# STUDIES ON TUNA LIVEBAIT FISHES OF LAKSHADWEEP

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
OF THE DEGREE OF
**DOCTOR OF PHILOSOPHY**
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**KOCHI, INDIA**

July 1993

# CERTIFICATE

This is to certify that the thesis entitled **Studies on tuna livebait fishes of Lakshadweep** is the bona fide record of the research work carried out by Shri. A.K.V. Nasser, under my guidance and supervision in the Postgraduate Programme in Mariculture, CMFRI, Kochi, and that no part thereof has been presented for the award of any other degree.

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# DECLARATION

I hereby declare that the thesis entitled **Studies on tuna livebiat fishes of Lakshadweep** has not formed the basis for award of any other degree, diploma, associateship or similar titles and recognition.

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Kochi

July 1993

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# PREFACE

Oceanic species of tuna such as skipjack (Katsuwonus pelamis) and yellowfin (Thunnus albacares) are being exploited by pole-and-line fishing using livebait and contribute to commercial fishery in Lakshadweep from September to April. In seventies the 'odies' (traditional craft) were completely replaced by mechanised boats fitted with bait tanks and since then tuna catch has increased considerably. The Lakshadweep Sea is estimated to have an annual fishery potential of 50,000 tonnes while the present yield is only about 7,000 tonnes a year. Some of the major constraints are the availability of live bait, man power, and adequate infrastructure facilities on shore. At present the skipjack catch which forms the major fishery is almost entirely dependent on the availability of live baitfish. There is no clear indication from published literature regarding the introduction of pole-and-line fishing to Minicoy from where it spread to other islands. It is believed that this fishery is in practice from time immemorial.

Extensive investigations on the distribution and biology of skipjack tuna are available but less is known of the bait fishes on which this fishery depends and what is known is inadequate, fragmentary and of cursory nature. The information available on tuna livebait fishes of Lakshadweep are mainly cofined to short term surverys aimed at estimating their availability and abundance. Reports on the biology of a few species from Minicoy are also present in the literature. This study was, therefore, prompted by a paucity of information on : 1) the livebits of Minicoy, 2) livebait fishery of the northern islands and 3) knowledge of livebait ecology.

Fishery biology and ecology form the two major sections of this study based essentially on the tuna baitfishery of Minicoy. Additional information was also collected on the fishery and biology of livebaits from Agatti, Bangaram and Perumal Par. The ecological investigations were, however, restricted to the lagoon at Minicoy. Resultes are presented in seven chapters : four dealing with fishery biology and three on ecology. Each chapter contains an introduction relevant to that study, the materials and methods employed and results and discussion.

The areas covered in biology are fishery, population characteristics, food and feeding habits and reprodcution of various species of liveabits. Estimates of catch, effort and size distribution forms the study on fishery while length-weight relationships and grwoth and mortality rates are the aspects covered in population dynamics. Observations on diet and reproductive biology was also attempted in the belief that they would help in better understanding of the availability and abundance of livebaits. Biology of livebaits are restricted to those species that were available in the fishery and was not intended as a detailed account of any particular species.

The second section on ecology includes observations on hydrography and primary and secondary productivity. Physical variables of water in the lagoon and adjacent sea at Minicoy were measured for a period of 16 months. Major areas of investigation included seasonal and spatial variation and interaction between environmental parameters especially nutrients. Relative contribution by reef flora and fauna to overall production and its influence by environmental factors formed the investigations under primary production. Seasonal composition and abundance of zooplankton were estimated from different regions of the lagoon and in the open ocean. Diurnal fluctuations and biomass by weight and volume were also investigated.

A summary of the important findings and literature cited in the text are presented. It is hoped that the information generated by this study would stimulated research in fields that require urgent attention for optimal utilization of livebait resources.

# ACKNOWLEDGMENTS

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# CHAPTER 1

# FISHERY

## INTRODUCTION

The two economically viable methods of catching tuna in good quantities in tropical waters are purse seining and pole-and-line fishing with live bait. Pole-and-line fishing comprises two fisheries, one for live bait and the other for tuna. This fishery depends upon quantities of suitable baitfishes, which are used to attract schools of tuna to the boat and to excite them into a feeding mode so that they can be caught by lure and a pole and line. The principal tuna species taken with baitfishes are skipjack, *Katsuwonus pelamis*; yellowfin, *Thunnus albacares* and albacore, *T. alalunga*. The live bait albacore fisheries are in temperate waters, while that of skipjack and yellowfin are in tropical waters.

There has been a shift from pole-and-line fisheries to purse seining during the last decade primarily due to economic reasons. But this method continue to be important in many islands of the Indo-Pacific. The pole-and-line method is labour intensive, hence providing more jobs and involves technologies suited to developing countries. The major problem associated with development of existing pole-and-line fisheries is the lack of adequate supplies of bait. In the most severe cases suitable baitfishes are altogether lacking. In some areas the stocks of naturally occurring baitfish species are inadequate to support a small domestic fishery, while in another baitfish may occur only in small quantities limiting catches of tuna to a level far below the optimum sustainable yield.

## Pacific Ocean fishery

The regions of pole-and-line fishing in the Pacific Ocean are the eastern Pacific off the coast of north and south America, the central Pacific fishery at Hawaii, the Japanese or the western Pacific fishery and the island nations of the south Pacific. Comprehensive and complete information on these fishery are available in reviews by Baldwin (1977), Yoshida et al(1977) and Lewis (1990). Baitfishery assessment, development and management in the central and western Pacific Ocean is reviewed by Hester and Otsu (1973). Hester (1974) suggests aquaculture, importation of bait from other areas and development of artificial baits as alternatives to the limited natural bait. The main characteristics of the bait in the central and western Pacific are : numerous species, small size fish, short survival and average yield (Boely et al 1980).

In the south Pacific, areas of previously active baitfisheries such as Papua New Guinea, Palau, and New Caledonia have switched over to purse seining due to economic reasons. The present areas of baitfishery are Solomon Islands (Nichols and Rawlinson, 1990), Fiji (Sharma and Adams, 1990) and Kiribati (Tekinaiti, 1990). Exploratory surveys conducted in the area to understand the species of baitfishes, their distribution and availability are : JAMARC (1976, 1978) and Saito (1977) in Micronesian waters, Smith (1977) and Lewis (1977) in Papua New Guinea, Wilson (1977a) in Palau and Wilson (1977b) in Ponape. Bait fisheries management of these areas in recent times have centered around the interaction of baitfishing with reef fisheries (Blaber et al 1990), subsistence fishing (Leqata et al 1990) and possible impact of non-target species (Rawlinson, 1990).

## Indian Ocean fishery

In the Indian Ocean exploratory fishing for bait at Thailand (Pimolchinda and Singhagraiwan, 1980) and Indonesia (Gafa and Merta, 1987) is reported. The Seychelles government is concentrating on purse seining for tuna, as it has been shown that pole-and-line fishing would be hampered by non-availability of baitfish (Hallier, 1990). Maniku et al (1990) described the bait-fishery at Maldives with reference to catch composition, seasonal variation and catch estimates.

## Lakshadweep skipjack pole-and-line fishery

### Major areas of baitfishery

At Lakshadweep, pole-and-line fishery is carried out in the waters around three inhabited islands. Mincoy, the southernmost island has a long history of pole-and-line fishing using a variety of bait fishes belonging to different families. The fishery in the northern islands is of recent origin and is concentrated at Agatti and Chetlat. The fishermen of Agatti depend on the lagoon at Bangaram and in the shallow ares of Perumal Par for live bait. Chetlat has a very small lagoon and does not have adequate bait fishes. The nearby island of Bitra which has one of the largest lagoon of the Lakshadweep archipelago support a variety of baitfishes and is used by the fishermen of Chetlat who migrate to Bitra for fishing. An another source of bait for the Chetlat fishermen is the nearby reefs of Chereapani and Baliyapaniyam. Similarly, bait and tuna fishery around the uninhabited island of Suheli is carried out by the fishermen of the capital island of Kavaratti. *Spratelloides delicatulus* is the only species of live bait used in the northern islands while fishes belonging to Clupeidae, Caesionidae, Pomacentridae and Apogonidae contribute to the fishery at Minicoy.

## Gear and methods of baitfishery

The fishermen of Minicoy use an encircling net for S. delicatulus and a lift net for all other species of bait. The encircling net is made of nylon mosquito netting 40 to 50 m long and 1.5 to 2 m wide with lead sinkers and wooden floats. The mesh size of this net is 5 mm. It is used to encircle shoals of blue sprat found in the shallow sandy area of the lagoon. Lift net is also made of nylon netting 5 to 6 m long and 4 to 5 m wide with mesh size of 6 to 8 mm. During the fishing operation the four ends of the net are tied to poles and lowered from the side of the boat. One set of poles is held near the boat while the other two is stretched so as to pass under a shoal of fish. The fishes are attracted to fish paste spread in the water column and when large quantities aggregate over the net, it is hauled up. Bait from the net is then transferred to the bait tank with a piece of cloth. The bait tank consists of two compartments separated by a perforated wooden board. It has an inlet pipe located in front passing through the hull and the tank. Excess water passes out of an outlet pipe located higher up on the side of the back compartment.

In the northern group of islands, the live baitfishery is dependent only on S. delicatulus caught by an encircling net. This net is similar to the one used at Minicoy with slight modifications. It consists of three components : a scare line, drag net and a collection net. The scare line is made of coconut leaves attached to ropes while the drag net is 40 to 50 m long 2 to 3 m wide with a mesh of 5 mm. The collection net is 3x4 m with a cloth piece of 1x2 m stitched in the centre. For fishing, the scare line is attached to the drag net and a shoal of fish is surrounded. When the shoal is enclosed the scare line is removed and bait is collected by the collection net.

There is no separate baitfishery at Lakshadweep. Each boat collects its own baitfishes from the lagoon before proceeding to the tuna fishing grounds. In the open sea, when a shoal of tuna is sighted, a chummer removes bait from the tank with a small scoop net and hurls it overboard. Bait is also used to retain the tuna shoal near the boat at the time of pole-and-line fishing. The tuna thus attracted and retained, bite at the silvery barbless hooks of the line mistaking it to be bait fish and is hauled onboard with a jerk of the pole.

