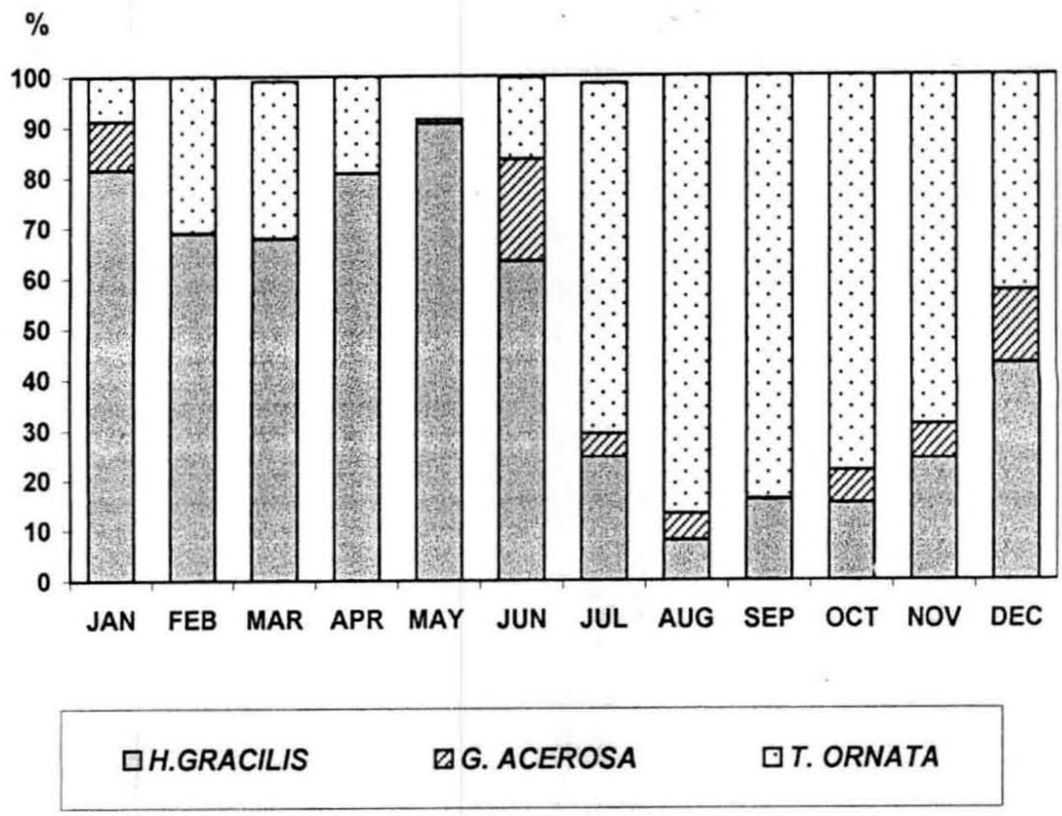


Fig. 15 Monthwise percentage availability of dominant macro algae in Station 6 at Minicoy

STATION. 7

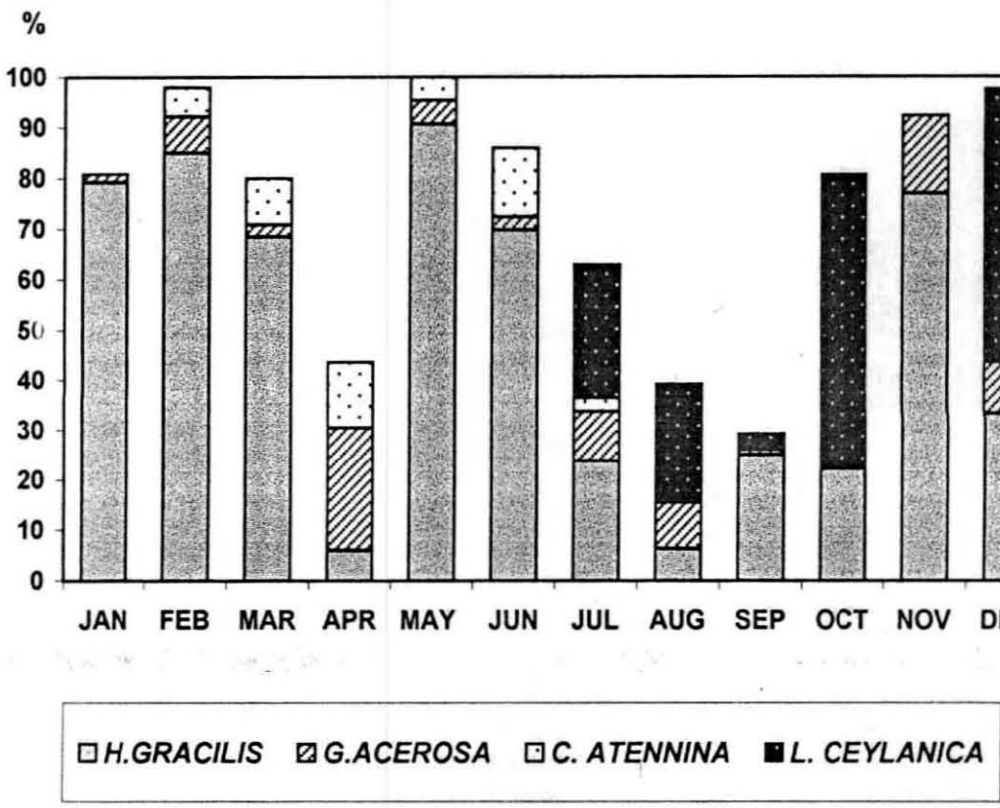


Fig. 16 Monthwise percentage availability of dominant macro algae in Station 7 at Minicoy

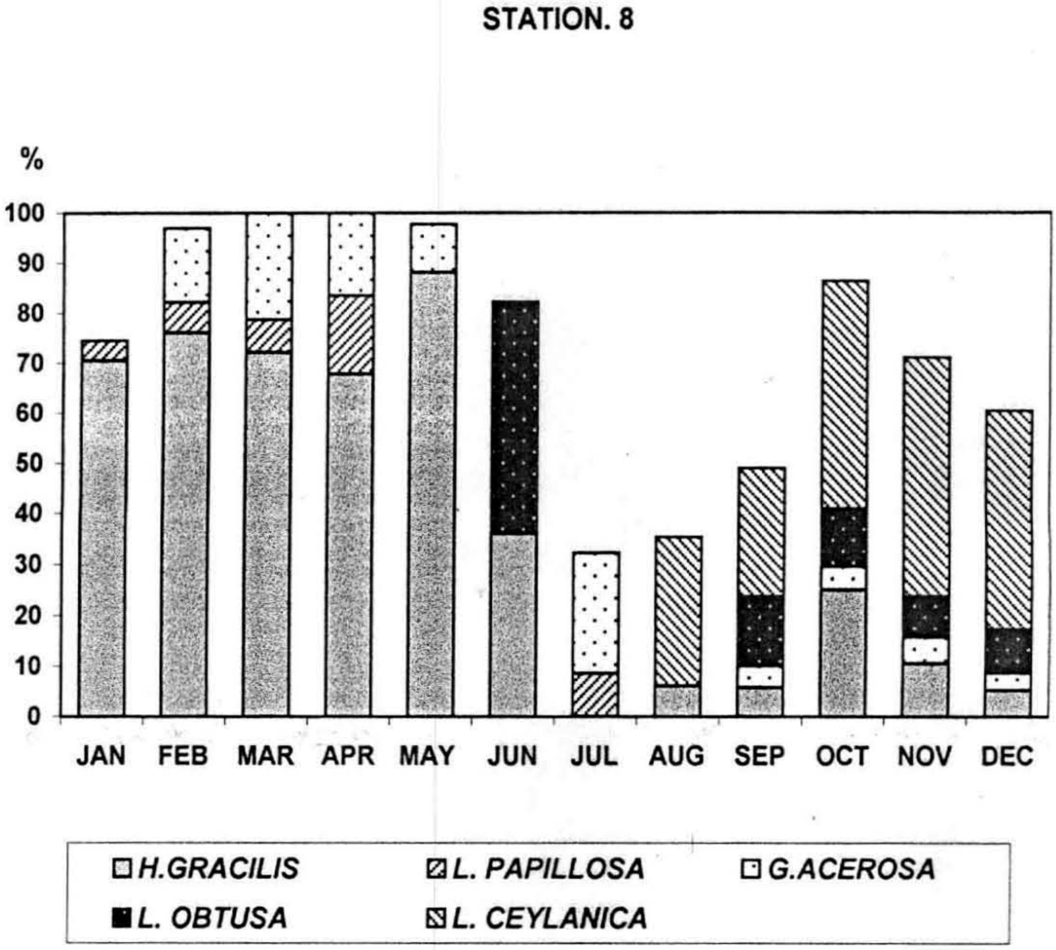


Fig. 17 Monthwise percentage availability of dominant macro algae in Station 8 at Minicoy

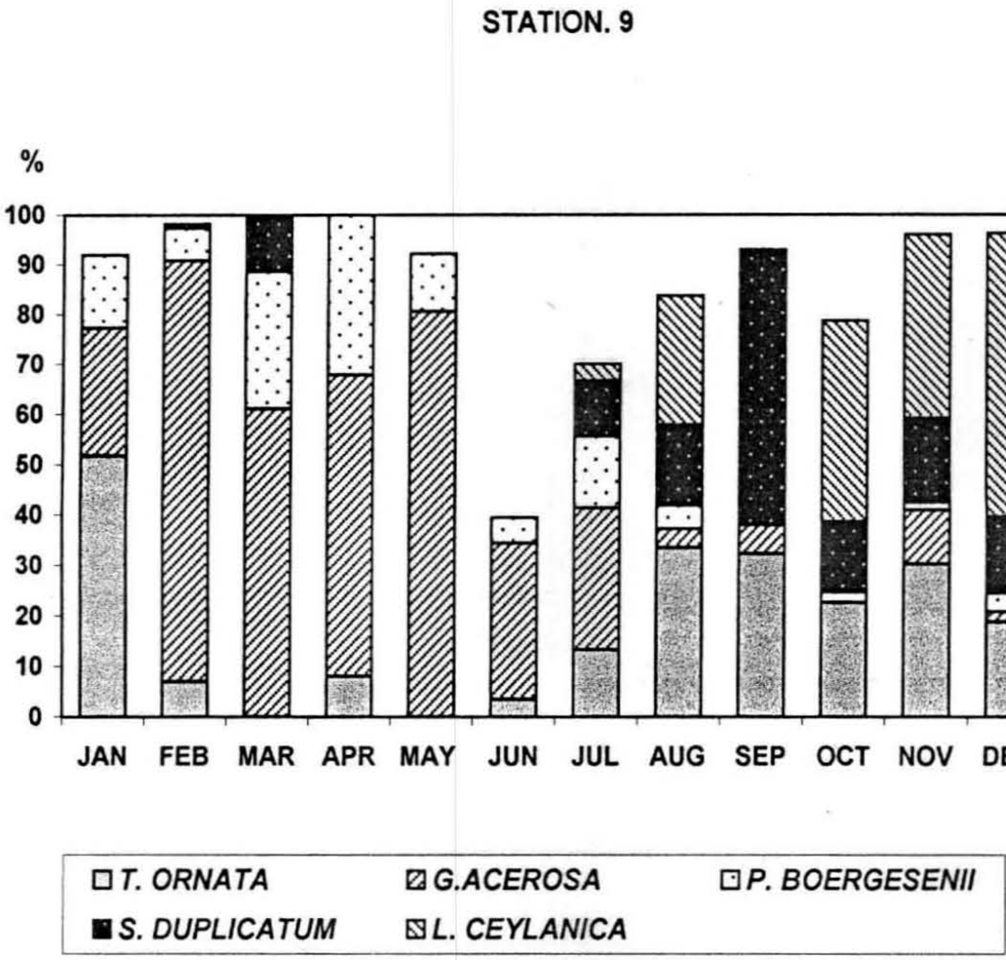


Fig. 18 Monthwise percentage availability of dominant macro algae in Station 9 at Minicoy

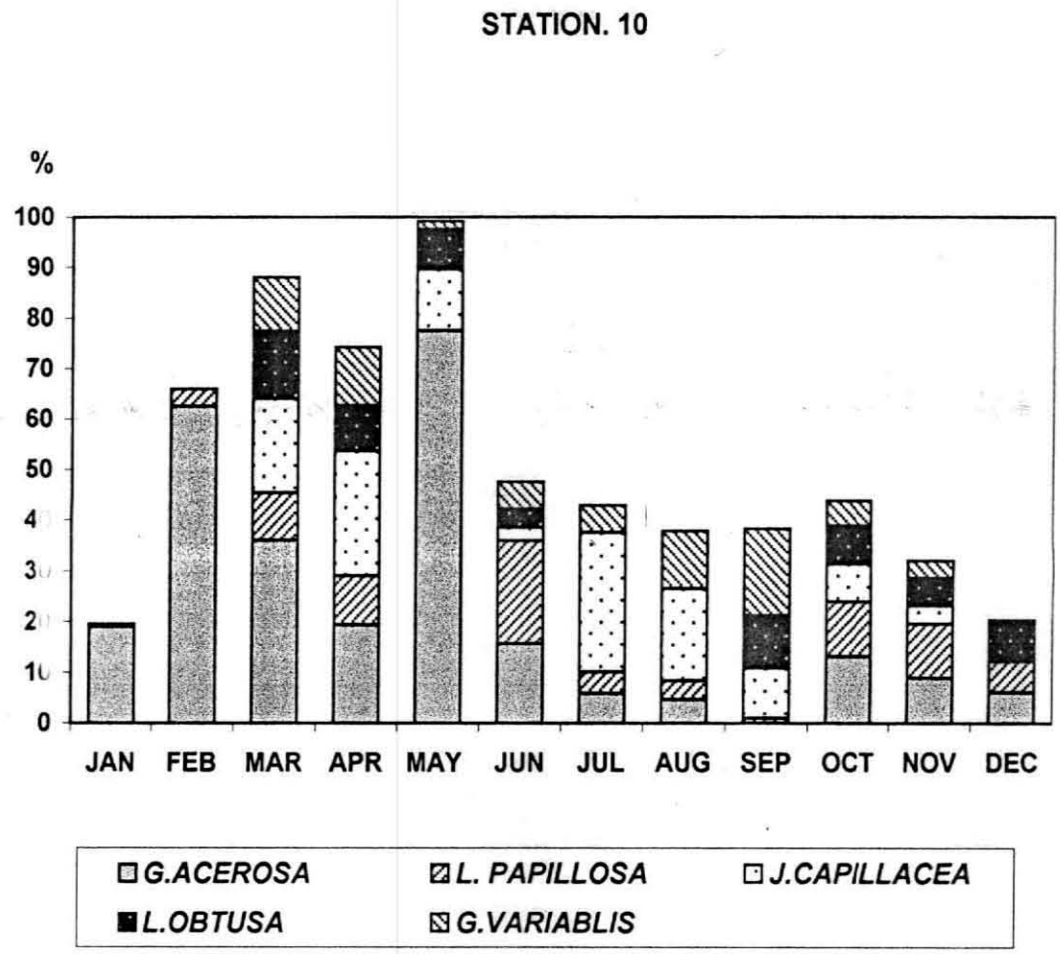


Fig. 19 Monthwise percentage availability of dominant macro algae in Station 10 at Minicoy

found during the period March to August. *Chaetomorpha linoides*, *Gracilaria corticata* and *Hypnea valentiae* occurred in traces (Table 6).