The tuna pole-and-line fishery of Minicoy in its early form is described by Mathew and Ramachandran (1956), Jones (1958), and Jones and Kumaran (1959). The craft used was the 'mas odi', the traditional pole-and-line fishing boat of Minicoy. Lengths of these boats ranged from 9 to 12 m and is provided with

14 to 18 oars. The deep bilge are divided into 4 to 5 compartments separated by perforated planks for storage of bait. Water circulation is maintained by bung holes made at the hull bottom and excess water is baled out from the end compartments. The nets and their method of operation has undergone little change from that of today except that they were made of cotton. Jones (1960) reports large congregation of Spratelloides delicatulus attracted to light at Bitra and suggested further studies on its availability and suitability as live bait. The blue sprat is today the only baitfish used in the northern islands. A preliminary survey of the common tuna bait fishes of Minicoy and their distribution in the Laccadive archipelago was given by Jones (1964). He listed 45 species belonging to 30 genera and 19 families. While studying the fluctuations in the occurrence of the major tuna live bait fishes of Minicoy, Thomas (1964) observed eleven species of bait fishes to be regular in occurrence in the fishery. The advent of mechanised fishing boats and its advantages over the traditional crafts is described by Varghese (1971). Puthran and Pillai (1972) described the pole-and-line fishing for tuna at Minicoy with suggestions for the future such as separate arrangement for bait collection, use of larger boats and providing radio telephone equipment.

The baitfishes and their fishing techniques in the Indian Ocean have been discussed by Silas and Pillai (1982). Varghese and Shanmugham (1983) described the status of tuna fishing in Agatti island in Lakshadweep. An exhaustive account of live bait fishery at Minicoy is given by Pillai et al(1986). They discuss the fluctuations in live bait catch, species composition, habits and habitats of live baits and the present status of live bait fishery at Minicoy. The reasons for the shortage of baitfishes at Lakshadweep is attributed to heavy exploitation of live and dead corals, lack of recruitment to the population and increasing demand of bait fishes to meet the expanding pole-and-line fishery (James et al, 1986). Although pole-and-line fishing is successful at Lakshadweep, the present tuna catch of 6,000 tonnes is far below the potential of 50,000 tonnes estimated by George et al(1977). James et al(1987) opines that it would be worthwhile to attempt a skipjack fishery by purse seining on a limited scale and monitor the effect of purse seining on the stocks, and the relationship between pole-and-line fishing and purse seining. Exploitation of species other than S. delicatulus at the northern group of islands and harvesting migrant species from the leeward side of the island are the major recommendations of Kumaran et al(1989). Luther (1990) reviewed the fishery and biology of whitebait anchovies of Indian seas. He observes that whitebaits of the genus Encrasicholina may be suitable as live bait for tuna and calls for intensive efforts in understanding the areas of their distribution, abundance, spawning, growth and survival in captivity. The importance of adequate and suitable data for stock assessment of bait fishes is emphasized by Gopakumar et al(1991). They also discuss strategies for the development and management of baitfish fishery of Lakshadweep.

Live bait fishery, as is evident from the above review has undergone vast changes at Lakshadweep. The advent of mechanisation and expansion of the fishery to more islands has improved the economic condition of the islanders. However, the dependence on pole-and-line fishing alone, the absence of adequate bait and effective management of the fishery are the matters that hinder further development. Management relies on information collected on the present status of the fishery and to analyse them in the light of rational exploitation using effective measures.

## MATERIAL AND METHODS

The present study concentrated on two locations of pole-and-line fishery in the Lakshadweep. Minicoy, the southernmost island of Lakshadweep is located 215 nautical miles off Kochi at a latitude of 8° 17' N and longitude 73° 04' E. Minicoy bears close affinities with Maldives in social structure. The lagoon with an area of about 25 sq.km has two ecologically distinct habitats - the coral shoals which occupy about 75% of the area and the sand flats in the southern area of the lagoon. The average depth of this lagoon is 4 m (approx.) with a tidal amplitude of 1.57 m and an exposed reef area of about 4 km. The coral shoals or the deeper area are inhabited by bait species of the families Pomacentridae and Apogonidae. The inner and outer reef areas are fished for the migrant caesionids while the sandy area is the habitat of clupeids.

The island of Agatti is located in the centre of the Lakshadweep group at a latitude of 10° 51' N and longitude 72° 11' E. The distance from Kochi is 248 nautical miles. The land area of Agatti is 2.7 sq.km while the area of the lagoon is 24 sq.km. Prior to the introduction of skipjack tuna fishing in 1963, fishing was restricted to the lagoon by using shore seines and drag nets. Today, Agatti contributed about 60% of the total tuna catch from Lakshadweep.

To the north of Agatti at a latitude of 10° 54' and longitude 72° 14' E is situated the islets of Bangaram, Tinnakara and Parali. Bangaram, the largest of this group is uninhabited but has recently been converted into a toursit resort. The lagoon which has an area of 34 sq.km harbours one of the richest fauna of the area. Situated at about 32 km northwest off Agatti is the submerged reef known as Perumal Par. The reef encompass a large lagoon with a sandy area of about 2 sq.m rising above the water. *Spratelloides delicatulus* is the only species of baitfish exploited from these areas.

Data on the baitfishery at Minicoy for the season starting from November 1988 to April 1989 and from September 1988 to April 1990 were collected by enquiry and by joining baitfishing trips. The boats set out for baitfishing in the wee hours of the morning and on its completion proceed to open sea for tuna fishing. The number of boats operating on an observation day can therefore be determined indirectly by counting the boats which had not gone for fishing and still anchored in the lagoon. Out of about 40 units at Minicoy a maximum of only 25 to 30 units operate on any given day. The boats return to the island by early afternoon if tuna fishing is good or by dusk if the biting is poor. Information such as the time spent on baitfishing, species caught, the number of hauls, quantity of bait caught and used, area of fishing and relative abundance of bait were collected. The above information were obtained from the captain and divers of 40 to 60% of the boats operating on the observation day. The observations were made 1 to 3 days in a week so as to cover a minimum of 50% of the total fishing days in the month. Species-wise recorded catches were raised to the number of units operating in a single day. The total catches of the observed days was further raised to the number of fishing days in a month. Effort represented in numbers is the total number of baitfishing trips made by the boats in a month while catch (in kg.) is the total amount of bait caught for the respective effort. Catch divided by the effort gives the catch per unit effort (CPUE).

The information given by the fishermen were checked periodically by joining baitfishing trips. A major drawback was estimating the quantity of bait caught as bait is generally transferred *en masse* from the lift or encircling net directly to the bait tank. An attempt was made to quantify the bait by scooping them into a pre-weighed bucket containing about 2 liters of sea water. The new weight was measured on a sensitive spring balance. Only a single species will be dominating in a haul as a shoal of that bait is caught. This information along with the number of hauls and relative abundance was used to estimate the quantity of bait caught by a boat in a day. Another major constraint was in procuring adequate sample of baitfishes for length measurements and other biological studies. As the quantum of bait caught by a boat is low, the fishermen are reluctant to part with even a small sample. This necessitated collection from bait tanks after the return from tuna fishing which was only a handful and occasionally from bait reservoirs.

The trips to Agatti to monitor bait catches at Agatti, Bangaram and Perumal Par were of short duration and hence detailed information of the catch and effort could not be collected. The period of stay at Agatti varied from 3 to 12 days and details of baitfishing such as quantity of bait used, area of bait fishing and relative fishing in the previous days were recorded. Information was also collected from experienced fishermen and data was raised to the month as was done at Minicoy. Given the inherent problems of estimating the catch of baitfishes such as the quantity of bait caught a day, a confidence interval of + or - 25% is arbitarily assigned to the estimates made in this study.

## RESULTS

### Effort, catch and CPUE at Minicoy

The 1988-89 fishery season commenced in September 1988 but was hampered by the non-availability of *S. delicatulus* during September and October. Catches were high in November and December and thereafter declined till the end of the season in April with a short recovery in March (Table 1). Effort varied between 141 fishing trips in April 89 to 552 in December 88. The variation in CPUE was small with a range of 1.6 to 2.4 kg and total baitfish catch during the season of 5 months was about 4.1 tonnes. The second season started in September 89 and recorded catches of over 1 tonne from November to March 90. CPUE as in the previous season fluctuated narrowly between 1.5 and 2.7 kg. Total catch was higher during this season at about 9.1 tonnes.

### Effort, catch and CPUE at Agatti

### Agatti

Table 1 : Minicoy baitfishery - catch and effort statistics.

| Month & Year | Effort | Catch | CPUE |
|---|---|---|---|
| November 88 | 465 | 1044 | 2.2 |
| December | 552 | 1324 | 2.4 |
| January 89 | 228 | 483 | 2.1 |
| February | 203 | 385 | 1.9 |
| March | 367 | 684 | 1.9 |
| April | 141 | 222 | 1.6 |
| September 89 | 170 | 251 | 1.5 |
| October | 360 | 527 | 1.5 |
| November | 581 | 1308 | 2.3 |
| December | 640 | 1507 | 2.5 |
| January 90 | 619 | 1652 | 2.7 |
| February | 629 | 1202 | 1.9 |
| March | 625 | 1675 | 2.7 |
| April | 400 | 955 | 2.4 |

Effort is expressed in total number of fishing trips in a month

Catch and CPUE are in kg.