At Station 2, 13 species were recorded. The dominant algae were *Laurencia papillosa, Gracilaria edulis, Hypnea valentiae, Lyngbya confervoides.* (Fig. 11). *G. edulis* was observed during January to March when its occurrence ranged from 40 to 83.5 %. The percentage occurrence of *Lyngbya Confervoides* showed an increasing trend from February to March and it was the only species available in the station during May to July. Other algae which formed a major part were *Chaetomorpha aerea* (53.1% in January) and *Caulerpa recemosa* (57.1 % in August and 100% in September) (Table 7).

Eleven species of macrolgae were found at Station 3 of which four species were found comparatively abundant. *Halimeda gracilis* was observed throughout the year expect in September. The peak growth for this species was in July (69.8 %). *G. edulis* was found in January to March with a decreasing trend and reappeared in December. The alga *G. crassa* was found in all 12 months and highest percentage of occurrence was in September (87.9%). *Lyngbya confervoides* showed an increasing pattern from

January to May with a sudden decrease in June and was not found later (Fig. 12). The other algae occurred only in traces. (Table. 8).

In Station 4, eleven species were recorded. The abundant species in this station was *Cladophora fascicularis* which was found during nine months and absent in June, October and November. *C. fascicularis* showed a decreasing growth pattern from January to May and then an increase upto September. In this station *Lyngbya confervoides* was available from January till August. It was occurring more in quantity during the months of April, May and July. *Chaetomorpha linoides* was found in comparable quantities with other two species of *Chaetomorpha* with maximum biomass in the month of December (59.5%) (Fig. 13). In the less abundant group *Chaetomorpha aerea* was found in January (38.5%) and not observed from March onwards. Other species occurred in traces (Table 9).

In Station 5, 13 species were observed during the period of study and five species have some significance in their occurrence and abundance. The green alga *C. linoides* was found in ten months except in May and June. Maximum biomass of 57.3 % in January and 100 % in August was recorded. *Laurencia papillosa* occurred with maximum quantity during June (100%) and

September (47.3%). *Halimeda gracilis* was present only in four months with maximum growth in March (21%). *Lyngbya confervoides* was available in five months and its occurrence was maximum in April (56.7%). *Cladophora fascicularis* was one of the dominant species in Station 5 and it occurred for eight months with the highest biomass in October (64.3 %) (Table 10, & Fig. 14). *G. edulis* was found only for two months in February and March and all other species occurred in traces.

Station 6 is in a different location i.e. is reef flat and only four species were available during the study period. *H. gracilis* was found in all the months with maximum biomass (90.7%) in May. *Gelidiella acerosa* occurred in nine months with maximum percentage of biomass during June and December. *Turbinaria ornata* was abundant in the reef flat area and occurred for 11 months except May. It was found in good quantities except April and January. *Sargassum duplicatum* was found in traces during three months from May to July. (Table. 11 & Fig. 15)

Fifteen species of algae were found in Station 7 which is situated in the southeastern side of the island. The following algae have some significance in occurrence viz, *Halimeda gracilis, Gelidiella acerosa, Chaetomorpha antennina* and *Laurencia* *ceylanica. H. gracilis* was available throughout the year. *G. acerosa* was prevalent in all the months in less quantity. *C. antennina* was present from February to June while *L . ceylanica* occurred from July to December except in November (Fig 16). *Padina boergesenii* was found in four months and *Turbinaria ornata* in three months. The other algae occurred in traces (Table 12).

In Station 8, fifteen taxa were recorded during the study period. *H. gracilis, L. papillosa, G. acerosa, L. obtusa* and *L. ceylanica* were the dominant species. *H. gracilis* was found throughout the year. *Laurencia papillosa* was available during the pre-monsoon months and was not available in postmonsoon. *G. acerosa* was found during nine months and was more abundant in the month of July. *L. obtusa* was not found in pre-monsoon and monsoon months except in June. But it was available throughout postmonsoon months. *L. ceylanica* started growing in August and was abundant till December (Fig.17). *T. ornata* and *Asparagopsis taxiformis* were found in four months. The other algae were seasonal and occurred in small in quantities. (Table 13).

Station 9 is also in the shore reef area where substratum is rocky with boulders along the coast and intertidal region. Eighteen algal species were recorded from this station. *T. ornata* ,*G. acerosa, P. boergesenii, S. duplicatum* and *L. ceylanica* were the dominant species. *T. ornata* with maximum percentage of biomass (51.6%) occurred in January and it was not found in March and May. There was no specific trend in the pattern of its occurrence except it was less during February, April, June and July. *G. acerosa* was observed during eleven months except in October. The growth was better in premonsoon and monsoon periods. Though *Padina boergesenii* was found in eleven months, quantitative it was comparatively very less. *S. duplicatum* was found for two months in the premonsoon season and it occurred from July to December with highest value during September (54.9%). *L. ceylanica* occurred from July to December except in the month of September. Its quantity was high in the month of December (56.6%) (Fig.18). *Acanthophora spicifera* was found in January and in the monsoon months. The other algae were sparsely distributed with very less biomass (Table.14).

In Station 10 maximum number of nineteen species of algae were recorded from January to December. The substratum is rocky with boulders along the coast. Each species has been identified as a major contributor in this station. *A. spicefera* was found for 7 months during January and from July to December. *G. acerosa* occurred throughout the year except in September with maximum biomass (77.5%) in May. *Jania capillacea was* found in 9 months. *Champia sp* was found from June to December with a peak growth in September (29.62%). *L. obtusa* was found during 8 months. *G. variabilis* which was also not found in other stations was recorded during 9 months (Fig.19). *Cladophoropsis zollingeri* was found during 7 months with highest biomass (13.6%) in June. *A. taxiformis* was present from June to December in lesser quantity. All other algae were not of much significance in their occurrence except *Ulva lactuca* for 8 months with meagre quantity and *E. compressa* and *L. ceylanica* for 4 months in traces (Table.15).

The biomass study carried out in all the 10 stations and calculated for the major seasons premonsoon, monsoon and postmonsoon. In Station 1, total biomass for pre-monsoon was estimated as 22281.4 g with maximum of red algae (17364.8g). followed by green algae (4796.8 g) and brown algae (120 g). In monsoon months red algae dominated with 3132 g and the green algae only with 48 g while brown algae were absent. In postmonsoon period the biomass of green, brown and red algae was 624.0 , 32.0 and 1059.2 g respectievely. The total biomass for the year was 27184 g (Table 16).

In Station 2 the total biomass of algae for one year was 12464.6 g and the major share was in premonsoon (12320.6 g). Red algae occupied more area having 9672.6 g while green algae comprised 2648 g and brown algae were absent. Red and brown algae were not available in monsoon and postmonsoon but meagre quantities of green algae were found during these seasons. (Table 17).

The total biomass assessed for Station 3 was 18525.6 g. Brown algae were absent in all the three seasons. The maximum biomass in premonson period was contributed by red algae (9832 g) followed by green algae (3499.2g). In monsoon period green algae dominated (1906.4g) over red algae (1656 g). In postmonsoon period red algae was abundant (1120 g) followed by green algae (512 g) and brown algae were absent (Table 18).

In Station 4, green algae dominated in all 3 seasons having the highest biomass in premonsoon (1024 g). Brown algae were not present in monsoon and postmonsoon season. This station was not having much vegetation and the total biomass for all algae in the whole year was only 1708 g (Table 19).

Table 16 : Biomass (g wet wt/m^2) of algae during different seasons at Station 1

Alga	Premonsoon	Monsoon	Postmonsoon
Chaetomorpha linoides	2708.8	-	-
Chaetomorpha aerea	1560.0	-	-
Ulva lactuca	16.0	-	-
Chaetomorpha recemosa	512.0	32.0	504.0
Enteromorpha compressa	-	16.0	-
Caulerpa peltata	-	-	120.0
Dictyota dichotoma	120.0	-	-
Padina boergesenii	-	-	32.0
Gracilaria edulis	10656.0	264.0	664.0
Gracilaria corticata	184.0	48.0	-
Acanthophora spicifera	1656.0	48.0	232.0
Laurencia papillosa	1764.8	344.0	160.0
Hypnea valentiae	464.0	-	-
Hypnea musciformis	200.0	-	-
Jania capillaceae	-	-	3.2
Lyngbya confervoides	2440.0	2435.2	-

Table 17 : Biomass (g wet wt/m^2) of algae during different seasons at Station 2

Alga	Premonsoon	Monsoon	Postmonsoon
Chaetomorpha linoides	124.8	-	-
Chaetomorpha aerea	2440.0	-	-
Ulva lactuca	43.2	-	-
Caulerpa recemosa	-	32.0	112.0
Caulerpa peltata	8.0	-	-
Boergesenii forbesii	32.0	-	-
Gracilaria edulis	8911.0	-	-
Gracilaria corticata	12.0	-	-
Acanthophora spicifera	64.0	-	-
Laurencia papillosa	188.8	-	-
Hypnea valentiae	448.0	-	-
Hypnea musciformis	48.0	-	-
Lyngbya confervoides	720.0	3355.2	-

Table 18 : Biomass (g wet wt/m^2) of algae during different seasons at Station 3

Alga	Premonsoon	Monsoon	Postmonsoon
Chaetomorpha linoides	-	-	48.0
Chaetomorpha antennina	-	68.0	80.0
Ulva lactuca	3.2	-	-
Caulerpa recemosa	40.0	-	-
Enteromorpha compressa	-	64.0	16.0
Halimeda gracilis	3456.0	1774.4	368.0
Gracilaria crassa	7360.0	1656.0	1064.0
Gracilaria edulis	1112.0	-	40.0
Gracilaria corticata	968.0	-	16.0
Laurencia papillosa	392.0	-	-
Lyngbya confervoides	1080.0	3220.8	-

Table 19 : Biomass (g wet wt/m^2) of algae during different seasons at Station 4

Alga	Premonsoon	Monsoon	Postmonsoon
Chaetomorpha linoides	136.0	232.0	40.0
Chaetomorpha antennina	40.0	-	-
Chaetomorpha aerea	272.0	-	-
Cladophora fascicularis	552.0	108.0	123.2
Halimeda gracilis	24.0	-	-
Turbinaria ornata	59.2	-	-
Hypnea valentiae	32.0	16.0	22.4
Gracilaria edulis	120.0	-	-
Tolypocladia glomerulata	-	-	3.2
Acanthophora spicifera	48.0	-	-
Lyngbya confervoides	825.6	2051.8	-

Green algae dominated in Station 5 during all three seasons. Brown algae were absent during monsoon and postmonsoon period. In premonsoon season maximum biomass of 3719 g and 1233.6 g was recorded for green and red algae respectively. The annual biomass calculated for this station was 7264.8 (Table 20).

The brown algae dominated in Station 6 with annual biomass of 6730.4 g and maximum biomass was in postmonsoon period.Only one species of red alga *G. acerosa* occurred with total biomass of 724.8 g .Annual biomass of green algae was 5308.8 g and was more in premonsoon period (Table 21).

In Station 7 the maximum biomass for green and red algae was during the premonsoon period while for brown algae it was in postmonsoon season. The total biomass was estimated as 10057.4 g, the highest for red algae in premonsoon (5440 g) followed by green algae in postmonsoon (3965.6 g). The total biomass for two species of brown algae was 1174 (Table 22).

Red and brown algae were dominant during premonsoon in Station 8. Green algae occurred in maximum quantity (5404 g) followed by red algae (2030.4 g) and brown algae (1406.4 g).The total biomass for all seasons was 12600.8 g (Table 23).

Table 20 : Biomass (g wet wt/m^2) of algae during different seasons at Station 5

Alga	Premonsoon	Monsoon	Postmonsoon
Chaetomorpha linoides	2567.0	85.0	105.6
Chaetomorpha antennina	40.0	584.0	-
Chaetomorpha aerea	32.0	-	88.0
Caulerpa taxifolia	16.0	-	-
Enteromorpha compressa	24.0	-	-
Chaetomorpha fascicularis	128.0	56.0	256.0
Halimeda gracilis	912.0	40.0	-
Turbinaria ornata	448.0	-	-
Hypnea valentiae	-	20.8	12.8
Gracilaria edulis	300.8	-	-
Laurencia papillosa	592.0	208.0	264.0
Acanthophora spicifera	340.8	-	144.0
Lyngbya confervoides	705.6	756.8	-

Table 21 : Biomass (g wet wt/m^2) of algae during different seasons at Station 6.

Alga	Premonsoon	Monsoon	Postmonsoon
Halimeda gracilis	2820.8	2012.8	475.2
Sargassum duplicatum	-	17.6	-
Turbinaria ornata	1108.8	1508.0	4096.0
Gelidiella acerosa	324.8	342.4	57.6

Table 22 : Biomass (g wet wt/m^2) of algae during different seasons at Station 7

Alga	Premonsoon	Monsoon	Postmonsoon
Caulerpa cupresoides	-	180.8	-
Chaetomorpha antennina	156.0	280.0	-
Caulerpa sertulariodes	-	16.0	8.0
Enteromorpha compressa	-	56.0	-
Cladophora fascicularis	104.0	-	-
Halimeda gracilis	3705.6	2209.6	504.0
Padina boergesenii	168.0	-	35.36
Sargassum duplicatum	33.6	24.0	-
Turbinaria ornata	-	192.0	721.0
Gelidiella acerosa	307.2	148.0	90.4
Laurencia papillosa	112.0	-	-
Acanthophora spicifera	124.8	144.0	-
Laurencia obtusa	-	48.0	-
Laurencia ceylanica	-	280.0	369.6
Jania capillaceae	-	40.0	-

Table 23 : Biomass (g wet wt/m^2) of algae during different seasons at Station 8

Alge	Premonsoon	Monsoon	Postmonsoon
Cladophoropsis zollingeri	-	68.8	-
Chaetomorpha antennina	-	36.8	-
Enteromorpha compressa	-	16.0	-
Chaetomorpha linoides	-	56.0	-
Halimeda gracilis	5404.0	1284.8	320.8
Rosenbingea intricata	56.0	-	-
Padina boergesenii	16.0	308.8	24.0
Sargassum duplicatum	-	56.0	-
Turbinaria ornata	-	512.0	433.6
Gelidiella acerosa	532.8	184.0	61.6
Laurencia papillosa	401.6	32.0	-
Acanthophora spicifera	1096.0	72.0	-
Laurencia obtusa	-	532.8	147.2
Laurencia ceylanica	-	272.0	584.0
Asparogopsis taxiformis	-	-	91.2

At station 9, 18 algae occurred with annual biomass of 9121.2g. Red algae dominated throughout the year with maximum biomass in premonsoon. Brown algae were second in all seasons with highest biomass 1107.6 g during monsoon period. The biomass of green algae was less with only 16 g in premonsoon and 246g in monsoon (Table 24).

A maximum number of 19 species of algae were found in Station 10. Brown algae were absent during monsoon and postmonsoon and only with 8 g biomass in premonsoon. Red algae were found to be dominating in all the three seasons with highest biomass in the monsoon period (4352.2 g). Green algae were more in premonsoon (11360 g) and in other seasons they were very less. The annual biomass for green, brown and red algae was 1936 g, 8 g and 8006.9 g respectively (Table 25). The percentage composition of macroalgae in different stations at Minicoy island are given in (Fig. 20 and 21).

DISCUSSION

During the present study, 38 species of marine algae were recorded from Minicoy Island and of which 14 were green algae, 5 brown algae, 18 red algae and 1 blue-green alga. The seaweeds were collected only from the quadrat at 10 stations. It was noticed

Table 24 : Biomass (g wet wt/m^2) of algae during different seasons at Station 9

Alga	Premonsoon	Monsoon	Postmonsoon
Cladophoropsis zollingeri	-	46.0	-
Chaetomorpha antennina			
Enteromorpha compressa	-	24.0	-
Chaetomorpha aerea	-	128.0	-
Halimeda gracilis	16.0	48.0	-
Rosenbingea intricata	32.0	-	-
Padina boergesenii	416.0	244.8	48.0
Sargassum duplicatum	56.0	320.0	232.0
Turbinaria ornata	640.0	612.8	512.0
Gelidiopsis variabilis	-	96.0	-
Gelidiella acerosa	2027.2	1096.0	104.0
Laurencia papillosa			
Acanthophora spicifera	72.0	353.6	-
Laurencia obtusa	-	-	249.6
Laurencia ceylanica	-	384.0	888.0
Caulerpa taxiformis	120.0	-	-
Jania capillaceae	-	123.2	-
Asparogopsis fragilissima	-	56.0	-
Gelidium pusillum	-	32.0	-
Centroceros clavulatum	-	-	144.0

Table 25 : Biomass (g wet wt/m^2) of algae during different seasons at Station 10

Alga	Premonsoon	Monsoon	Postmonsoon
Ulva lactuca	56.0	9.6	28.
Cladophoropsis zollingeri	56. 0	283.2	70.4
Chaetomorpha antennina	112.0	-	-
Enteromorpha compressa	8.0	184.0	-
Chaetomorpha linoides	152.0	-	-
Chaetomorpha aerea	976.0	-	-
Padina boergesenii	8.0	-	-
Asparogopsis taxiformis	-	344.0	248.0
Gracilaria corticata	-	443.2	-
Gelidiella acerosa	624.0	1102.4	182.72
Laurencia papillosa	164.8	408.0	141.28
Acanthophora spicifera	472.0	116.8	169.6
Laurencia obtusa	136.0	131.2	160.0
Laurencia ceylanica		232.0	320.0
Amphiroa fragilissima	-	145.6	-
Gelidiopsis variabilis	136.0	26.3	140.5
Hypnea valentiae	-	44.8	-
Champia sp	-	435.2	328.0
Jania capillaceae	264.0	679.2	161.5

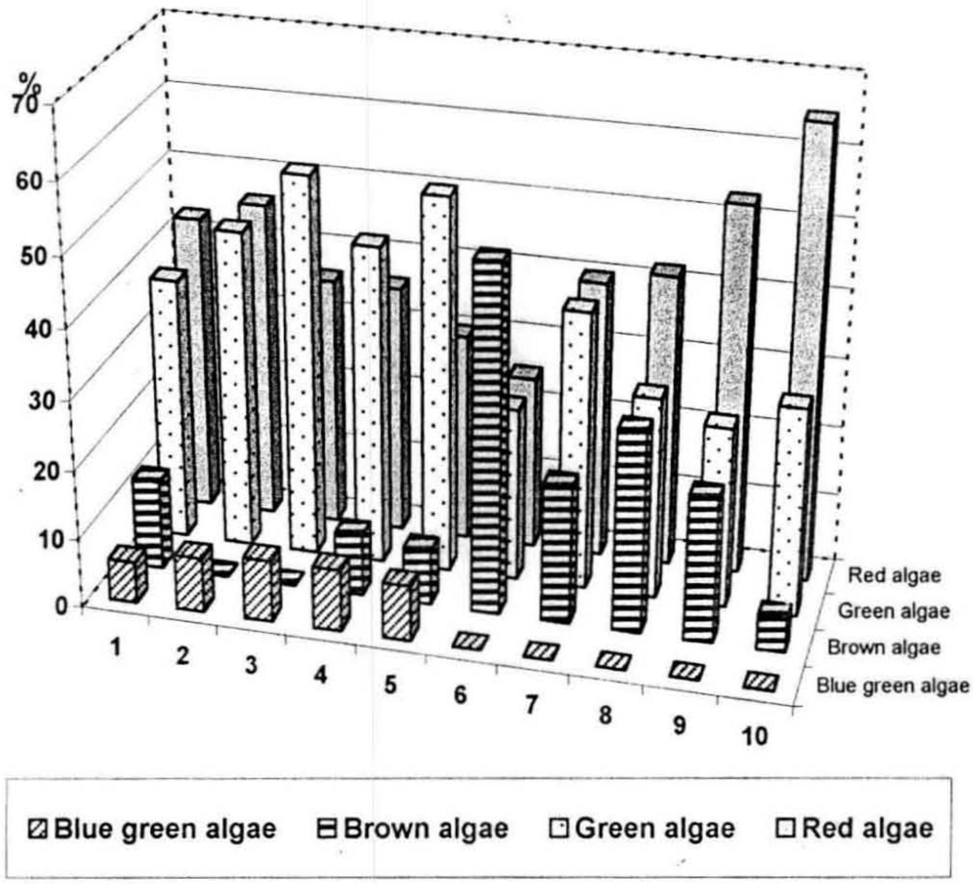


Fig. 20. Percentage composition of macro algae in different stations at Minicoy island

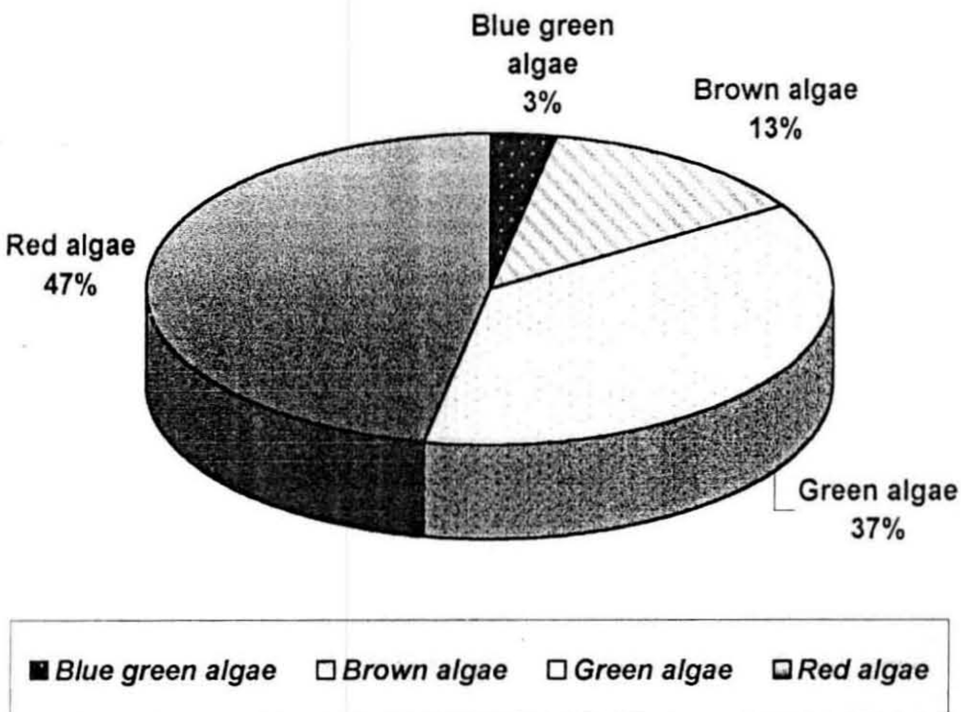


Fig. 21. Percentage composition of different algae at Minicoy

that 10 species occurred in lagoon side and 12 occurred on eastern shore reef area. In the survey conducted by CSMCRI, 21 species were reported from the lagoon and 27 species from the reef and shore reef. The species availability of macroalgae was more in eastern side in the present study also. Among the Lakshadweep islands surveyed, the maximum resources of marine algae was found in Minicoy Island though the economically important species were not fully represented (Anon 1979). Jagtap (1984) reported 34 species of marine algae from Lakshadweep atoll belonging to green algae (10 species), brown algae (5 species) and red algae (19 species). Kaliaperumal *et al.* (1989) surveyed the seaweed resources of 12 islands of Lakshadweep and reported 54 species of *Rhodophyceae,* 14 species of *Phaeophyceae* and 43 species of *Chlorophyceae.* In Minicoy, 52 species were recorded out of which 21 species belong to green algae, , 6 species to brown algae 23 species to red algae and 2 species to blue-green algae. In all Lakshadweep islands *Rhodophyceae* was more and *Phaeophyceae* was less. Maximum of 10 brown algae was found in Kalpeni Island (Kaliaperumal *et al.,* 1989).

Gopinathan and Panigrahi (1983) surveyed the Andaman and Nicobar islands and found a total number of 55 species of algae of which 16 belong to Chlorophyceae, 22 Rhodophyceae and 17

Phaeophyceae. Jagtap (1985) studied macroalgae from Andamans and found 64 species of which 26 red, 14 brown and 21 green algae the remaining blue green algae.

Chennubhotla and Kaliaperumal (1983) recorded 34 species of algae from intertidal and subtidal region of Kerala coast. Balakrishnan Nair *et al.* (1986) recorded the occurrence of 44 species of algae from southwest coast of India. Among these species 17 belong to Chlorophyceae, 6 to Pheophyceae and 21 to Rhodophyceae. Saji (1993) found 52 species of seaweeds from Kerala coast comprising 10 brown, 20 green and 22 species of red algae. Ganesan and Kannan (1995) studied the seasonal variation and distribution of seaweeds in Gulf of Mannar from Tuticorin to Pudumadam and found 31 red and 21 green respectively. Chennubhotla *et al.* (1990) studied the seaweed resources of Tuticorin and Tiruchendur coast and found 58 species of algae of which 39 species belonged to Rhodophyceae, 7 to Chlorophyceae and 12 to Phaeophyceae. Pondicherry coast was surveyed for two years and a total number of 15 species was recorded with 3 species of Chlorophyceae, 3 species of Phaeophyceae 7 species, Rhodophyceae and 2 species Cyanophyceae (Jayachandran and Ramaswamy 1997). Untawale *et al.* (1989) found maximum species of red algae (25) followed by green (23) and brown algae

(17) from the Karnataka coast. Subba Rao et al. (1985) recorded 65 species of marine algae from Andhra Pradesh coast consisting of 24 species of Chlorophyceae, 7 of Phaeophyceae and 34 of Rhodophyceae. Agadi and Untawale (1978) reported 51 species of marine algae from Goa, out of which 19 belonged to Rhodophyceae, 13 to Chlorophyceae, 15 to Phaeophyceae and 4 to Cyanophyceae. Murthy *et al.* (1978) found domination of red algae along the Gujarat coast. It is evident from the above studies that members of Rhodophyceae were found more in almost all parts of Indian coast, Lakshadweep and Andaman group of islands. The earlier studies and present study carried out in Minicoy indicate similar type of distribution of algae having more diverse species of Rhodophyceae. Out of the total 38 species, 18 species were red algae. Green algae constituted 14 species and brown algae were only 5 in numbers and 1 brown green.

More than 300 species of macroalgae growing on corals, reefs , rocks and sand stones are widely distributed along Brazilian coast (Durairatnam, 1989). Commercialisation of seaweeds in Micronesia is presently not existing. Knowledge of the seasonal distribution patterns of indigenous marine flora is of utmost important if wild crops are to be utilised and temperature plays a major role in the littoral seaweed growth in Guam (Tsuda, 1978).

Seasonal studies of the algal population from the coral reef complex of Tiahura (Moorea island, French Polynesia) showed that algal coverings have shifted from the fringing reef to the oceans. In 1971, 96 % of the algae were found in the fringing reef while 40 % was shifted to reef flat in 1980. The factor influencing variations in algal population are yet unknown. Rainfall (December to February) seems to influence the seasonality of the ephemeral species (Payri and Nain, 1982).

In the present study it was observed that the seagrass and seaweed vegetation were washed from Station 2 and no vegetation occurred during October to December. The cyclonic wind and heavy rain in the end of September may have caused the evacuation of these two patches of macrophyte bed.

Seven marine macroalgae were thought to have been introduced into the Pacific Northwest. The methods of introduction for many of them are unknown. Few formal ecological studies have been done on introduced macroalgae and the apparent increases in algal introduction suggest that similar studies should be undertaken (De-Wreedee, 1996).

Consultancy studies were conducted in Laamu atoll in Maldives to determine the feasibility of farming, processing and marketing. It was concluded that almost all plantable size for *Eucheuma* in several islands of Laamu atoll meet the environmental suitability criteria (Barraca, 1996).

The seaweed *G.edulis* was introduced to Mincoy from Mandapam mainland and Kavaratti island in the year 1990 (Kaladharan and Chenubhotla 1990). Now it is found that the growth in the lagoon side is quite considerable against other seaweeds of the islands. Biomass from *G.edulis* was also similar with other macroalgae. The percentage of agar and gel strength of this species is comparable with mainland species at Mandapam and other areas (Chennubhotla *et al.* 1977). It is evident from this, that there is no harm in introducing the commercially important seaweeds. There are plenty of cultivable areas in lagoons of Lakshadweep and other economically important seaweeds also could be attempted. This should be monitored regularly to get data and the effects on ecology and the existing biodiversity.

The studies on seaweeds of Cape Comorin revealed maximum number of Rhodophyceae (38) . The total biomass of seaweeds was high at 0.5 m depth and the species diversity was high at 1 m depth. The percentage of algal cover was highest during postmonsoon and lowest during monsoon (Giraspy and

Padmakumar, 1993). Maximum algal growth was found during late summer in the Venice lagoon (Sfriso *et al.,* 1993). A seasonal variation in algal species composition and biomass were examined on a rocky jetty at Port Mansfield, Texas in the northwest Gulf of Mexico. Over 30 algal species were collected and the species composition was dominated by *Rhodophyceae* (Kaldy *et al.,* 1995).

The present study in Minicoy atoll was made in the sublittoral water at the depth ranging from 0.5 to 1.5 m. It is observed that there is marked periodicity in the availability and biomass of macroalgae in all seasons.

The environmental conditions regulate the nature, abundance and productivity of seaweed communities (Trono, 1988). Wang and Chen (1980) conducted an ecological survey on the intertidal macroflora of northern part of Taiwan. Flora was different on sandy and rocky slope shores.

Krisnamurthy (1965) and Krishnamurthy and Subbaramaiah (1970) described the importance of shore types in the zonation of Indian marine macroalgae. Sandy shores are bereft of algal vegetation because of the absence of firm substratum for the attachment of rhizoids. Station 4 had sandy area except few patches of seagrass beds. The number of species collected from this station was less. In the lagoon side altogether seaweed diversity is less. The shore reef area with rocky substratum and boulders had a maximum number of species. *Turbinaria ornata, Gelidiella acerosa and Sargassum duplicatum* grows abundantly in the rocky areas. This may be due to the substrata which are favourable for their attachment. *Ulva lactuca* was found *maximum* in Station 10 below the eastern side jetty.

Chapman (1943 and 1955), Stephenson (1943) and Lewis (1964) have discussed the effects of sand on marine communities. Untawale and Dhargalkar (1975) observed seaweed growth mostly in rocky shores at Goa coast. The continuous erosion were responsible for the absence of algae along the sandy substrates. Daly and Mathieson (1977) suggested that sandy shores exhibit reduced population of seaweed due to the extensive sand movement and reduced light levels and lack of stable substrate. Agadi (1985) noted that along Karnataka coast sandy areas were devoid of algal vegetation. Shunula (1985) observed that sandy beaches were devoid of algal vegetation in the five shores of Zanzibar.