Table 2 : Agatti baitfishery - catch and effort statistics.

| Month & Year | Effort | Catch | CPUE |
|---|---|---|---|
| Agatti | | | |
| November 88 | - | - | - |
| December | 271 | 2198 | 8.1 |
| January 89 | - | - | - |
| February | 105 | 882 | 8.4 |
| March | 52 | 430 | 8.3 |
| October 89 | - | - | - |
| November | 88 | 752 | 8.5 |
| December | - | - | - |
| January 90 | - | - | - |
| February | - | - | - |
| Bangaram | | | |
| November 88 | 240 | 2040 | 8.5 |
| December | - | - | - |
| January 89 | 538 | 4361 | 8.1 |
| February | 525 | 4410 | 8.4 |
| March | 263 | 2153 | 8.2 |
| October 89 | 112 | 918 | 8.2 |
| November | 618 | 5263 | 8.5 |
| December | 607 | 5341 | 8.8 |
| January 90 | 773 | 7190 | 9.3 |
| February | 649 | 5934 | 9.1 |
| Perumal Par | | | |
| November 88 | 560 | 4760 | 8.5 |
| December | 631 | 5128 | 8.1 |
| January 89 | 359 | 2907 | 8.1 |
| February | 420 | 3528 | 8.4 |
| March | 210 | 1722 | 8.2 |
| October 89 | 168 | 1378 | 8.2 |
| November | 176 | 1503 | 8.5 |
| December | 405 | 3560 | 8.8 |
| January 90 | - | - | - |
| February | 432 | 3956 | 9.2 |

Effort is expressed in total fishing trips in a month

Catch and CPUE are in kg.

In the beginning of the first fishing season, bait fishery was reported from Agatti during December 88 and February and March 89 (Table 2). Total catch was about 3.5 tonnes with a CPUE of 8.2. During the second season bait was caught at Agatti only in November 88 with a CPUE of 8.5.

### Bangaram

Bangaram contributed to the baitfishery of the area in all the months except in December 88 of the first fishing season. A total catch of about 13 tonnes with a CPUE of 8.3 was obtained (Table 2). In the second season catches of above 5 tonnes was observed in all the months from November 88 to February 90. The total bait caught in this season was about 25 tonnes at an higher CPUE of 8.9.

### Perumal Par

Catches ranged from 1.7 tonnes in March 89 to 5.1 tonnes in December 88. A total catch of 18 tonnes with a CPUE of 8.3 was recorded during the first season (Table 2). A CPUE of 8.9 kg. and a total catch of about 13 tonnes was observed in the second season. Total catch of about 34 tonnes in the first season and 39 tonnes in the second is obtained for the baitfishery based at Agatti.

### "Manja chala" fishery

Mature *S. delicatulus* which are ready to spawn congregate in large numbers in the shallow sandy areas of the lagoon. They are dark bluish in colour before sunrise and changes to yellow just after sunrise and is locally known as "manja chala" or yellow bait. Fishermen encircle these shoals before sunrise and harvest them at the break of dawn. Catches per haul varies between 40 to 60 kg. enough for 4-6 boats. After the fishery the baitnet and bodies of the fishermen are covered by numerous eggs. Fishing for "manja chala" occurs on low tide days at Agatti, Bangaram and Perumal Par and usually coincides with good tuna catch.

## Species composition of bait catches at Minicoy

A total of 11 species contributed chiefly to the fishery at Minicoy during the two seasons under study. They were the sprats, Spratelloides delicatulus and S. gracilis; fusiliers, Gymnocaesio argenteus, Caesio striatus, Pterocaesio pisang and P. chrysozona; damsel fishes, Chromis caeruleus and Lepidozygous tapeinosoma; and the cardinal fishes Archamia fucata, Apogon thermalis and Rhabdamia gracilis.

In the beginning of the first fishing season, C. striatus and G. argenteus dominated the fishery and were supported by the sprats, S. delicatulus and S. gracilis (Fig. 1). Towards the end of the season in March and April, A. fucata and R. gracilis also entered the fishery. During second season, the early months of September and October were dominated by S. delicatulus while the middle months from November to January was supported by G. argenteus and C. striatus (Fig. 2). In January

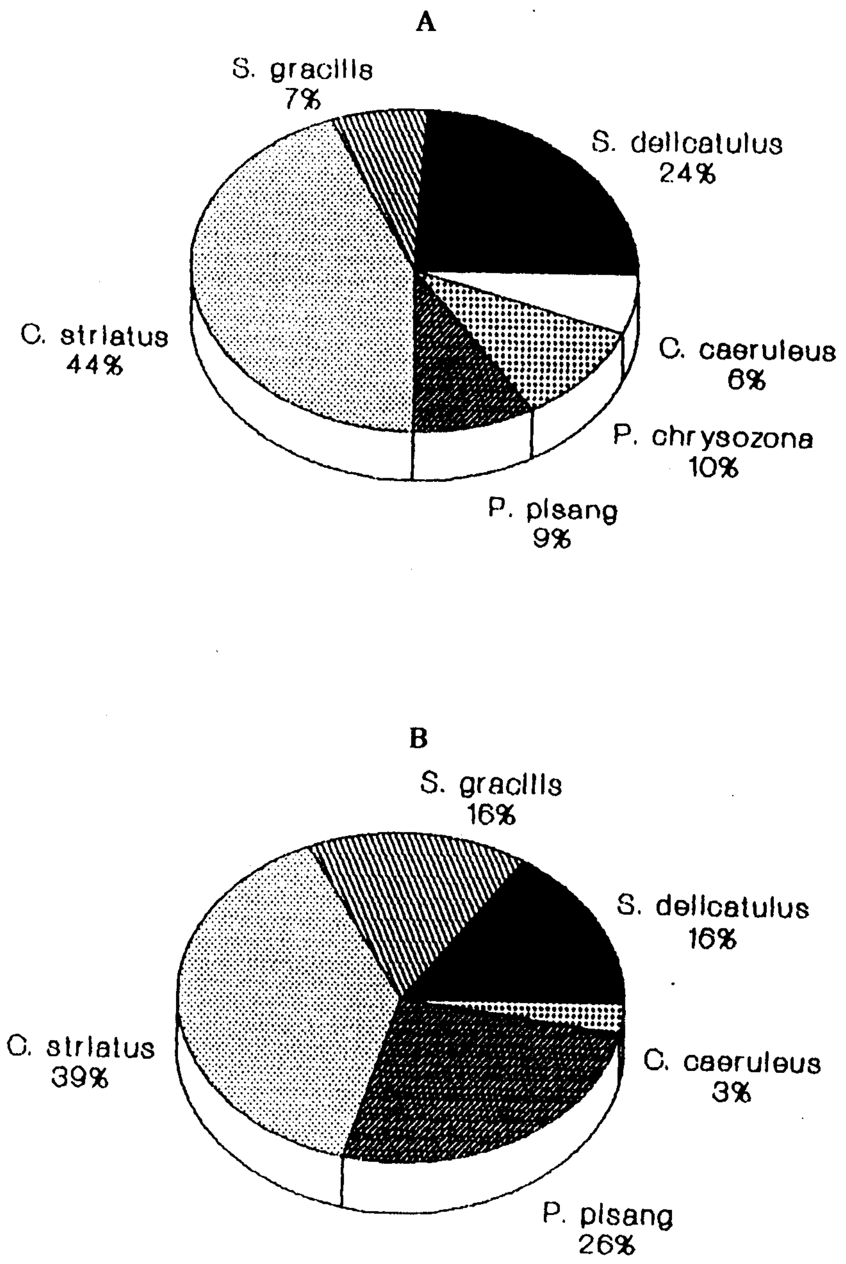


Fig. 1. Percentage species composition of livebait fishery at Minicoy, 1988-89. A. November 88 B. December 88.

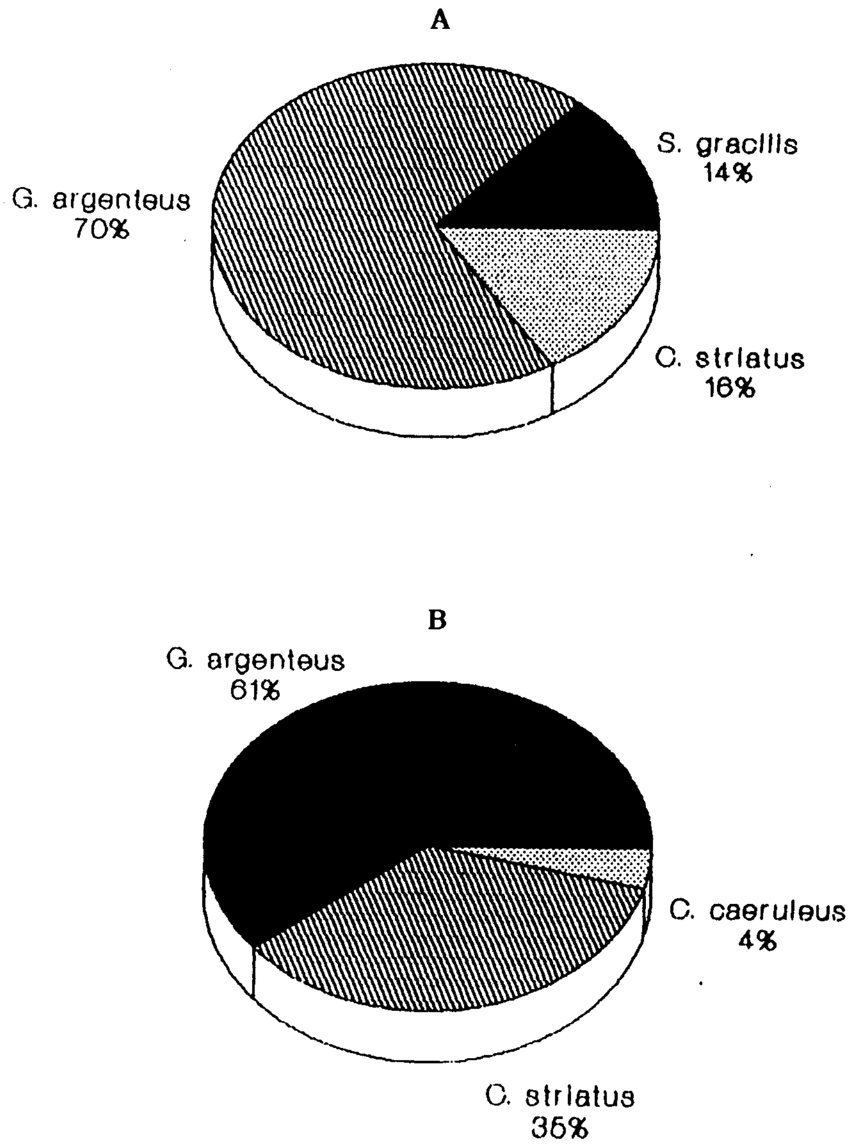


Fig. 2. Species composition of livebait fishery at Minicoy, 1988-89. A. January 89 B. February 89.

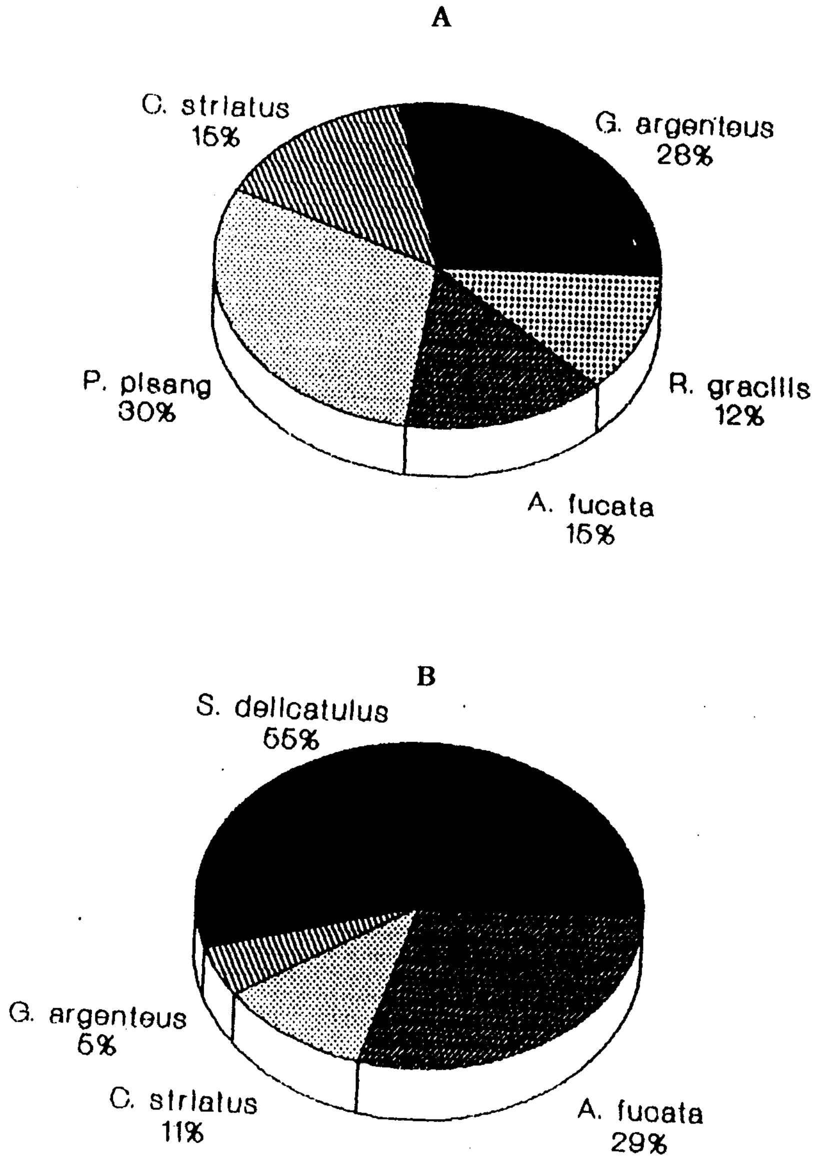


Fig. 3. Species composition of livebait fishery at Minicoy, 1988-89. A. March 89 B. April 89.

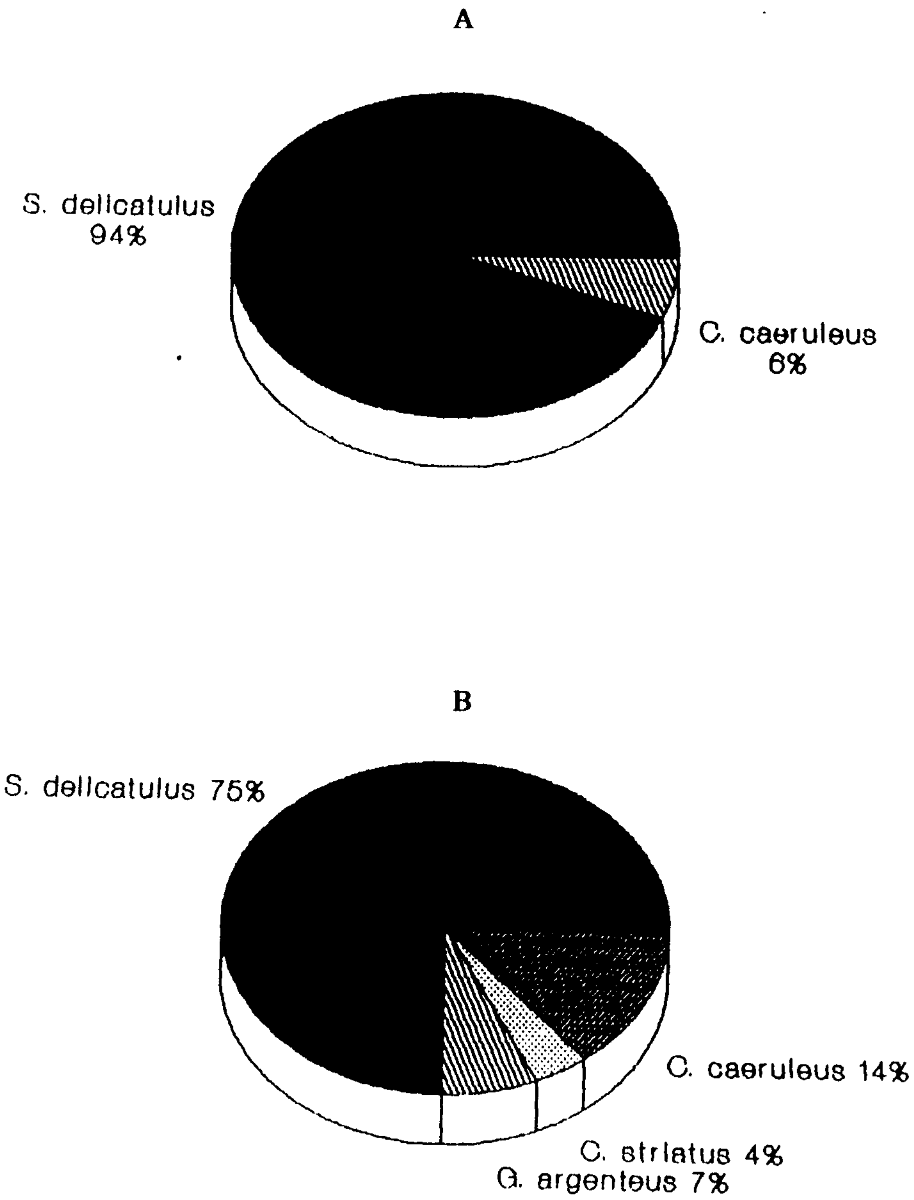


Fig. 4. Percentage species composition of livebait fishery at Minicoy, 1989-90. A. September 89 B. October 89.

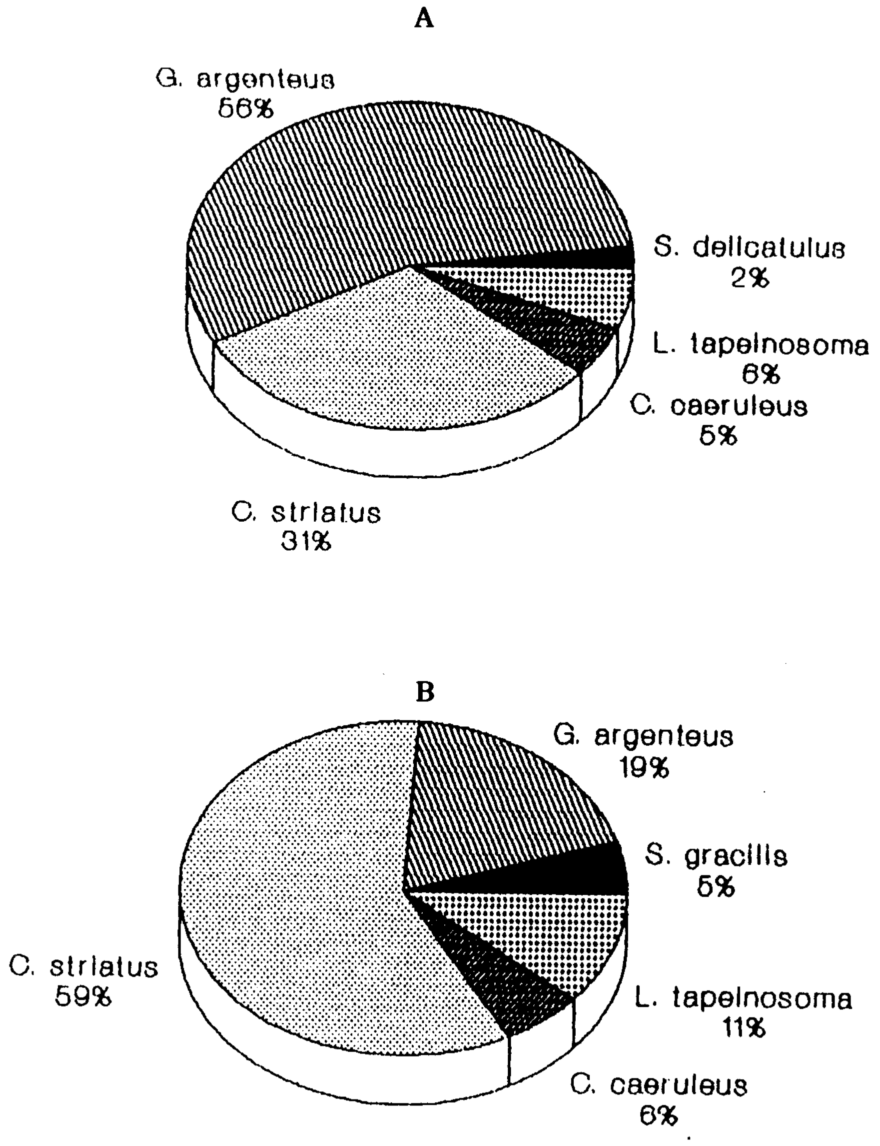


Fig. 5. Species composition of livebait fishery at Minicoy, 1989-90. A. November 89 B. December 89.