It is clear from the above studies that substratum is an essential prerequisite for distribution and growth of seaweeds.

Unavailability of suitable substrate is the reason for limiting the growth of many varieties of macro algae in sandy lagoon areas of the islands. It is obvious to state that the species composition and diversity and density of seaweeds varied from station to station though the study was conducted in one island, the reason being the change of substrate and suitable atmosphere for the growth.

Station 10 showed the maximum species diversity with 19 species followed by Station 9 and Station 1. The station with highest species diversity did not have the high biomass. It is understood from the present study and other earlier works that the factors controlling the occurrence and distribution of an algal species are not necessarily be conducive for its further growth and development. Environmental and biotic factors play a major role in its overall development and distribution pattern. There are other factors having more or lesser effects.

Atmadja (1992) has listed some algae of medicinal properties. They include species belonging to the genera *Acanthophora, Gelidium, Hypnea, Sargassum* and *Ulva.* Species of *Acanthophora, Hypnea* and *Ulva* are available in the Lakshadweep group of islands and assesment of the harvestable quantity of these seaweeds is essential.

The environmental conditions regulate the kind, nature, abundance and productivity of seaweed communities. The understanding of the influence of these parameters in nature, biology and distribution of seaweed are important in the evaluation and assessment of sites for mariculture purpose. Hence the salinity, temperature, substratum, depth, nutrients, dissolved oxygen and other factors were studied in detail.

RESULTS OF MULTIPLE REGRESSION

To understand the influence of the environment variable on biomass, multiple regression and correlation analysis were carried out using computer based programs. The environmental variables were: water temperature (x1), salinity (x2), dissolved oxygen (x3), phosphate (x4), nitrite (x5), nitrate (x6), silicate (x7).

The equation obtained for the three sites are depicted in Table. 26.

Y	S.E	R square
1. Lagoonside : Y = 263.40 + 263.05 + 93.15 - 51.54 - 672.90 - 532.26 + 15.09 - 15397.45	307.65	0.69
2.Reefflat: Y= -38.68 - 54.55 - 2.29 - 448.56 - 398.36 - 295.61 - 9.23 + 4351.36	246.84	0.29
3. Shore reef: Y= 85.25 + 2.42 - 85.40 - 384.63 + 67.00 - 268.32 + 4.44	201.96	0.24

The multiple regression equations show that there is significant interaction between environmental variables and biomass at lagoon side indicated by high R squared value. The relationship was weak at reef flat and shore reef with comparatively low R squared values. Mean and standard deviation for three regions are depicted in Table. 27, 28 and 29.

Table 27: Mean and standard deviation and correlation matrix of different characteristics at lagoon side.

Variable	Mean	S.D.
Water temperature	30.083	6.456
Salinity	32.833	1 .478
Dissolved oxygen	6.456	6.017
Phosphate	0.778	0.212
Nitrite	0.476	0.146
Nitrate	1.292	0.522
Silicate	2.207	0.699
Biomass	642.321	774.504

CORRELATION MATRIX

Variable	Water temp. 1	Salinity 2	Dissolved oxygen 3	Phosphate 4	Nitrite 5	Nitrate 6	Silicate 7	Biomass 8
1	1.00							
2	0.313	1.000						
3	0.189	-0.025	1.000					
4	0.219	0.088	0.081	1.000				
5	-0.208	-0.482	0.075	-0.065	1.000			
6	0.245	0.348	-0.009	-0.015	-0.122	1.000		
7	0.015	-0.057	0.427	0.210	0.019	0.033	1.000	
8	0.548	0.565	0.007	0.099	-0.483	-0.120	0.013	1.000

Table 28: Mean and standard deviation and correlation matrix of different characteristics at reef flat side.

Variable	Mean	S.D.
Water temperature	28.846	1.453
Salinity	32.006	6.215
Dissolved oxygen	5.341	2.374
Phosphate	0.776	0.181
Nitrite	0.458	0.135
Nitrate	1.429	0.543
Silicate	2.384	1.636
Biomass	423.233	345.996

CORRELATION MATRIX

Variable	Water temp. 1	Salinity 2	Dissolved oxygen 3	Phosphate 4	Nitrite. 5	Nitrate 6	Silicate 7	Biomass 8
1	1.000							
2	- 0.148	1.000						
3	0.163	0.117	1.000					
4	-0.181	0.012	0.131	1.000				
5	-0.224	- 0.082	0.337	0.290	1.000			
6	-0.493	0.358	-0.236	0.208	0.166	1.000		
7	0.153	0.041	-0.151	0.074	-0.526	0.241	1.000	
8	0.153	0.041	0.024	-0.169	-0.218	-0.459	-0.098	1.000

Table 29 : Mean and standard deviation and correlation matrix of different characteristics at shore reef side.

Variable	Mean	S.D
Water temperature	30.063	0.938
Salinity	32.260	6.351
Dissolved oxygen	5.104	1.503
Phosphate	0.792	0.172
Nitrite	0.399	0.143
Nitrate	1.213	0.496
Silicate	2.218	1.438
Biomass	449.789	300.853

CORRELATION MATRIX

Variable	Water temp. 1	Salinity 2	Dissolved oxygen 3	Phosphate 4	Nitrite 5	Nitrate 6	Silicate 7	Biomass 8
1	1.000							
2	-0.059	1.000						
3	-0.047	-0.612	1.000					
4	-0.203	0.149	-0.109	1.000				
5	-0.295	-0.314	0.302	0.234	1.00			
6	0.088	0.413	-0.554	-0.211	-0.42	1.000		
7	0.133	0.056	0.003	0.187	-0.27	-0.211	1.000	
8	0.262	0.060	-0.165	-0.124	-0.050	-0.155	0.069	1.000

Seaweeds are major coastal renewable resources which are valuable to both the economy and environment of many countries. The uses of the seaweeds as raw material for phycocolloid production have become a major worldwide industry.

At present Lakshadweep harbours 114 species of marine algae coming under different genera. Detailed studies of their distribution, resources, seasonality, ecology, and reproduction have to be made.

Basic natural history and inventory works are important prerequisites for taking decisions for utilising the resource and its conservation.

CHAPTER - III

PRIMARY PRODUCTIVITY AND CULTURE

SECTION A

PRODUCTIVITY OF MACROALGAE

INTRODUCTION

Marine macroalgae are major primary producers of coral reefs and maintain the ecosystem at an optimal level by their high levels of production. In general, primary productivity in the waters flowing over reefs greatly exceeds the production of oceanic waters (Sargent and Austin, 1954). This high production is because of the large standing crop of benthic algae; zooxanthille of corals in the reefs ecosystem of seagrass beds and seaweeds.

There are no much studies from Lakshadweep on seaweed primary production. It is restricted to primary production of the lagoon waters (Nair and Pillai, 1972; Wafar, 1977) and seagrass beds (Qasim and Bhattathiri, 1971; Kaladharan and David Raj, 1989). Kaladharan and Kandan (1997) estimated net primary production of 10 seaweeds of Minicoy atoll. Gulshad Mohamad *et al.* (1999) studied domestic waste impact on production of *Caulerpa recemosa* in Minicoy lagoon. Productivity of the coral reef algae *Halimeda gracilis* at Minicoy island, Lakshadweep was studied by Haneefa Koya *et al,*(1999).

MATERIAL AND METHODS

The algae used in the study were *Enteromorpha compressa* (green alga), *Turbinaria ornata* (brown alga) and *Gracilaria edulis* (red alga). *T.ornata* from shore reef area (eastern side) of the island, *E. compressa* from fisheries jetty and *G.edulis from* northern side of island were collected. The procedure of Qasim *et al.* (1972) was followed to estimate productivity. Freshly collected specimens were carefully washed with filtered seawater and a small quantity of each species (2-3 gm) was weighed and kept in jars of 1000 ml capacity. These jars were filled with filtered seawater, closed tightly and immersed in a bucket of seawater to prevent entry of atmospheric oxygen. A jar painted with black colour, covered with aluminium foil and further covered by black plastic sheet was used as dark bottle. A sample of seawater was fixed with Winkler A and B and it was treated as initial concentration of oxygen. The jars were then suspended in the lagoon approximately 30 cm from the surface where the total depth of the lagoon was about 2.5 m. In each experiment triplicate sets were used and incubated for a period of three hours. At the end of the exposure, the water in jars were carefully siphoned off and fixed. A set of controls containing only seawater was also exposed in light and dark bottles. Increase and decrease in the light and dark bottles from the initial values were taken for photosynthesis and respiration respectively. Winkler determination is carried out to calculate the oxygen produced and consumed in ml/g/hr.

RESULTS

The mean and standard deviation of gross primary production (GPP) and net primary production (NPP) of the three species of algae are given in (Table 30). *Enteromorpha compressa* of the Chlorophyceae showed maximum gross primary production and net primary production for all the seasons. It was followed by the *Gracilaria edulis* and the lowest values were is found in the brown algae *Turbinaria ornata.*

A two way ANOVA statistical analysis for all the three species are not significant (Table 31).

DISCUSSION

Rogers and Sailesky (1981) reported that macroalgae produced more oxygen than algal turf or live coral and concluded that macroalgae may represent a major part of the total primary productivity of some coral reefs. Hanisak *et al.* (1989) found algal diversity to be relatively constant throughout the year with abundance being high in certain months.

Table 30. Mean and standard deviation of gross primary production (GPP) and net primary production (NPP) of three species of algae.

Alga	Premonsoon		Monsoon		Postmonsoon	
	GPP	NPP	GPP	NPP	GPP	NPP
Enteromorpha compressa	0.58 ± 0.36	0.42 ± 0.24	0.46 ± 0.24	0.33 ± 0.18	0.48 ± 0.17	0.37 ± 0.22
Turbinaria ornata	0.22 ± 0.15	0.16 ± 0.14	0.20 ± 0.08	0.12 ± 0.05	0.23 ± 0.09	0.14 ± 0.07
Gracilaria edulis	0.32 ± 0.07	0.19 ± 0.04	0.35 ± 0.06	0.26 ± 0.08	0.27 ± 0.06	0.16 ± 0.05

Table 31. Two way ANOVA between species (treatment) and seasons (replicate) for net primary production of three species of algae.

Source	DF	SS	MSS	F	P
Treatment	2	0.086	0.043	20.34	$P < 0.01$
Replicates	2	0.002	0.001	0.43	$P > 0.05$
Error	4	0.008	0.002		

Nassar (1993) estimated that the production rate of macroalgae in Minicoy lagoon is about 200-800 g C/sqm./yr and it is about 25-35 % of the total reef production.

Primary production was measured under natural conditions for five common species of seaweeds from the coast of the State Sao Paulo, Brazil. Available biomass information showed that the maximum standing stock did not correspond to the growth potential determined from measurement of primary productivity and growth rates, suggesting that levels of standing stocks are determined by physical factors (wave action) and biological interactions (grazing) than by intrinsic growth rate potentials (Rosenberg *et al.*, 1995).

Photosynthetic and respiratory performances of annual forms *Enteromorpha intestinalis* and *Cladophora glomerata* (Chlorophyta), *Ceramium tenuicormne* (Rhodopyhta) *Pilayella littoralis* and perennial forms *Fucus vesiculosus* (Pheophyta) were determined by measuring their dissolved oxygen concentration in light and dark bottle using the traditional Winkler method or oxygen meter. The highest production rate was measured for *E. intestinalis* and *C.glomerata*. Relatively high production rate close to that of above mentioned green algae was obtained for red algae and significantly lower production rate for brown algae (Paalme, 1995).

Levitt (1993) assessed the primary production in Cape of Good Hope and confirmed that the kelps are the major macrophyte primary producers of the west coast inshore regions.

In the present study it is found that the green alga *Enteromorpha compressa* is the highest primary producer and next is the red alga *Gracilaria edulis*. The brown alga *Turbinaria ornata* is found to be the lowest primary producer in the lagoon system.

SECTION-B

CULTURE OF *Gracliaria edulis*

INTRODUCTION

Culture of seaweeds are very important as far as Lakshadweep islands is concerned. It is having a total lagoon area of 4200 sqkm. In most of the lagoon area seaweeds can be cultured. Four distinct sites were selected for this study. The culture was carried out in all the three seasons premonsoon, monsoon and postmonsoon.

In addition to the exploitation of natural seaweed resources, cultivation or farming of seaweeds has been tried to increase the production of the raw materials by introducing high yielding and commercially valuable species. Placing boulders or concrete structures in the natural habitat where useful species can grow, placing artificial substrata such as bamboo, coir or synthetic fibre nets in protected area and transplanting the important varieties to other coastal areas of the country are the measures suggested by Uma maheswara Rao (1973).

Culture of seaweeds has been attempted in many parts of the world. Mairh *et al.* (1991) reported the results of the culture of brown algae *Laminaria japonica* in Japan. Seaweeds are also being cultured along with oysters in the brackish water fishponds of Brazil (Araujo *et al.* 1986). The methods of seaweed culture and their economics at Malaysia (Anon (b) , 1987), Philippines (Iaw, 1996), Asia Pacific (Chen & Xia, 1986), South pacific (South, 1994), South Africa (Anderson *et al.*, 1996), Chile (Buschmann *et al.*, 1990) and U.S.A (Hansen *et al.*, 1981) are available. The production levels of cultivated *G.chilensis* in Chile were reduced due to grazing by polycheates and mussels, which compete with the farming seaweeds (Buschmann *et al.* 1997). Barracke (1996) reports the feasibility study on farming, processing and export of *Eucheuma* from Maldives.

In India, mariculture of different species of seaweeds has been attempted along the Tamilnadu coast, Gujarat and Lakshadweep. Agarophytes such as *G.edulis, G.corticata, Gelidiella acerosa* and alginophytes such as *Turbinaria ornata, T.conoides* and *Sargassum* spp. are the various macroalgae that have been considered for culture. Reports on the experimental culture and technology of seaweed farming in Tamilnadu are those of Bharathan (1987), Kalkman *et al.* (1991), Paramasivam and Devadoss (1987), Paramasivan and Srivasthava (1989) Patel *et al.* (1986). Chennubhotla *et al.* (1978), Kalimuthu and Najmuddin

(1979), Kaliaperumal *et al.* (1986), Rama Rao and Subbaramaiah (1986), and Rama Rao *et al.*(1985).

The red alga *G.edulis* which was not occurring earlier at Minicoy lagoon was collected from Mandapam area and also from Kavaratti Island and transported to Minicoy in live condition. *G.edulis* had established since then at Minicoy Kaladhran and Chennubhotla (1993). Some attempts have been made on the experimental field cultivation of *Gracilaria edulis at* Minicoy (Anon (b), 1990), Kaliaperumal *et al.,* 1992; Chennubhotla *et al.,* 1992, Kaladhran *et al.,* 1996). With a view to understand the seasonal variation in production of *G.edulis* and also to locate suitable culture sites, the present work on field culture of *G. edulis* was carried out.

MATERIAL AND METHODS.

Four sites were selected at the sub tidal area with seagrass beds in Minicoy lagoon. Site 1 was near the Navodaya Vidyalaya. The seagrasses at this site was bordered by a coral shoal of about 600-m in length Site II was nearby fisheries jetty, where the wastes of from Tuna Canning Factory are letout. The dominant seagrasses present at Site I and II in order of abundance were

Thalassia hemprichi, *Cymodocea serrulata* and *Syringodium isoetifolium*. Site III was near the Lakshadweep harbour works and is relatively free from any human impact and boats operation. This area has luxuriant growth of seagrass *Syringodium isoetifolium*. Site IV was near the lighthouse and lie in the path of water movement from the adjacent mangrove ecosystem. Apart from the occurrence of above mentioned dominant seagrass, this area had the vegetation of another species of seagrass *Halophila ovalis*.