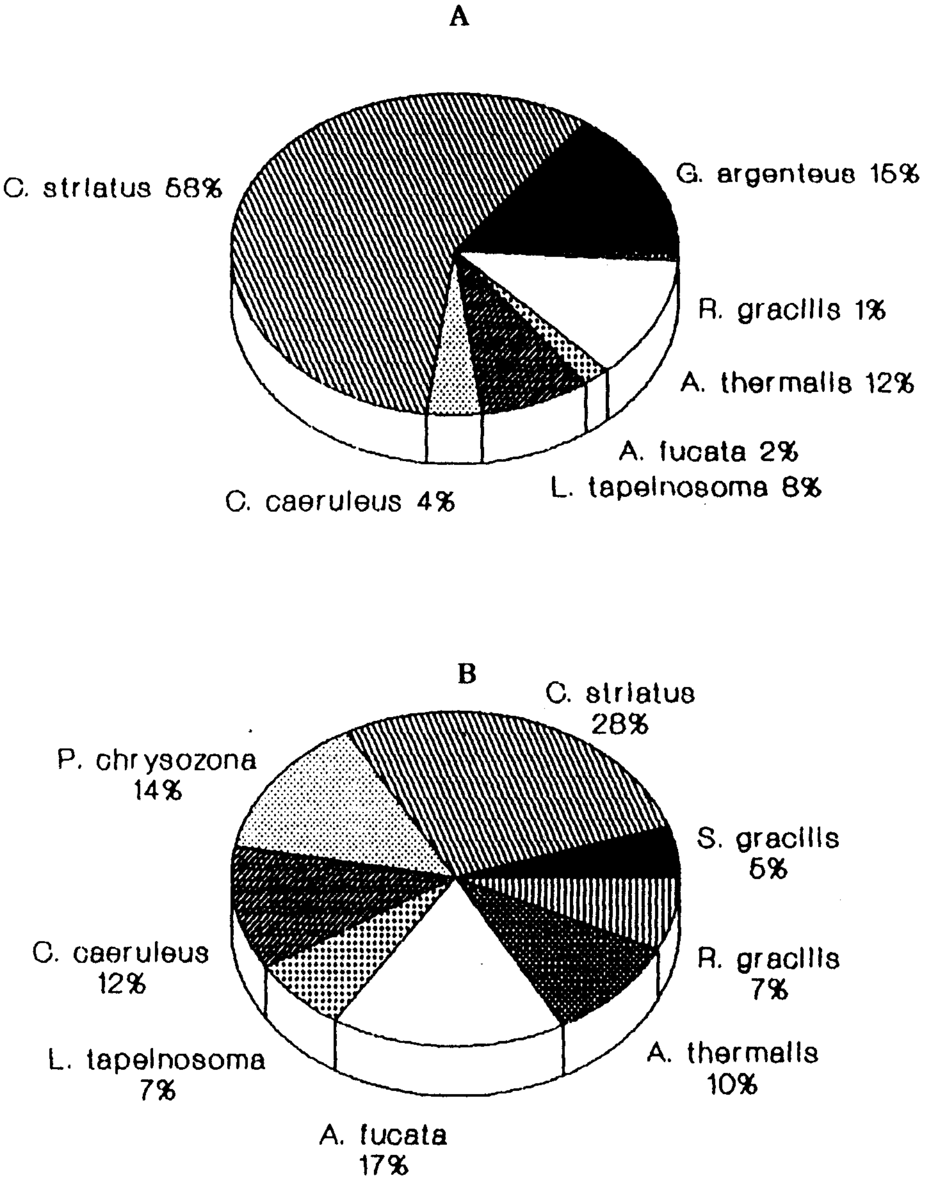


Fig. 6. Percentage species composition of livebait fishery at Minicoy, 1989-90. A. January 90 B. February 90.

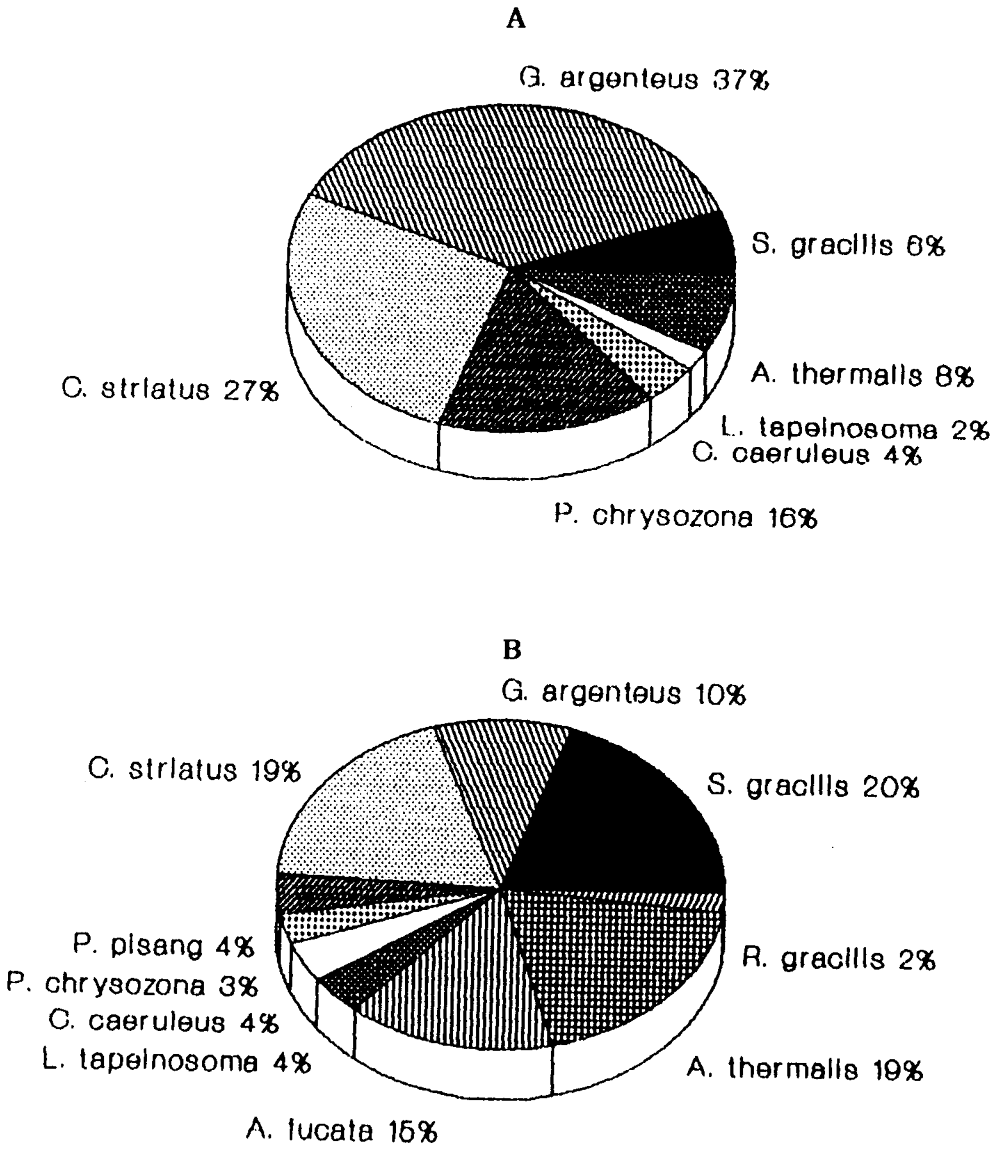


Fig. 7. Species composition of livebait fishery at Minicoy, 1989-90.
A. March 90 B. April 90.

about 25% was constituted by pomacentrids and apogonids which increased to 53% in February. However, the fishery shifted back to caesionids in March. April had the maximum bait diversity when 10 out of the 11 species were recorded (Fig. 3).

A higher percentage of boats used species of the family Caesionidae for a major period of the first fishing season (Fig. 4a). Clupeids also contributed significantly during November, December and April. However, pomacentrids were fished only by a very small percentage of boats while apogonids formed the catch of more than 30% of the boats during March and April. About 80 to 90% of the boats fished for clupeids during September and October of the second season (Fig. 4b). Caesionids were caught by about 60 to 80% of the boats from November to January and in March. Pomacentrids made a more significant contribution during this season with the percentage of boats catching them ranging from 6 to 23%. As in the first season, apogonids were fished only in the latter months when 9 to 43% of the boats were engaged in its fishery.

## Bait caught per haul at Minicoy

Among the clupeids, *S. delicatulus* had a higher mean weight per haul when compared to *S. gracilis*(Table 3). Except for *P. pisang*, the other caesionids recorded maximum weight of 1 kg. and above per haul. The Pomacentrid *C. caeruleus* showed a greater mean weight per haul when compared to *L. tapeinosoma* and

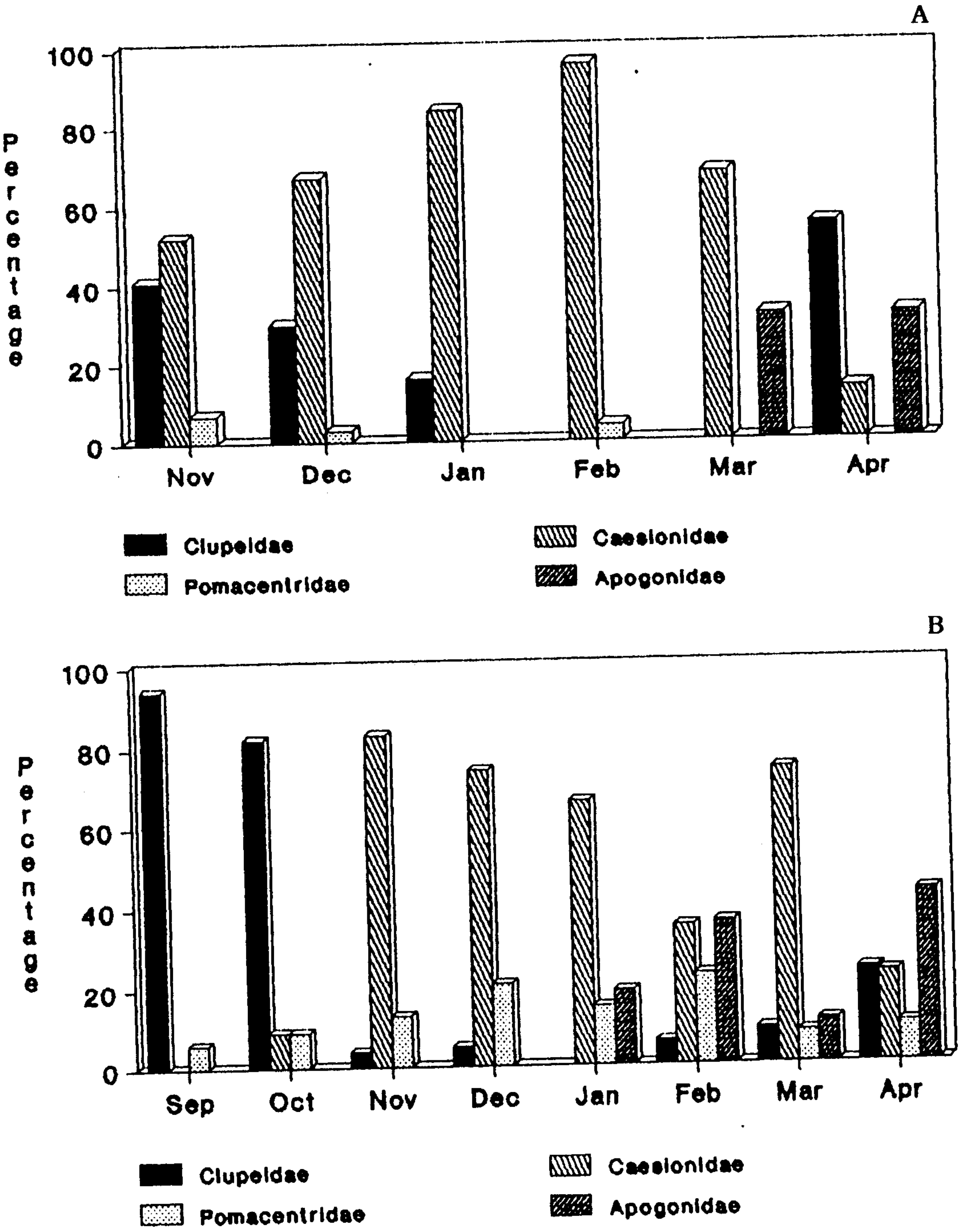


Fig. 8. Percentage of boats utilising a particular group of bait at Minicoy. A. 1988-89 B. 1989-90.

Table 3 : Weight of baitfish caught per haul at Minicoy

| Species | Number of hauls | Weight (gm) | | | |
|---|---|---|---|---|---|
| | | Minimum | Maximum | Mean | SD |
| *S. delicatulus* | 11 | 100 | 1500 | 657 | 470 |
| *S. gracilis* | 9 | 50 | 700 | 283 | 211 |
| *G. argenteus* | 22 | 50 | 1100 | 301 | 266 |
| *C. striatus* | 11 | 100 | 1000 | 441 | 291 |
| *P. pisang* | 4 | 60 | 300 | 217 | 108 |
| *P. chrysozona* | 10 | 70 | 1800 | 879 | 524 |
| *C. caeruleus* | 11 | 50 | 1900 | 602 | 652 |
| *L tapeinosoma* | 8 | 70 | 1000 | 409 | 326 |
| *A. fucata* | 5 | 150 | 1500 | 950 | 536 |
| *A. thermalis* | 9 | 50 | 320 | 158 | 104 |
| *R. gracilis* | 7 | 80 | 250 | 151 | 62 |

also had the maximum variation as indicated by a higher standard deviation than the mean. *A. fucata* was the dominant Apogonid and had a higher mean weight per haul when compared with *A. thermalis* and *R. gracilis*.

## *Size distribution of live baits*

The total length of the fish samples collected were measured to the nearest millimeter and frequency was analysed by grouping into 5 mm class intervals. *S. delicatulus* at Minicoy showed a mode at 33 mm (class size 31-35 mm) with larger sizes at a low frequency except for 48 mm. *S. gracilis* on the other hand peaked at 53 mm with sizes ranging from 33 to 48 mm contributing significantly to the fishery (Fig. 5a). Among caesionids (Fig. 5b)*G. argenteus* showed a wide size distribution from 53 to 83 mm with minor peaks at 58 and 68 mm. *C. striatus* however showed distinct peaks at 83 and 93 mm while sizes of *P. pisang* contributing to the fishery were considerably smaller with peak at 33 mm. Sizes of 73, 78 and 88 mm were observed in higher percentages in the case of *P. chrysozona*. In the case of pomacentrids (Fig. 5c) *C. caeruleus* with mean size of 28 mm formed the bulk of the fishery and the frequency reduced as the size groups advanced. *L. tapeinosoma* showed a peak at 48 mm between minor peaks at 43 and 53 mm. The major size groups in the fishery of apogonids (Fig. 5d) varied widely with *A. fucata* at 53 mm, *A. thermalis* at 38 and *R. gracilis* at 28 mm. . *delicatulus* at Agatti which were found in the fishery were of

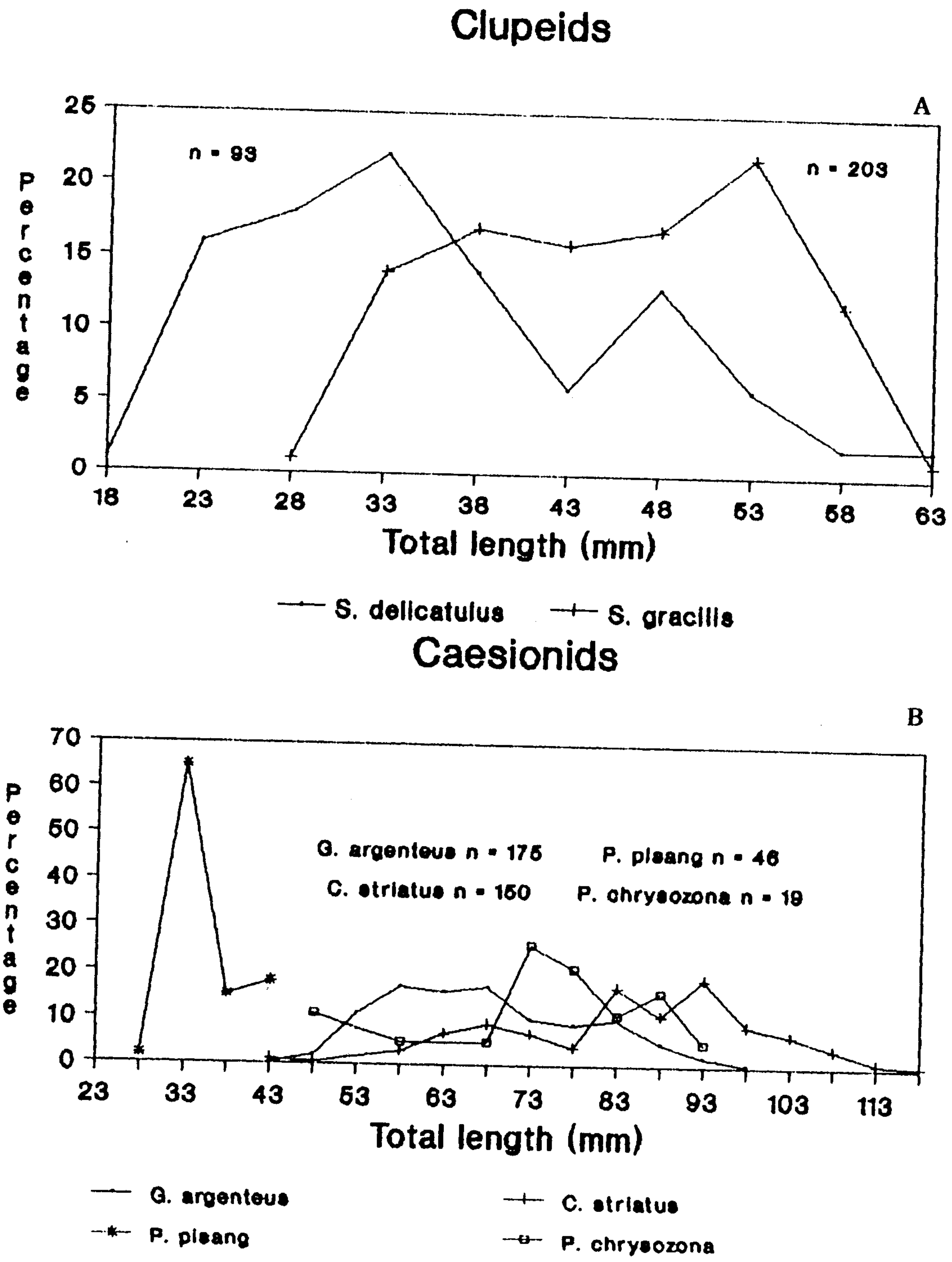


Fig. 9. Size distribution of Clupeids and Caesionids in the fishery at Minicoy.