The off bottom culture method using single line coir ropes was followed in the present study. Coir ropes of 5-m length with seedlings of *G.edulis* inserted in the twists of ropes were introduced perpendicular to the shore on seagrass beds. The quantity of the seed material introduced at each site was fixed as 150 g and the culture period was 60 days. Totally five ropes were introduced at each Site during all the 3 seasons.

RESULTS

Significant variation in the production of cultured *G. edulis* was observed between the sites (Table. 32). A constant pattern in the yield of crop was noticed with low quantities during premonsoon period and the maximum quandity during

Table 32. Culture of *Gracilaria edulis* – Seasonwise yield after 60 days growth

Site	Season	Wt of the seed Material (kg)	Wt of harvested material (kg)	Percentage Increase in Yield
1	Premonsoon	0.150	0.441 ± 0.037	294
	Monsoon	0.150	0.576 ± 0.178	230
	Postmonsoon	0.150	1.369 ± 0.172	320
2	Premonsoon	0.150	0.418 ± 0.016	279
	Monsoon	0.150	0.619 ± 0.133	242
	Postmonsoon	0.150	1.288 ± 0.169	268
3	Premonsoon	0.150	0.530 ± 0.034	353
	Monsoon	0.150	0.729 ± 0.113	292
	Postmonsoon	0.150	1.766 ± 0.140	505
4	Premonsoon	0.150	0.330 ± 0.189	220
	Monsoon	0.150	0.751 ± 0.069	300
	Postmonsoon	0.150	1.410 ± 0.168	331

postmonsoon months. The maximum yield was obtained at Site III with 11.8 fold increase over the seed material (Plate - 4).

DISCUSSION

In the present study, the yield ranged from 2.2 fold (Site IV, premonsoon) to 11.8 (Site III, postmonsoon). The high production rate is comparable to those obtained by Kaliaperumal *et al.* (1992) and Chennubhotla *et al.* (1992a, 1992b growth during pre and postmonsoon season and poor growth during monsoon period due to the turbulent condition of the sea and heavy sedimentation on the cultured seaweeds. However, based on the present observations it may be concluded that the period from late monsoon and postmonsoon are the most favourable periods for the good growth of *G.edulis*. The grazing phenomena as reported by James *et al.* (1980) and Chennubhotla *et al.* (1994) was also observed during the present study. The very high yield 31 fold obtained by Chennubhotla *et al.* (1992) indicates that there is immense potential for the culture of *G.edulis* at Minicoy. As pointed out by Kaladharan *et al.* (1996) mariculture of *G.edulis* in Minicoy lagoon and in the lagoons of other atolls of Lakshadweep can be taken up as a part time job by the fisher folks in areas where problems of silt, wind and wave action are at a minimum.

CHAPTER - IV

BIOCHEMICAL AND PHYCOCOLLOID CONTENTS OF MACROALGAE

SECTION -A

BIOCHEMICAL COMPOSITION

INTRODUCTION

Biochemical studies of algae in Indian waters pertain mainly to the algal resources along the Tamil Nadu and Gujarat coasts. Aims of these studies were to screen the algae for its chemical constituents and to evaluate the level of protein, carbohydrate and lipids in these resources. Biochemical composition of algae is controlled by the habitat, season, and physiological and developmental stages at any given time (Cuonge *et al.* 1980). Ganesan and Kannan (1994) have reported seasonal variation in the chemical constituents of economic seaweeds in the Gulf of Mannar. They observed that biochemical contents vary, generally during the monsoon and postmonsoon seasons. Qari (1988) studied the seasonal changes in biochemistry of seaweeds from Karachi coast and found high protein and lipid values in winter months and high carbohydrate values in the summer months. Floreto *et al.* (1993) studied the fatty acid composition of *Ulva pertusa* and *Gracilaria incurvata* and temperature was negatively correlated with crude lipid content of *U. pertusa*. *G. incurvata* was unrelated to seasonal changes in temperature and day length. The effect of temperature, time of harvest and nitrogen deprivation were studied with emphasis on lipid and fatty acids in the alga

Palmaira palmata (Misra *et al.*, 1993). Fleurence *et al.* (1994) studied the fatty acids from 11 macroalgae of the French Brittany Coast. The chemistry of some useful Jamaican seaweeds was analysed by Devi-Prasad and Grant (1985) and Prasad and Potluri (1992 a;1992 b). Their results indicated that apart from species of *Gracilaria*, other algae such as *Gelidiella acerosa*, species of *Sargassum* and *Hypnea* could also be exploited for commercial purpose. Aliya *et al.* (1993) reported the fatty acid content of five siphonaceous green seaweeds and Qari and Siddiqui (1993) reported the biochemical composition of *Gracilaria corticata* from the coastal waters near Karachi. The chemical composition of common marine macroalgae from Hongkong was determined both in the winter and in summer by Kaehler and Kennish (1996) and concluded that the members of Pheophyta have the highest levels of nutrients. Ilyas and Sukan(1994) have reported a seasonal variation in the chemical constituents of *Gracilaria verrucosa* from the Aegian coast of Izmir.

Behariya and El-Sayed (1983) studied the biochemical composition of marine brown algae from Jedda Coast, Saudi Arabia and suggested that these seaweeds have a potential use as animal feed and fertilizers. Castro-Gonzalez *et al.* (1996) studied the chemical composition of the green alga *Ulva lactuca* and concluded that it can be used as a mineral supplement for poultry due to its chemical composition and high mineral content. The differential fatty acid composition of marine algae associated with their habitat depths indicated that the contents of fat and protein in seaweeds decreased with increasing depths while carbohydrate increased (Ito and Tsuchiya, 1981). Fan et *al.* (1993) investigated the nutrient component of edible seaweeds and found that there are about 100 species of seaweeds with application values in China Sea area.

Ganesan and Kannan (1994) studied seasonal variations in the biochemical constituents of economically important seaweeds of Gulf of Mannar. The biochemical contents are generally more during the monsoon and postmonsoon seasons. Padmini Sreenvasa Rao (1989) estimated free fatty acids from different species of Indian *Sargassumspp* and Ramavat and Rao (1997) studied the fatty acid composition of marine algae of Saurashtra coast. Parekh and Chauhan (1987) estimated the total lipid content of seaweeds from Tamil Nadu and Gujarat Coast. The total lipid content varied from 19-85, 17-65 and 22-71 mg/g in green, brown and red seaweeds respectievely. The Andaman Islands offers a congenial environment for the growth of seaweeds (Chauhan *et al.* 1987). Dave and Chauhan (1985) and Dave and Parekh (1997) studied the amino acid and protein contents of seaweeds from Gujarat coast. Devi *et al.* (1996) described the organic constituents of marine algae of Cape Comorin. Murthy and Radia (1978) made eco-biochemical studies of some intertidal algae from Port Okha and found that factors like temperature, salinity and pH have no bearing on the different biochemical contents of the algae. Saji Susan (1993) studied ecology and biochemical aspects of seaweeds of Kerala coast. Sumitra Vijayaragavan *et al.* (1980) studied the seasonal variations of the biochemical components of Goa coast. Dhargalkar (1986) studied the biochemical composition of *Ulva reticulata* in Chapora Bay in Goa and found that it contributes a major part of detritus, thus forming an important pathway in biological systems. The biochemical composition showed significant variations between genera of green algae (Reeta *et al.* 1990). Kaliaperumal *et al.* (1987) summarise the work alone on chemical composition of seaweeds.

The work on macroalgae from Lakshadweep in general is restricted to distribution, abundance, primary productivity and culture of seaweeds. Biochemical studies on the algae from these areas are only by Chennubhotla (1992) and Kaliaperumal *et al.* (1994). In the present study, protein, carbohydrate, and lipid contents of 6 species of algae from Minicoy lagoon were estimated.

MATERIAL AND METHODS

Samples of the green alga *Cheatomorpha antennina* and red algae *Gracilaria edulis, Gelidiella acerosa,Hypnea valentiae, Acanthophora spicifera and Laurencia papillosa* were collected from different stations of the lagoon and shore reef. Monthly samples were collected for one year from January to December 1998.The samples were repeatedly cleaned in fresh water and distilled water. They were then oven dried at 60° to 70 °C pulverised in mortar and pestle and sieved. The dried powder was stored in airtight containers for estimation of the protein, carbohydrate and lipid.

Protein

Folin–ciocalteu's method (Lowry *et al.* 1951) was employed for the estimation of the protein. The principle of this method involves two steps .The carbonyl group of protein molecules react with copper and potassium to give a blue colour, copper potassium–biurette complex. This compound together with tyrosine and phenolic compounds present in the protein reduce the phospho- molybdate of the Folin's reagent to intensify the colour of the solution .The colour thus developed is measured at 530 nm .Gelatin (10 mg / ml) was used as standard and a graph was prepared. The concentration of protein is expressed in percentage of the proximate composition.

Carbohydrate

The carbohydrate in algal samples were anlaysed by phenol sulphuric acid method (Roe, 1955). Sulphuric acid in anthrone reagent hydrolyses di-oligosachrides into monosachrides and dehydrates all monosachrides into furfural or fufural derivatives. These two compounds react with number of phenolic compounds like anthrone which produces a complex colour product and this is measured at 620 nm. Glucose at one mg/ml is used as standard.

Lipids

Total lipid was measured gravimetrically with chloroform-methanol extraction procedure of Freeman *et al.*,(1957). The methanol chloroform (1:2) mixture was added to the powdered algal sample and was allowed to stand for one hour and then the supernatant was transferred to a pre-weighed test tube. These test tubes were evaporated in oven at 30 °C. The difference in weight of the tubes gives the weight of the lipid present in the sample.

RESULTS

Protein content of the green alga *C.antennina* ranged from 18.7 in February to 25.9 % in September (Fig. 22). The protein content of the brown algae was found to be lower than that of *C. antennina*. The protein content in red algae ranged from 4.5 % (*G.edulis*, December) to 15.9 % (*L.papillosa*, January) (Fig. 23). Among the red algae *G.edulis* showed consistently low values than other species of algae. Season wise comparison of protein in *C.antennina* indicates that the values are high in monsoon and postmonsoon months (Table. 33). However, in the case of red algae high values are observed in

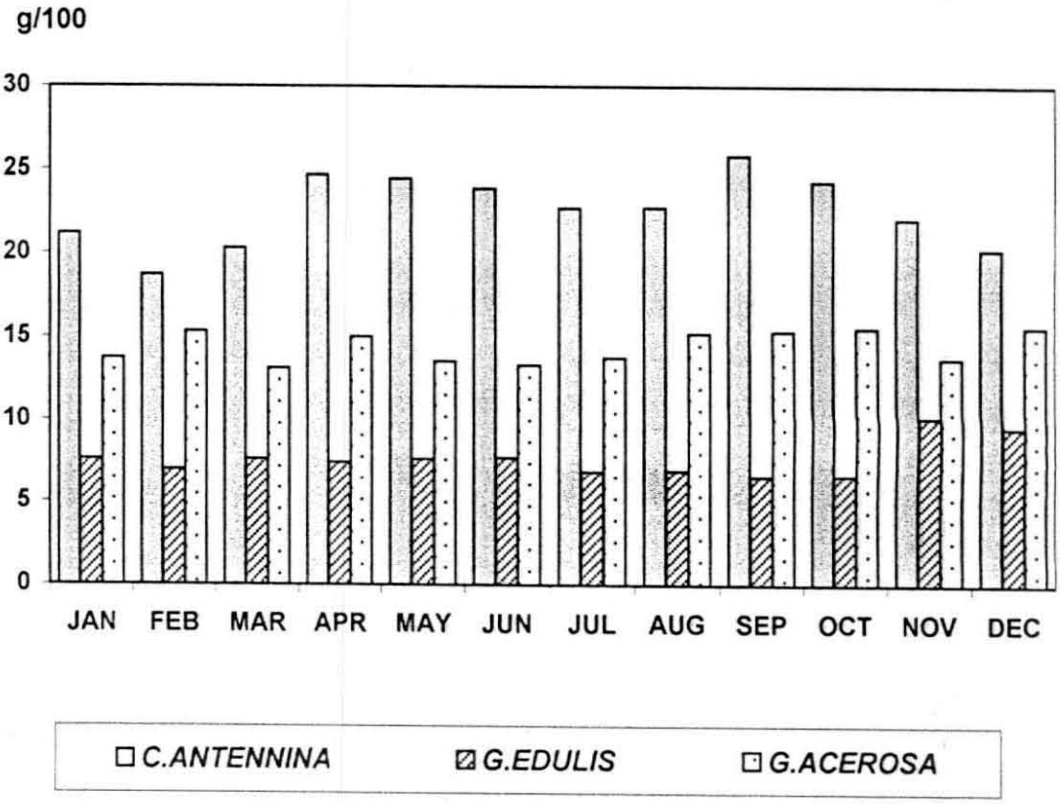


Fig. 22. Monthly variations in protein content of three species of macro algae

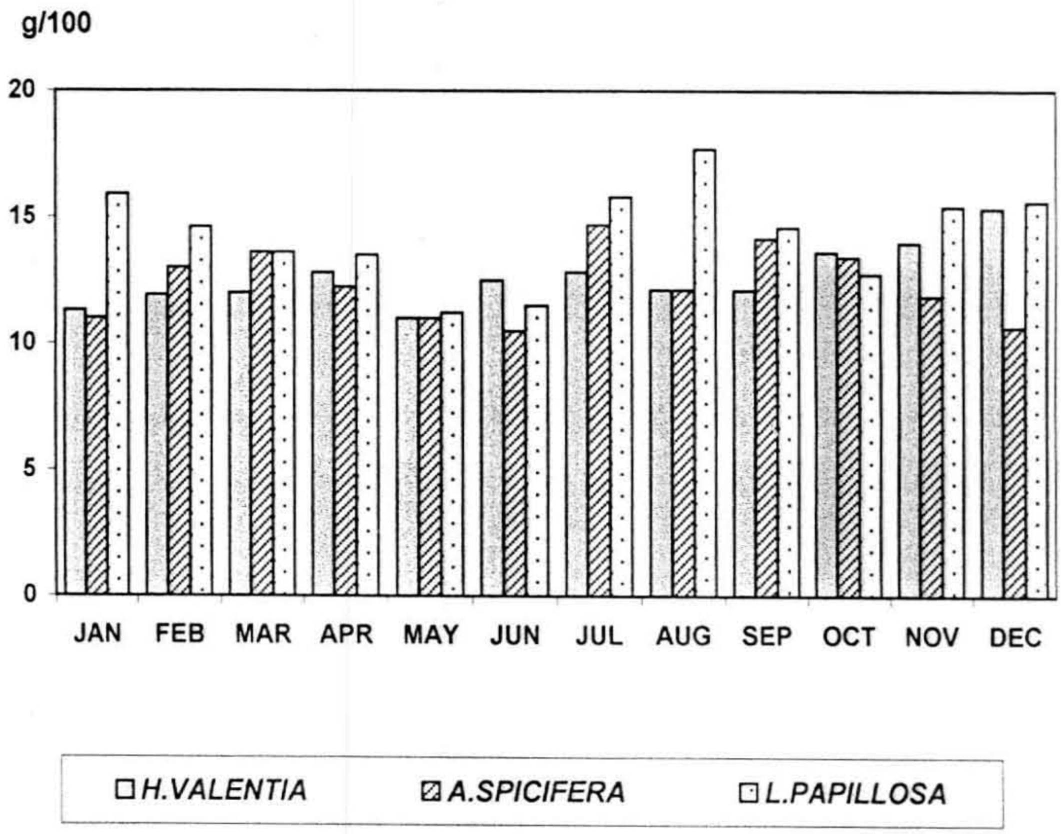


Fig. 23. Monthly variations in protein content of three species of macro algae

Table 33. Comparison between species based on ANOVA tables.