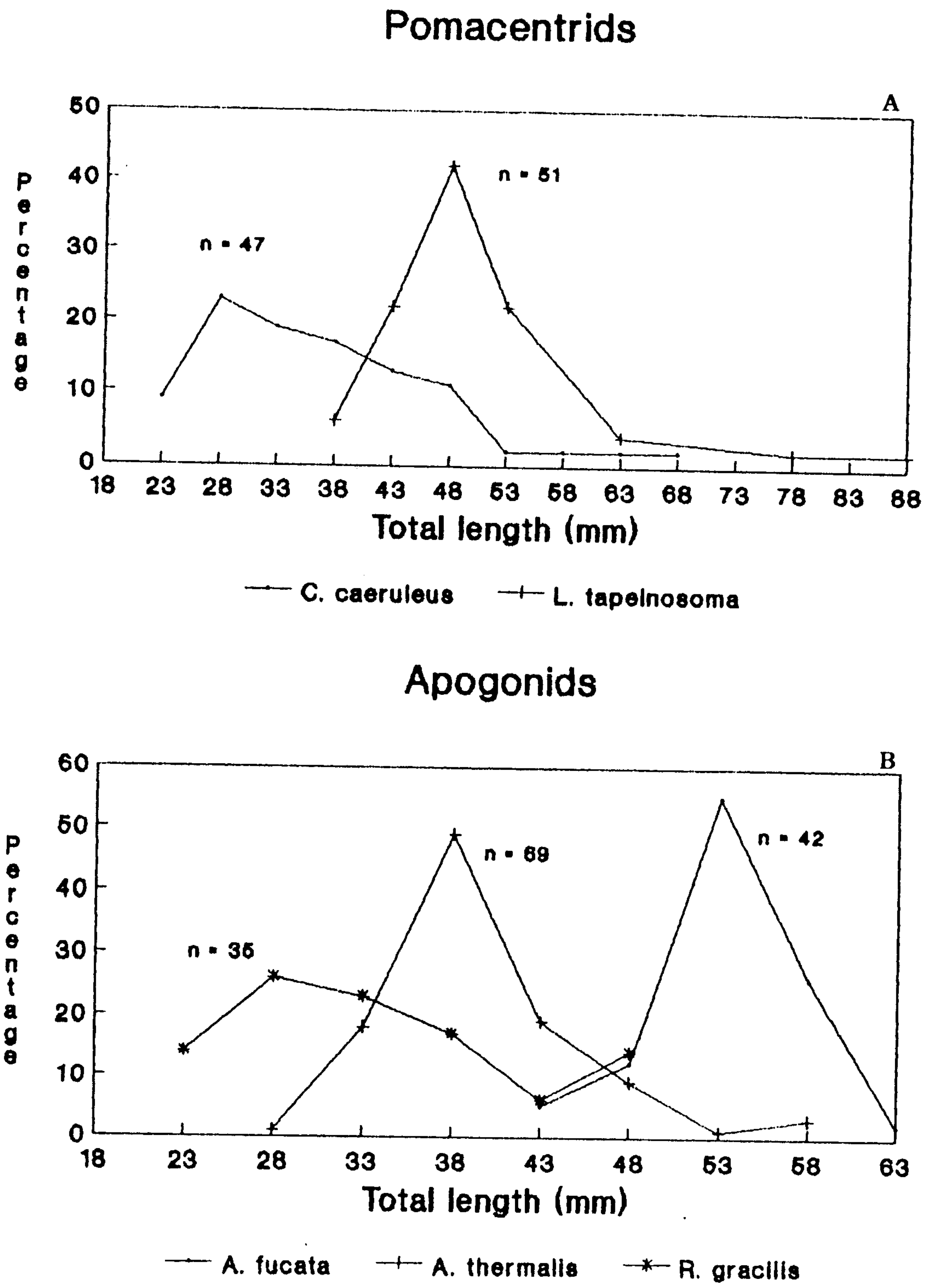


Fig. 10. Size distribution of Pomacentrids and Apogonids in the fishery at Minicoy.

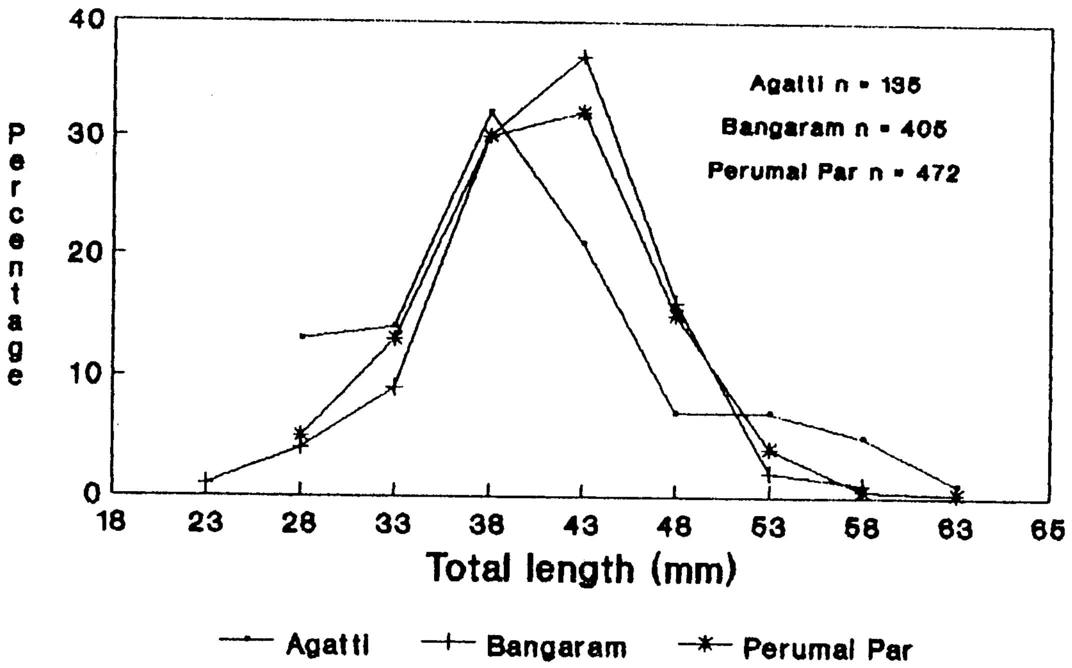


Fig. 11. Size distribution of *S. delicatulus* at Agatti, Bangaram and Perumal Par.

smaller sizes with peak at 38 mm when compared to that of Bangaram and Perumal Par where the peaks were at 43 mm (Fig. 6).

## DISCUSSION

The livebait fishery at Minicoy depends on the availability of migratory species mainly caesionids. Bait catch during the second season more than doubled mainly due to the increase in catches of C. striatus and G. argenteus from November to April. Pillay et al(1986) observed a similar trend at Minicoy and Maniku et al(1990) reports caesionids as the major group of baitfishes used at Maldives. Juvenile fusiliers, locally known as Muguraan are good baitfish because they are easy to catch, are good chummers and are fairly hardy. They appear in the fishery from late October and is available mostly in all the months till the end of the fishing season. It is interesting to note that they are taken most frequently during the NE monsoon season in the north of Maldives (Maniku et al(1990). The importance of migratory species on the bait fishery at Minicoy is also indicated by the catches of L. tapeinosoma. This Pomacentrid was the most important baitfish and used to rank first in the availability of baitfishes (Thomas, 1964). But from the 1981-82 season onwards, this species was either not observed or contributed little to the fishery. Generally, when these migratory pomacentrids or caesionids does not contribute to the fishery, bait catches and hence tuna catches are low. Fishermen at Minicoy believe that their appearance is an indication of greater availability of tuna as they come near the island to feed on these baitfishes. The fluctuations in baitfishery at Minicoy, therefore, seems to depend mostly on these migrant forms. Further the stocks of resident forms chiefly the apogonids are on the decline due to the deterioration of their habitat and what remains is inadequate to form a sizable fishery.

A first order yield estimate at Minicoy can be made following the method of Marten and Polovina (1982) which uses the empirical relationship between primary productivity and potential pelagic fish yield. Nair and Pillai (1972) reported primary productivity of a reef at Minicoy to be 3000 gC/sq.m/year. This would give a potential pelagic fish yield of 118 t/sq.km/year. Assuming that 60% of pelagic fish production is attributable to small (baitfish) pelagics, potential yield of 71 t/sq.km/year are obtained. If 15 sq.km of the Minicoy lagoon is used for bait fishing the yield would be 1065 t/year or 88 t/month. The present maximum exploitation of about 1.6 tonnes in a month can therefore be increased. Caesionids during the second fishing season were obtained from outer reef areas by some fishermen. This indicates that baitfishery has to move away from traditional areas of the lagoons to reefs and outer reef areas and also on the leeward sides as pointed out by Kumaran *et al*(1989).

The catch estimates for Agatti, Bangaram and Perumal

Par with its inherent errors are significant as this is the first estimate of bait caught from these areas. Due to its fragile nature, one third of S. delicatulus caught dies during transportation to the tuna grounds. The more the time taken for tuna fishing greater is the mortality. From experience the fishermen have learned that if they carry smaller amounts of bait the mortality is greatly reduced. In spite of this, boats in these areas usually carry three times more than what is required fearing shortage when tuna shoals are sighted. The capture of matured fishes in large quantities and mass destruction of eggs during the "manjachala" fishery may have an adverse effect. Intensified fishery at any one area for a prolonged period of time also causes shortage. At Perumal Par if all the units operate for 2-3 days at a stretch, bait shortage is reported. The surveys conducted (Kumaran et al 1989, Gopakumar et al 1991) clearly show that there ia potential for other live baits in these areas. Although the use of lift net was demonstrated by fishermen of Minicoy, it has not found acceptance in the northern group of islands. This may be because of the ready availability of S. delicatulus, but for optimum utilization other species will also have to be exploited which will also reduce the fishing pressure on blue sprat.