Parameter	Species	*Gracilaria edulis*	*Gelidiella acerosa*	*Hypnea valentiae*	*Acanthophora spicifera*	*Laurencia Papillosa*
Protein	*Chaetomorpha antennina*	SIG	SIG	SIG	SIG	SIG
	Gracilaria edulis	-	SIG	SIG	SIG	SIG
	Gelidiella acerosa	-	-	SIG	SIG	NS
	Hypnea valentiae	-	-	-	NS	SIG
	Acanthophora spicifera	-	-	-	-	SIG
Carbohydrate	*Chaetomorpha antennina*	NS	SIG	SIG	NS	SIG
	Gracilaria edulis	-	SIG	SIG	SIG	SIG
	Gelidiella acerosa	-	-	SIG	NS	SIG
	Hypnea valentiae	-	-	-	SIG	NS
	Acanthophora spicifera	-	-	-	-	SIG
Lipid	*Chaetomorpha antennina*	SIG	NS	SIG	SIG	NS
	Gracilaria. edulis	-	SIG	NS	NS	SIG
	Gelidiella acerosa	-	-	SIG	SIG	NS
	Hypnea valentiae	-	-	-	NS	SIG
	Acanthophora spicifera	-	-	-	-	SIG

SIG = Significant NS = Not significant

the postmonsoon months. (Table. 34). A two-way ANOVA showed that variations between species to be significant. ($P < 0.01$, Table. 35). Seasonal variations were not significant ($P > 0.05$). Comparison between species showed significant variations between green and red algae. In red algae, the comparisons were significant for all combination except between *G.acerosa, L. papillosa,* and *H.valentiae* and *A.spicifera.*

The carbohydrate content of algae studied did not show wide monthly variations (Fig. 24 & 25). The carbohydrate content of *C.antennina* is more than red algae except *G.edulis* (Table. 33). Seasonal variations in carbohydrate content for the different species was not significant while the carbohydrate content between species was highly significant ($P<0.01$). *C.antennina* did not show significant variations with *G.edulis* and *A. spicifera*(Table.4).

The monthly variations in lipid content are presented in (Fig. 26 & 27). In general, *C.antennina* showed higher values than red algae. (Table 33 and 34). As in the case of protein and carbohydrates, comparison between species was significant while between seasons it was not significant (Table. 35). Comparison between species indicated that the lipid content of *C.antennina* is not significantly different from that of *G.acerosa* and *L.papillosa.*

Table 34. Mean and standard deviation of protein, carbohydrate and lipid of six species of algae.

Parameters	Season	*C.antennina*	*G.edulis*	*G.acerosa*	*H.valentiae*	*A.spicifera*	*L.papillosa*
Protein	Pre	21.2 ± 2.53	7.4 ± 0.28	14.3 ± 1.05	12.0 ± 0.62	12.2 ± 1.29	14.4 ± 1.12
	Mon	23.5 ± 0.86	7.3 ± 0.44	13.9 ± 0.86	12.1 ± 0.79	12.1 ± 1.87	14.1 ± 3.22
	Post	23.1 ± 2.47	8.2 ± 1.92	15.1 ± 0.90	13.8 ± 1.34	12.5 ± 1.57	14.6 ± 1.31
Carbohydrate	Pre	20.3 ± 1.69	21.3 ± 1.20	17.9 ± 0.49	15.5 ± 2.15	19.4 ± 0.79	15.1 ± 1.56
	Mon	19.0 ± 0.60	22.5 ± 0.80	18.0 ± 0.57	13.6 ± 1.74	19.3 ± 0.93	17.1 ± 1.05
	Post	21.9 ± 1.46	21.6 ± 1.02	17.4 ± 0.60	14.8 ± 0.87	19.4 ± 0.79	15.8 ± 1.55
Lipid	Pre	0.95 ± 0.09	0.27 ± 0.01	0.89 ± 0.19	0.37 ± 0.07	0.39 ± 0.06	0.83 ± 0.18
	Mon	1.06 ± 0.09	0.40 ± 0.09	0.82 ± 0.24	0.49 ± 0.12	0.52 ± 0.20	0.91 ± 0.07
	Post	0.81 ± 0.12	0.41 ± 0.06	0.72 ± 0.16	0.51 ± 0.06	0.69 ± 0.04	1.00 ± 0.03

Pre = Premonsoon Mon = Monsoon Post = Postmonsoon

Table 35. Two way ANOVA between species (treatment) and seasons (replicate)protein carbohydrate and lipid.

Parameter	Source	DF	SS	MSS	F	P
Protein	Treatment	5	361.084	72.217	193.87	P< 0.01
	Replicates	2	2.419	1.209	3.25	P> 0.05
	Error	10	3.725	0.373		
Carbohydrate	Treatment	5	110.563	22.113	24.31	P< 0.01
	Replicates	2	0.240	0.120	0.13	P >0.05
	Error	10	0.094	0.909		
Lipid	Treatment	5	0.922	0.184	17.59	P< 0.01
	Replicates	2	0.023	0.012	1.10	P> 0.05
	Error	10	0.105	0.010		

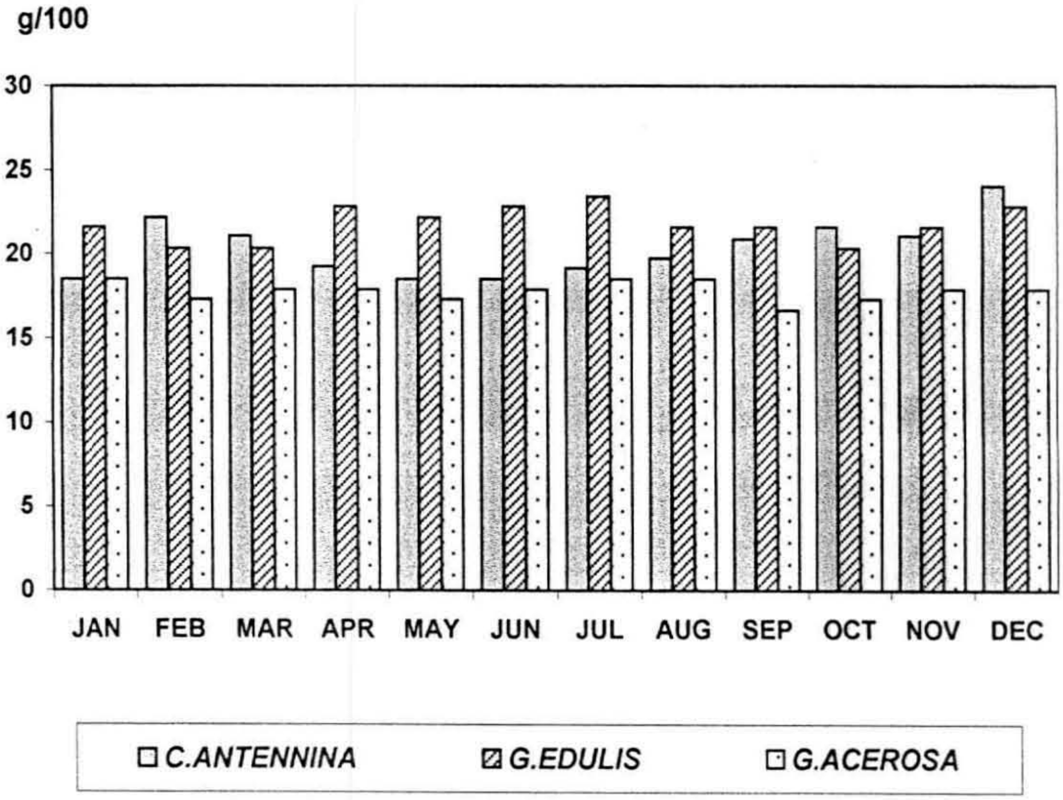


Fig. 24. Monthly variations in carbohydrate content of three species of macro algae

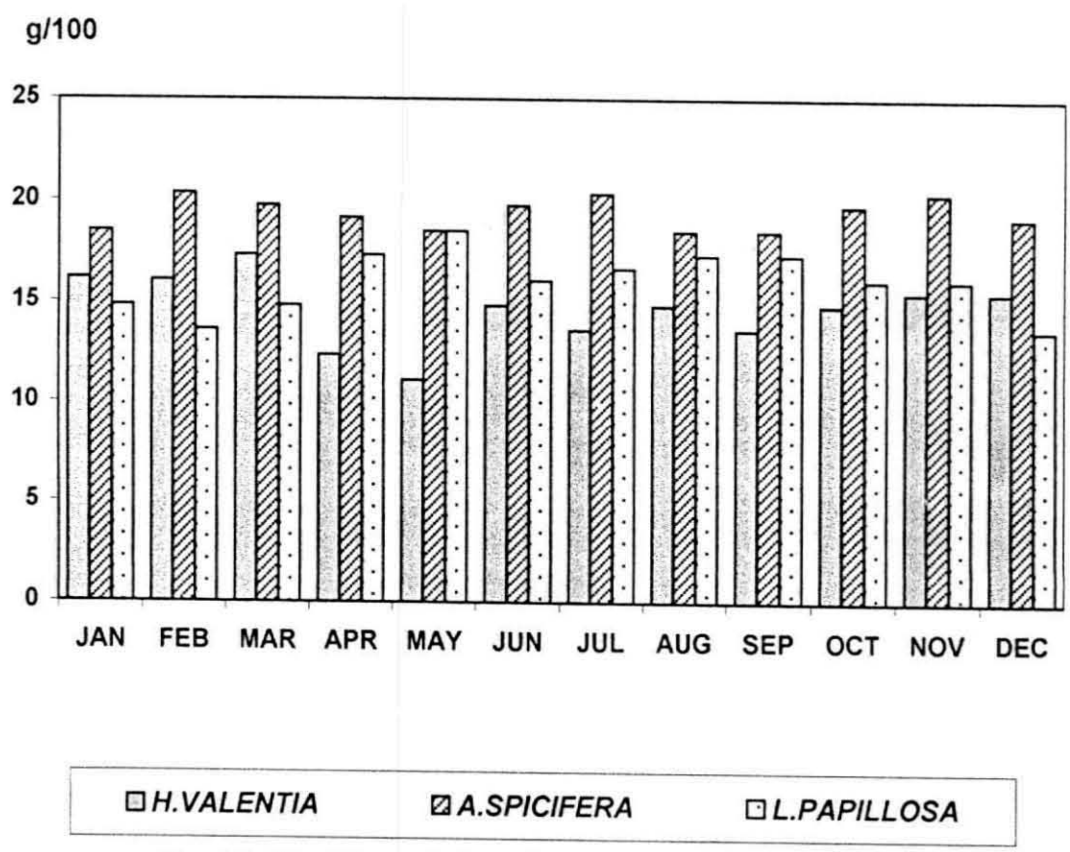


Fig. 25. Monthly variations in carbohydrate content of three species of macro algae

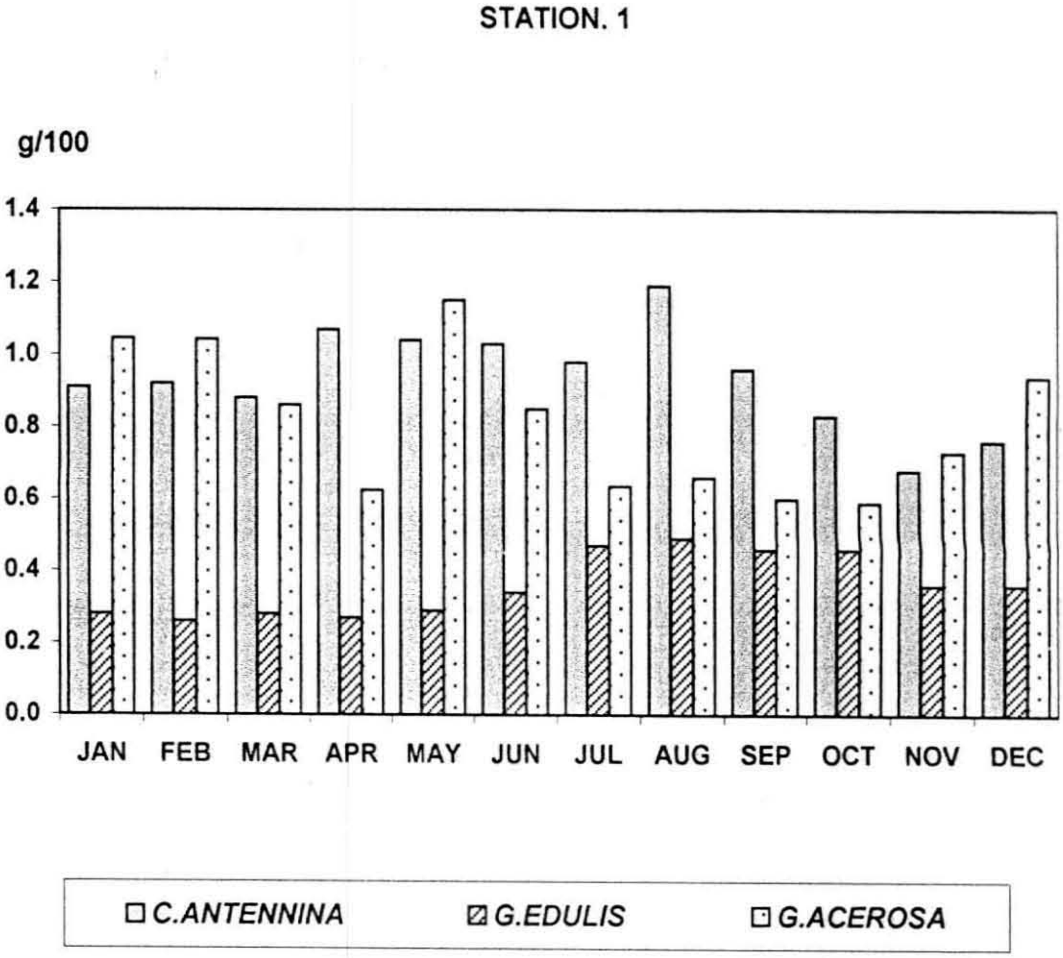


Fig. 26. Monthly variations in lipid content of three species of macro algae

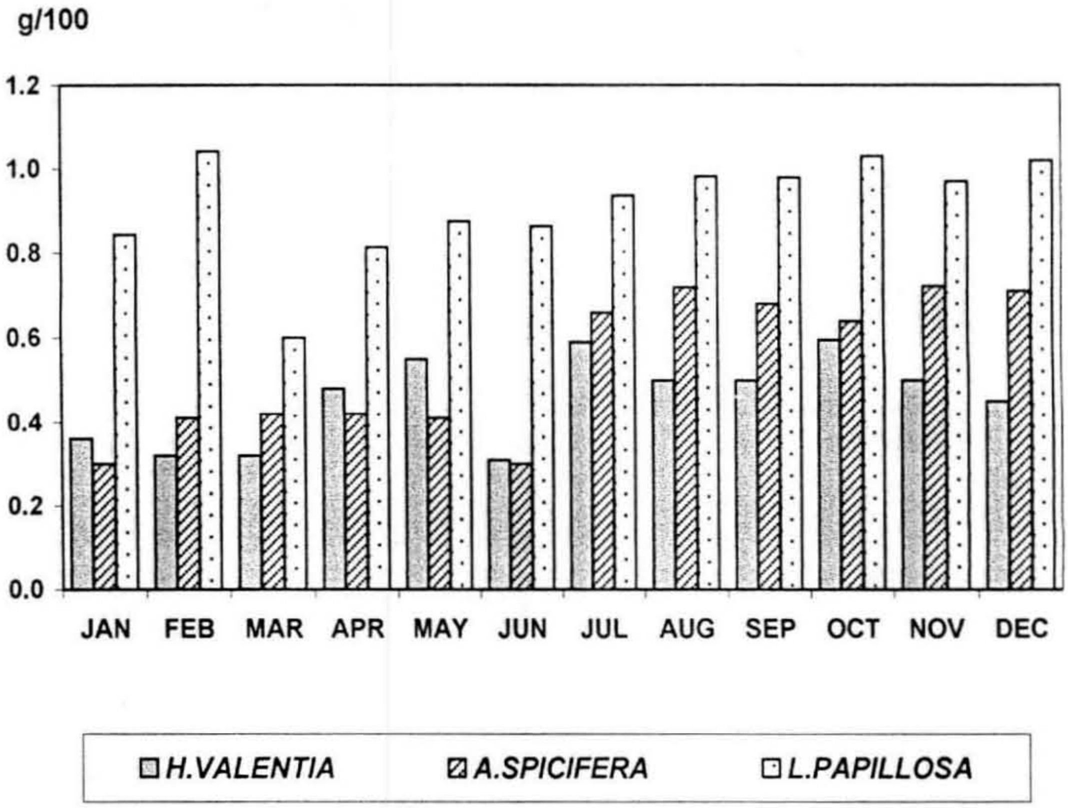


Fig. 27. Monthly variations in lipid content of three species of macro algae

DISCUSSION

The protein value of *C.antennina* reported by Reeta *et al.* (1990) from Mandapam coast i.e. 10.13 % is less than the value of 22.6 % obtained in the present study. Chennubhotle (1992) kaliapermal *et al* (1994) also reported low values of protein in *C.antennina* from Lakshadweep. The protein value ranged from 10.9 to 19.8 % in *Ulva reticulata* (Dhargalkar, 1986). A maximum of 18.8 % in *C.midas* and 19% in *U. faciata* were reported (Sumitra *et al.*, 1980). Sithakar Rao and Tipins (1964) observed a range of 7.22 to 25.48 % protein in green algae of Gujarat coast. It is evident from the above studies that the protein content of algae within the group and between locations shows wide variations. This could probably account for the wide variations in protein observed in the present study and that of Reeta *et al.* (1990). *C.antennina* was collected from fisheries jetty at Station 3 where the wastes from the Tuna Canning Factory is let out and the high protein content may be due to the accumulation of more nitrogen by the algae from available nitrogenous organic matter in the water. The average protein content of red algae in the present study was 7.63% (*G.edulis*) to 14.37 (*L.pappilosa)* Chennubhotla (1992) observed lower values ranging from 4.49 (*G.acerosa)* to 6.30 % (*A.spicifera*). The protein content of green algae is much more than that of red algae collected from Minicoy. Qari and Qasim (1993) also reported high values of protein among members of Chlorophyta when compared to that of Rhodophyta. However Gutirrez *et al.* (1990) observed that red algae contain considerably higher protein value than green algae.

The carbohydrate content of *C.antennina* was 20.4 % while in red algae it ranged from 14.63 (*H.valentiae)* to 21.8 % (*G.edulis)* . The carbohydrate content of red algae was found to be more than protein and lipid in all the species. In the case of *C.antennina* carbohydrate content was lower than that of protein. However Reeta *et al.*(1990) observed that the carbohydrate content of 27 species of green algae were higher than that of protein and lipid. Carbohydrate : protein ratio showed more fluctuations in *G.edulis* and *A.spicifera* than *C.antennina.* The ratios among red algae were; *L.papillosa* < *H.valentiae* < *G.acerosa* < *A.spicifera* < *G.edulis.* The near uniform carbohydrate : protein ratio is presumed to represent uniform growth rate and asynchronous reproduction in the population of these algae (Prasad and Potluri, 1992).

The lipid content of *C.antennina* is far lower than those reported by Reeta *et al.* (1990). Similarly, the lipid content of red algae is also low when compared to similar genera from other areas (Sumitra *et al.* 1980). Chennubhotla (1992) reported low values of lipid ranging from 0.25-1.65% in red algae collected from Lakshadweep area. The crude lipid content of green and red algae was unrelated to seasonal changes in temperature. Florito *et al.* (1993) also did not find significant relation in the case of *G.incurvata* while temperature was negatively correlated with lipid content in the case of *U.pertusa*. Lipid content of *C.antennina* was higher than that of the lipid content of the red algae studied at Minicoy. Similar observations were made by Parekh and Chauhan (1987) and Qari and Qasim (1993) reported that species belonging to Chlorophyta had comparatively high value of lipid than the species belonging to Rhodophyta.

A seasonal variation in biochemical composition of marine algae is well documented from temperate waters but little is known of tropical forms. Significant variations in protein, carbohydrate and lipid between seasons were not observed in the present study. Sumitra *et al.* (1980) did not observe a clear-cut seasonal trend in algae collected from Goa coast and attributed it to a lack of definite seasonal rhythm in the growth and reproductive cycles. On the other hand, Prasad and Potluri (1992) observed significant seasonal changes in the chemical composition of algae which was found to coincide with changes from the vegetative to the reproductive stages.

Another factor that could influence the biochemical contents is the change in physico-chemical parameters of the area. Ganesan and Kannan (1994) observed biochemical contents to be more during monsoon and postmonsoon months and attributed it to changes in environmental variables such as salinity, dissolved oxygen, light penetration and nutrients. Biochemical composition of algae at Minicoy is lower than those reported for similar or related species from other areas. A definite seasonal pattern was also not observed in the present study indicating the absence of definite growth cycles and influence of environmental parameters.

SECTION – B

PHYCOCOLLOIDS

INTRODUCTION

The use of seaweeds as raw materials for phycocolloid production has become a major worldwide industry involving food, cosmetics, dairy products, drugs, fertilizers, animal feeds and other valuable commodities. The most valuable product is agar, which is produced from different species of red algae. Agar consists of heterogeneous biopolymers containing galactose units and their derivatives. Agar is classified into different grades depending on the qualities such as gel strength, gel clarity and the quantity of charged particles in the agar composition. The most important colloid product from brown seaweed is the alginate which is widely used in textile, printing, paints and pharmaceutical industries.

Species of *Gracilaria* is used as raw material for the agar industry worldwide. Chile is the largest producer of *Gracilaria* and Japan is the largest producer of agar. The agar industry probably represents market value well in excess of US$ 200 million and agarophytes command a higher price than other colloids bearing seaweeds (Anon, 1996). India produces 110-132 tones of agar annually utilising about 880 to 1000 tonnes of dry agarophytes and 360-540 tonnes of algin from 3600 to 5400 tonnes dry alginophytes (Kaladhran and Kaliaperumal, 1999).

Hoyle (1978) found that crude agar yield in *Gracilaria cornopifolia* has about twice that of *G. bursapastoris* in Hawaiian waters. Christeller and Laing (1989) found that cultured seaweeds produces comparable yields and agar properties to those of wild grown plants. The composition of agar varies from species to species. However, less is known about the variations that may occur within one species (Craigie *et al.* 1984). Nelson *et al.* (1983) analysed the yield, gel strength and chemical composition of agar extracts from several species of *Gracilaria* collected from Guam, Saipan in Micronesia and from Taiwan. Variations in yield, gel strength and gelatin characteristics of the agar of *Gracilaria* was demonstrated to be dependent of time, season and life stages of the algae (Whyte *et a.*, 1981). Rebello *et al.* (1997) compared the agar quality of commercial agrophytes from different geographical regions and found that the highest agar yield is from *G.gracilis* from Argentina, while the lowest was from Brazilian *G.gracilis*. Structure and properties of agar from different agarophytes have been reported (Murana *et a.*, 1996; Oliveira *et al.* 1996; Freile-Pelegrine *et al.* 1996 and Suwalee, 1996).

The single and interactive effects of light, temperature, salinity and urea enrichment on the growth, agar yield and quality were determined by Macchiavallo (1990) Hurtado – Ponce and Ponevida (1997) and brackish water canals by De-Castro (1996).

In India, there are several agar and algin industries situated in different maritime states. These industries depend on the raw material collected from the natural seaweed beds in the southeast coast of Tamil Nadu mainly from Mandapam area. Kalimuthu *et al.* (1991) studied the standing crop, algin and mannitol of selected alginophytes from Mandapam coast. Seasonal changes in growth, alginic acid and mannitol content in *Sargassum ilicifolium* and *S. myriosystum* were reported by Chennubhotla *et al.* (1982). The agar and algin industries play an important role in providing employment opportunities to many fishing communities particularly who harvest the seaweeds from the coastal waters (Coppen and Nambiar, 1991). Alankara Rao *et al.* (1988) described an improved method for extraction of alginic acid from the brown seaweed *Sargassum vulgare*. Uusitalo (1987) discussed the different methods of seaweed cultivation from a biological, technical, economical and sociological point of view. The seasonal variation in agar and gel strength of *G.corticata* from the coast of Veraval, Gujarat was reported by Oza, (1978). Thomas and Krishnamurthy (1976) reported the yield of agar, time of extraction, gel strength, gelling and melting temperatures of *G.edulis.* Umamaheswara Rao and Kalimuthu (1972) reported changes in mannitol and alginic acid content of *T.ornata* in relation to growth and fruiting. A comparative study of the yield and the physical properties of agar from different blends of seaweeds is described by Chennubhotla *et al.* (1977a). Chennubhotla *et al.* (1977b) studied the growth variations, alginic acid and mannitol contents in *Padina gymnospora.* Seasonal variations in growth, alginic acid and manitol contents in two species of brown algae were reported by Kaliaperumal *et al.* (1988).

Agar and algin content of seaweed from Lakshadweep have not been studied in detail except for the work of Kaliaperumal *et al.* (1989) *and* Chennubhotla (1992). The present study reports the monthly variations in percentage of agar, gel strength, gelling and melting temperature of *G.edulis* and the algin content of the brown seaweed *T.ornata* growing at Minicoy.

MATERIAL AND METHODS

Collection of seaweeds

Gracilaria edulis was collected from the seagrass beds near Station 1. This site was selected due to the occurrence of

G.edulis throughout the year and healthy condition of the plants than in other stations. *Turbinaria ornata* for the algin estimation was collected from the lagoon near the reef flat at the southern end (Station 6). They were found attached to coral boulders and submerged even at lowest low tides. The size of *T.ornata* at this locality is much longer than the plants growing on reef flat and on the shore reef. As the plants were always submerged and due to its healthier stature, the number of attached organisms were found to be much less.

Extraction of agar

G.edulis samples were analysed monthly to study the seasonal variations in the yield and physical properties of agar. The bleached seaweed was cleaned, soaked in soft water, wet grounded and leached in soft water. The pulp was separated by filtration and extracted at 90^0C and the hot gel was filtered through organdy cloth. It was allowed to settle, cooled at room temperature, cut into strips and sun dried.

Analysis of Physical properties of agar

The yield of agar was determined by weighing the dried agar strips and expressed as percentage. Gel strength was determined using a gelometer described by Funaki and Kojima, (1951). 1.5% solution of agar was prepared and the incipient temperature at which it started gelling was taken as the gelling temperature. The melting temperature of agar was taken as the temperature at which the solidified gel of 1.5 % agar solution allows a 1.5g weight of iron ball to go down on heating.

Extraction of algin

Five grams of dried *T.ornata* was washed and boiled for 30 min and digested at room temperature with 2 % soda ash solution. The filtered solution is diluted with water to obtain a crude sodium alginate. It is then precipitated with 5 % Hcl. The precipitate is filtered and bleached with 2 % Potassium permanganate and 5 % Hcl. The filtrate is dried and weighed to calculate the percentage of algin content.

RESULTS

The results obtained on the yield and physical properties characters of agar from *G.edulis* of Minicoy is presented in (Table 36). The percentage yield of agar was maximum during the postmonsoon season (Plate - 5). Gel strength increased from premonsoon months and maximum mean values were observed in postmonsoon period. High gelling point was found in premonsoon while maximum melting point was observed during postmonsoon months. The monthly variation in yield of agar indicates low values from March to June and a sudden increase in July with peak in September and October (Fig. 28). The gel strength showed a similar pattern with maximum value

Plate - 5

a. *Gracilaria edulis*

b. Agar strips from *Gracilaria edulis*

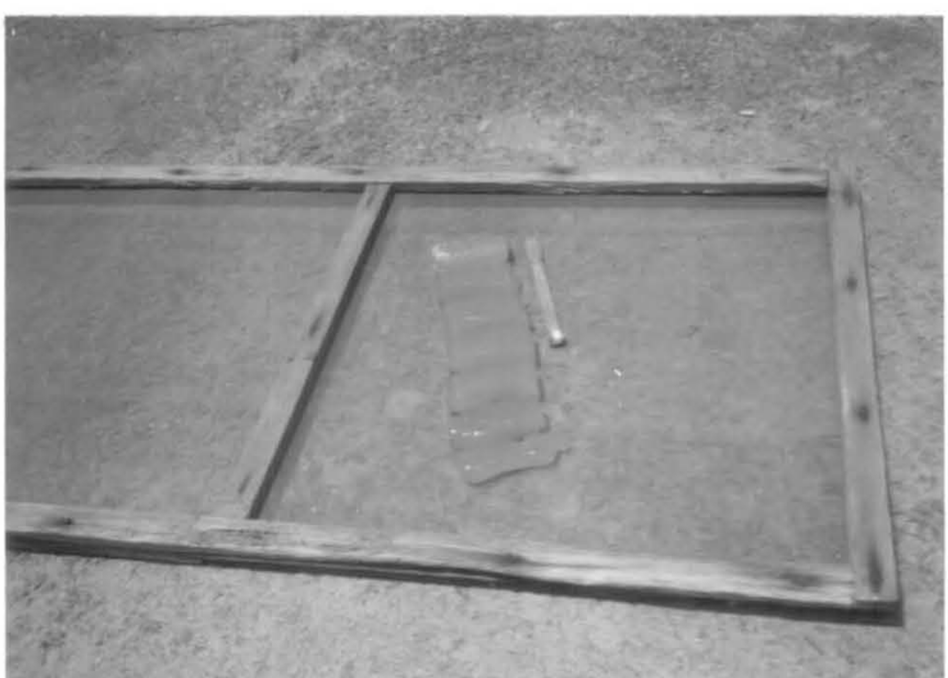


Table 36. Yield and quality of agar from *G. edulis* of Minicoy.

Season	% of agar	Gelstrength	Gelling point	Melting point
Premonsoon	15.86 ± 2.43	56.6 ± 6.7	48.8 ± 0.25	97.0 ± 2.83
Monsoon	21.46 ± 8.18	69.2 ± 18.7	47.3 ± 1.85	94.0 ± 3.74
Postmonsoon	32.32 ± 2.18	96.2 ± 22.6	47.5 ± 1.47	98.6 ± 0.75

Table 37. Yield of algin from *T.ornata* of Minicoy.

Parameter	Premonsoon	Monsoon	Postmonsoon
% Algin	32.95 ± 6.85	28.95 ± 5.73	28.51 ± 2.14

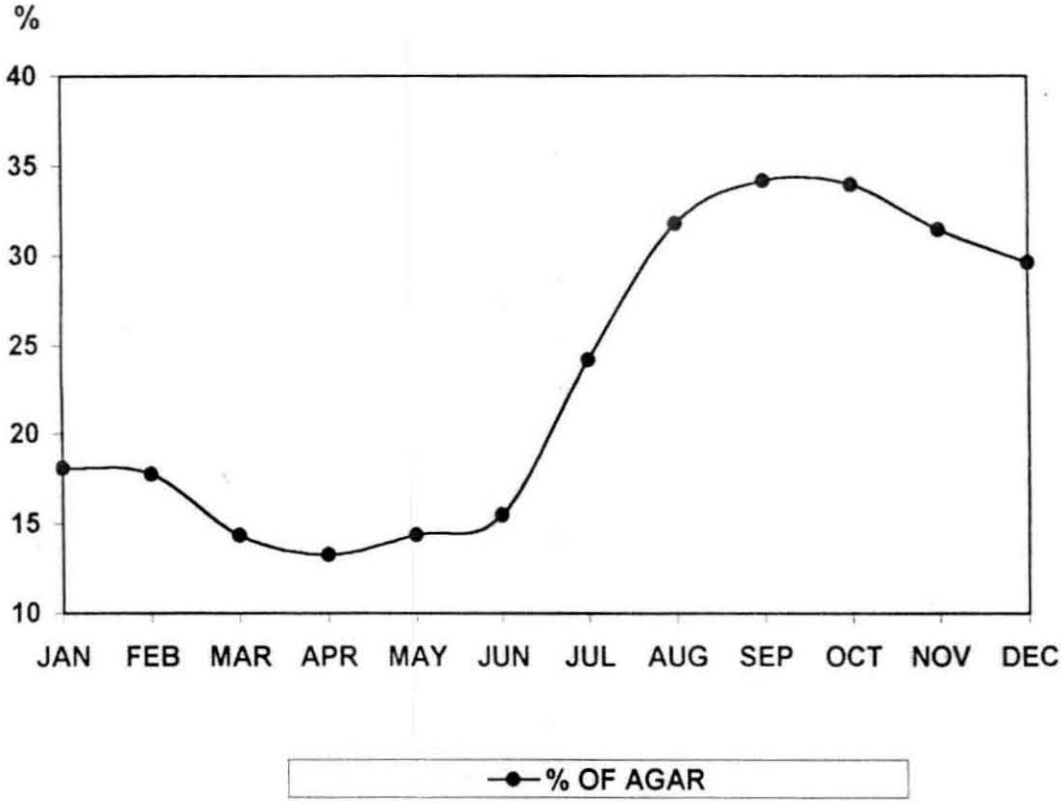


Fig. 28. Monthly variations in the yield of agar from *G. edulis*.

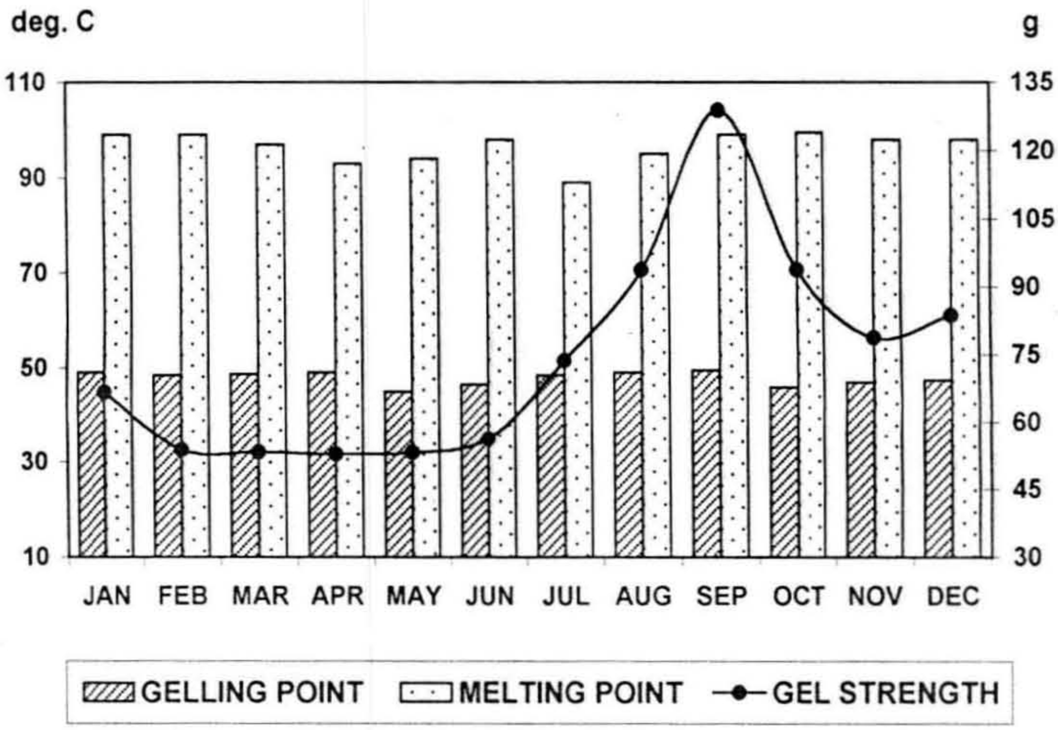


Fig. 29. Physical properties of agar extracted from *G.edulis.*

in September (Fig. 29). The gelling and melting point were more or less uniform throughout the period of study.

The percentage yield of algin in *T.ornata* (Table. 37)was high in premonsoon and showed a decreasing trend during monsoon and postmonsoon periods. The monthly fluctuations indicate peak values in February, April and May and lowest value in July. (Fig. 30)

DISCUSSION

The maximum agar yield from *G.edulis* of Minicoy was 34.2 % in the month of September. This value is lower than the yield obtained from G.edulis of other Lakshadweep islands by Kaliaperumal *et al.* (1989). The yield of agar from *G. edulis* collected from Mandapam was much higher with 55% (Kaliaperumal *et al.* 1987) ,while at Guam it ranged from 20.3 to 71.1 and in Taiwan it was 31.6 percent . The gel strength is comparable to already available reports Kaliaperumal *et al* (1987., 1989), Nelson *et al.* (1983). *G. edulis* is a potentially valuable species as source of agar but the gel strength of extracts from this species is generally very low .The high yield obtained may be due to the presence of other non–agar water soluble materials and algal debris. (Nelson *et al.* 1993). The potential for mariculture of this species can be enhanced by increasing the gel strength either through modification of the extraction techniques or by manipulation of environmental and

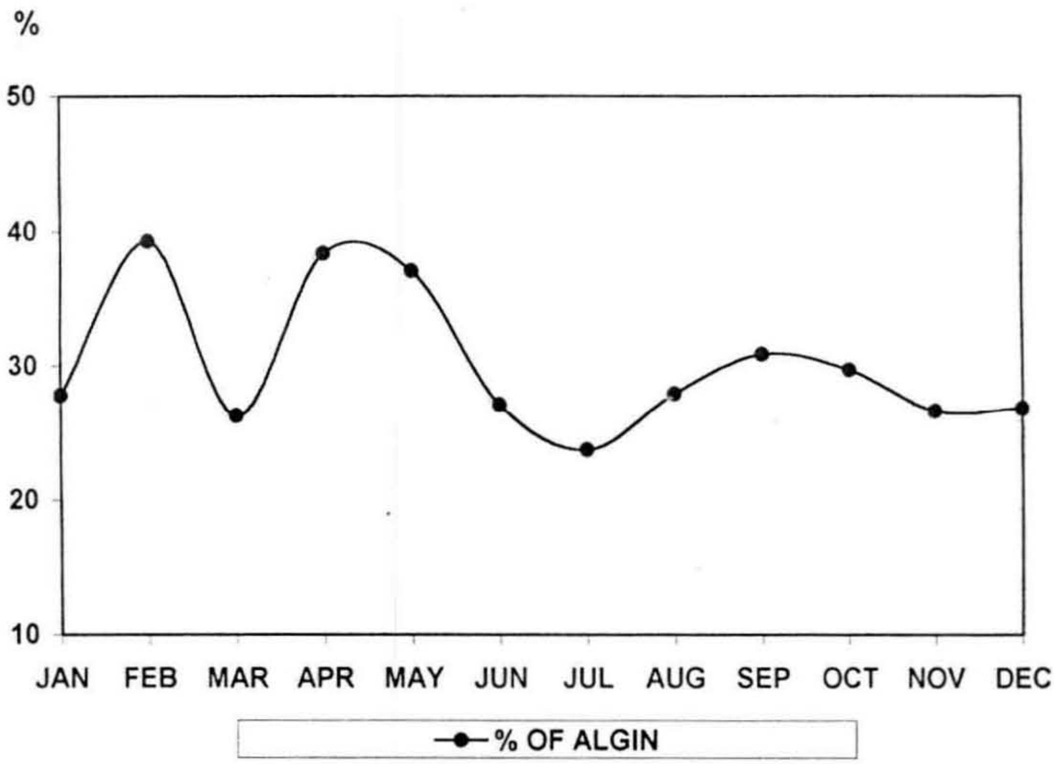


Fig.30. Monthly variations in the yield of algin from *Turbinaria ornata.*

hydrological parameters.De boer *et al* (1978), Bird and Hunson (1992).

A definite seasonality is observed in the yield and gel strength of agar with maximum values in the postmonsoon months. Therefore it is concluded that the suitable period for commercial harvesting of *G.edulis* from Minicoy is during September and October. The gelling temperature and melting temperature of *G. edulis* at Minicoy compares well with the values reported for this species and relatedspecies.(Whyte and Englar 1980.; Kaliaperumal *et al.,* 1989). Melting temperature is considered to be dependent on the molecular weight of the polymer and the viscosity of polysaccharide solutions.(Sellby and Wynne.,1973). Simple linear relationships between agar yield and water temperature and nitrate did not show significant correlation. Therefore it appears that the environment does not effect the agar yield and gel characteristics of *G.edulis* at Minicoy. However Christeller and Laing (1989) found significant relationships in *G. sordida* of New Zealand.

Algin content of *T.ornata* was maximum in the month of February with 39.3 % yield. This value was higher when compared with the values reported for *T. ornata* from other islands of Lakshadweep ranging from 19.1 – 26.1 % (Kaliaperumal *et al.,* 1989). A lower value of 22.4 % were reported for this species from Minicoy. There was no marked seasonal variation in the yield of algin from *T.ornata* at Minicoy which is in conformity with the results of Umamaheswara Rao and Kalimuthu, (1972). Kalimuthu *et al.*(1991) found that ideal period for commercial harvest *T.ornata* from Mandapam coast is from December to February. At Minicoy the favourable period for commercial exploitation of *T.ornata* seems to be from February to May. The agar content of *G.edulis* and the of algin content of *T.ornata* the present study compare well with the results obtained elsewhere. Therefore rational exploitation of these resource may be made to set up a small-scale agar and algin plant at Minicoy or transport these raw materials to the mainland, for increasing the production of agar and alginates in the country. Mariculture of these economically important algae can also be undertaken in the vast unpolluted lagoons of Lakshadweep to improve the economic status of the people living in this Union Territory.

The Union Territory of Lakshadweep consists of 10 inhabited and 17 uninhabited islands with submerged and live reef ecosystem. Lakshadweep is having a land area of 32 sq km. its lagoon area is about 4200 sq km. where very few research studies have been carried out. The earlier investigation dates back in 1979,1989 and 1992. These surveys revealed the occurrence of 114 species of seaweeds, many of which are industrially important and edible. Most part of the lagoon of the islands generally serves as an ideal site for farming and on account of the availability of natural stocks of seaweeds.

Minicoy Island ($8^{0} 17^{I}$N and $73^{0} 04^{I}$E) is a coral reef island among the Lakshadweep group of islands. It is about 10 km long and having a land area of 4.4 sq. km. Studies on these major renewable resources have not so far been undertaken in the island waters for a comprehensive period.

Islands and its reef ecosystems are one of the most diverse and colourful of any communities with the most complex inter relationship between species. Lakshadweep islands are one of the least studied area though it had such a complex ecosystem. Seaweeds were one among the group which is not studied in detail.

Studies on the ecology biomass, hydrography, biochemical analysis for protein, carbohydrate and lipids, phycocolloides such as agar, algin along with primary productivity and culture were carried out in Minicoy island, Lakshadweep.

Ten different stations were fixed for the study of biomass, physico chemical parameters. Physico chemical parameters influence the surroundings and the living in many ways, hence their study is essential in any of the ecosystem. The water temperature pattern of three areas that is lagoon, reef flat and shore reef indicate that they are more or less homogenous. It also indicates that the reef flats and shore reefs is not inundated by cool nutritionally rich waters from the surrounding portions. The inorganic nutrients, phosphorous and nitrogen are essential to the primary production on all systems. At Minicoy, the nutrient showed distinct seasonal pattern although variations in space were insignificant. Studies on nutrient flux on coral reef indicate that there is active recycling of phosphorous with minimum leakage to the overlying waters. Silicon is utilised in low quantity in most of the reef environments. The extensive shallow base coral reefs and lagoons characterised by slow to moderately strong currents and sandy coralline bottom of the Minicoy islands are found to be ideal habitat for many economically seaweeds.

The present study was carried out with a view to estimate the abundance of algae in space and time. Moreover to provide information on the seasonal availability and its harvest of economically important seaweeds. *G.edulis* was cultured and found suitable throughout the lagoon side. The species, though, introduced from mainland and Kavarati is growing and shown an average growth of 7.8 fold for all the three seasons. The percentage of agar and algin found comparable which is available from other areas of the mainland.

Seaweeds are used as human food and utilised in feeds in various aquaculture and poultry. Six species of macro algae have been analysed for its protein, carbohydrate and lipid contents. The agar content was extracted from *Gracillaria edulis*, percentage and its gel strength, melting point, gelling point have been found out.

During the period of study 38 species of algae from Minicoy island our of which 14 were green 5 brown and one red and one blue green algae were collected. The Rhodophytes in algae were more in eastern side of the island i.e. shore reef. Maximum number of algae were obtained from the same side. Phaeopyceae were only obtained 5 in number and low in most of the island ecosystem. Chlorophyceae came second and mostly abundant in lagoon area. Thus the present study observation on the ecology of seaweed flora of Minicoy island their distribution and biomass, monthly/seasonal occurrence, data on physico-chemical characters of ambient waters at 10 stations and their help us in the farming of economically important seaweeds, by providing information on the ideal conditions of seaweeds biomass production. Biochemical observations on protein carbohydrate and lipid contents on different species of seaweeds will give us an idea of their nutritive value. The study on monthly seasonal place wise variation will provide necessary information on the appropriate time and place of harvesting to sustainable use.

To understand the influence of the environment variable on biomass, multiple regression and correlation analysis were carried out using computer based programs. The environmental variables were: water temperature (x1), salinity (x2), dissolved oxygen (x3), phosphate (x4), nitrite (x5), nitrate (x6), silicate (x7).

The multiple regression equations show that there is significant interaction between environmental variables and biomass at lagoon side indicated by high R squared value. The relationship was weak at reef flat and shore reef with comparatively low R squared values.

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