The livebait fishery of Lakshadweep is lesser in magnitude when compared to other pole-and-line fishing areas of the world (Table 4). A preliminary estimate of about 60 tonnes

Table 4 : Species and quantity of livebait used at the various pole-and-line fishing areas

| Location | Major species of bait used | Year | Quantity (tonnes) |
|---|---|---|---|
| PACIFIC OCEAN | | | |
| Eastern Pacific | *Cetengraulis mysticetus*, | | |
| | *Engraulis mordax*, | | |
| | *Sardinops caerulea* | 1969 | 996[a] |
| Central Pacific | *Stolephorous purpureus* | 1972 | 125[a] |
| Western Pacific | *Engraulis japonicus* | 1971 | 20,248[a] |
| SOUTH PACIFIC | | | |
| Solomon Islands | *Stolephorous heterolobus* | 1988 | 2,500[b] |
| Fiji | *Spratelloides delicatulus* | | |
| | *Amblygaster sirm* | | |
| | *Herklotsichthys* sp. | | |
| | *Stolephorous* spp. | | |
| | *Rhabdamia gracilis* | 1989 | 71[c] |
| Kiribati | *Spratelloides delicatulus* | 1989 | 1[d] |
| Papua New Guinea | *Stolephorous heterolobus* | | |
| | *Spratelloides gracilis* | 1978 | 1,900[e] |
| Palau | *S. heterolobus* | 1969 | 220[f] |
| New Caledonia | *S. heterolobus* | | |
| | *H. quadrimaculatus* | | |
| | *Decapturus* spp. | 1983 | 5[f] |
| INDIAN OCEAN | | | |
| Maldives | *Caesio caerulaurea* | | |
| | *Spratelloides* spp. | | |
| | *Apogon* sp. *Archamia* sp. | 1987 | 5,000[g] |
| Minicoy | *Spratelloides* spp. | 1981 | 3[h] |
| | *Apogon* spp. *Archamia* spp. | 1983 | 3[h] |
| | *Caesio* spp. | 1984 | 6[h] |
| | *Pterocaesio* spp. | 1986 | 7[i] |
| | *C. caeruleus* | 1988 | 4 |
| | *L. tapeinosoma* | 1989 | 9 |
| Agatti | *S. delicatulus* | 1988 | 4 |
| | | 1989 | 0.8 |
| Bangaram | *S. delicatulus* | 1988 | 13 |
| | | 1989 | 25 |
| Perumal Par | *S. delicatulus* | 1988 | 18 |
| | | 1989 | 13 |

a = Yoshida *et al*. (1977); b = Diake (1989); c = Sharma and Adams (1990); d = MacInnes (1990); e = Tuna Programme (1984); f = Lewis (1990); g = Maniku *et al*. (1990); h = Pillai *et al*. (1986); i = Gopakumar *et al*. (1991).

of baitfish per year is obtained when the fishery at Bitra and Suheli is also taken into consideration. This low production may be due to the isolated nature of pole-and-line fishery being restricted to only a few islands. The longer distance between islands also makes it impossible for the fishermen to exploit the bait of other lagoons. Maldivian baitfishery which has many similarities with that of Lakshadweep is supported by fishery from more than 30 islands. Fijian fishery on the other hand has more than 100 recognised baiting sites and the effort is spread widely. A cursory study of the species composition indicates that there is an interaction between G. argenteus and C. striatus. The relation seems to be antagonistic with the abundance of one limiting the other. Such species interactions are reported for the anchovy and sprat at Papua New Guinea (Chapau, 1983 and Dalzell, 1984) and between sardine and herring at Kiribati (Ianelli, 1988) and Fiji (Sharma, 1988). In multispecies baitfisheries, as a response to exploitation, there are possible species interactions at many levels which is in general attributed to variations in recruitment.

The size of apogonids used in the tropical Pacific Ocean fishery is reported to be in the range of 7.5 to 15.2 cm (Baldwin 1977). But in the present study the size range of apogonids were 2.3 cm (for R. gracilis) to 6.3 cm (for A. fucata). Yuen (1977) observes that the maximum size of a bait need to be only 8 cm. Except for G. argenteus and C. striatus, the other species which contributed to the fishery were below this size. Catch per haul at Minicoy which is in the range of 1.5 to 2.7 kg and at Agatti, Bangaram and Perumal Par from 8.1 to 9.3 kg is far less when compared to other baitfisheries. It is 30 kg for caesionids, apogonids and pomacentrids and 40 kg for Spratelloides at Maldives (Maniku et al 1990), 117 kg for engraulid anchovies and sprat at Solomon Islands (Nichols and Rawlinson, 1990) and 84 kg for a variety of baitfishes at Fiji (Sharma and Adams, 1990). The major points of difference in the mode of fishing are the night fishing for livebaits widely practiced in the South Pacific and the availability of a wider area for baitfishing in Maldives.

The relationship between catch and effort is found to be linear with a near uniform CPUE (Tables 1&2). A similar observation is reported from Solomon Islands (Nichols and Rawlinson, 1990) and Papua New Guinea and Fiji baitfisheries (Dalzell and Lewis, 1988). Dalzell and Lewis (1988) suggests that the lack of a curvature in the catch-effort relationship may be due to the dynamics of the pole-and-line fishery, as bait are essential to the capture of tuna, fishermen will quickly leave a baitground when catches decline and will try other locations for bait supply. This is the case with the fishermen of Agatti who can choose from more than one site. The selection of baiting locations by the fishermen depends on the close proximity to the tuna fishing grounds and the expected catch rate from a baitground at that particular time. Baitfishery at Agatti may therefore be self regulatory. When catch rates in a particular baitground decrease the fishermen move to new baiting locations. This movement gives the baitfish at the first site to undergo recovery due to the reduced fishing effort. The favored batigrounds of Agatti fishermen are Bangaram and Perumal Par. But in recent times some of them migrate to Bitra and Suheli for tuna fishing when bait is scarce. Baitfishery at Bangaram and Perumal Par has to be therefore monitored closely for if there is a collapse of baitfish stocks at these sites it would have adverse economic effects on the pole-and-line fishery of the area. This once again brings into sharp focus the need for diversifying the fishery to species other than S. delicatulus. Situation at Minicoy is further complicated by the absence of nearby atolls which may support alternate fishery. But data (Table 1) indicate that the amount of bait caught is generally on the rise. Other than locating new areas on the reef and leeward side, night fishing for bait may have to be tried. During acute shortage of migratory forms, apogonids are fished at night. Cardinal fishes are nocturnal and leave their habitats among corals in search of food and return just before the break of dawn. Fishermen exploit this behaviour by covering previously marked coral heads at midnight with bait net and lift them at dawn when the fishes return and hover above the net trying to enter their homes. The lack of additional bait grounds is compensated by the judicious use of a wide variety of bait fishes. Fishing starts with clupeids then shifts to caesionids and migratory pomacentrids when they enter the lagoon and finally to resident apogonids. There is even a traditionally followed closed season for apogonids which can be fished only by the middle of the fishing season when the amount of other baits are low. The destruction of coral heads has depleted the stock of resident bait fishes and the fishery at present relies heavily on the migratory species. Recruitment or arrival of these fishes in the lagoon depend on a number of favorable environmental factors such as currents and rainfall. The fishery at Minicoy therefore merits further attention with particular reference to habitat changes and drastic and sudden environmental fluctuations.

Expansion of baitfishery at Lakshadweep with need for management will depend on the state of skipjack fishery. If the tuna fishery is to span over a larger area covering many kilometers around the islands, more bait will be required, carrying capacity of livebaits on board has to be enhanced and pole-and-line fishing in general will undergo suitable modifications. The present tuna catch of 6,000 tonnes is a far cry from the exploitation of about 50,000 tonnes at neighbouring Maldives. Vast resources of skipjack tuna can be exploited by introducing alternate methods to pole-and-line fishing or amplification of the present fishery. Till such time the bait resources of Lakshadweep seems to be adequate to support the existing Katsuwonus pelamis fishery.

# CHAPTER 2

# POPULATION CHARACTERISTICS

## INTRODUCTION

Length-weight studies and population dynamics of baitfishes have only received attention in recent times. The object of these investigations is to rationally manage and conserve the live baitfish resource. Effective management of any fishery requires considerable knowledge regarding population parameters such as age and growth, mortality and recruitment patterns of the exploited stock. Tuna baitfisheries by their very nature are supportive fisheries only and the magnitude and distribution of baitfishery will normally depend on tuna fishery factors. Pole-and-line fishermen will always want to maximize bait catches, either to take advantage of good tuna fishery or to catch as much tuna as possible when fishing is poor.

Dalzell (1990) reviewed the studies on biology and population dynamics of baitfishes in Papua New Guinea. The major species involved are the anchovies Stolephorus heterolobus and S. devisi and the sprats Spratelloides gracilis and S. delicatulus. In one of the rare estimates of MSY for commercially exploited baitfishes, he obtained a value of 1 to 2 t/km$^2$/yr based on biomass and natural mortality rates. Another study where maximum yield has been considered is for the fishery in Palau which was found to operate near optimal levels (Muller, 1977). Length-frequency analysis of major baitfish species in Solomon Islands indicated that anchovies were lightly to moderately fished while sprats experienced higher mortalities (Tiroba *et al*., 1990). Otoliths of the major baitfish species in Solomon Islands and Maldives were examined by Milton *et al*. (1990c). Growth varied between sites and countries and were related to the differences in the local environment at each site rather than the changes in the intensity of baitfishing. Anchovies of the genus *Stolephorus*, the mainstay of Pacific tuna baitfisheries, form very important coastal fisheries in India (Luther, 1990) and Indonesia (Wright *et al*. 1990) where they are used for human consumption. Biology of anchovies from non baitfishing countries or where they are not used as bait have also been reported (Williams and Cappo, 1990; Luther, 1990; Wright, 1990; Hoedt, 1990). Somerton (1990) applied a new stock assessment procedure known as the Egg Production Method on the Hawaiian anchovy, *Encrasicholina purpurea*. Analysis of catch and effort data for the Solomon Islands baitfishery showed that baitfishery is self-regulatory due to the presence of a large number of alternative baiting sites (Rawlinson and Nichols, 1990). Milton *et al*. (1991) found that fishes of the genus *Spratelloides* have an extremely flexible growth pattern and that biological variation within a site can be as great as variation between sites.

The Papua New Guinea baitfisheries closed for economic reasons at the end of 1981 and apart from a brief period of activity in 1984-85, has not resumed (Lewis, 1990). Similarly, management of the bait stock at Solomon Islands has not received serious attention because of its self regulatory nature and the decline in importance of pole-and-line fishery with the advent of purse-seining (Rawlinson and Nichols, 1990). However, the studies on population dynamics of baitfishes in these two areas of the Pacific may contribute immensely to similar studies made elsewhere.

At Lakshadweep, the population studies of baitfishes have been restricted mostly to length-weight relationships. Mohan and Kunhikoya (1985) studied the age and growth of *S. delicatulus* from length-frequency data and length-weight and age and growth of *S. japonicus*(*gracilis*) at Minicoy. They reported a growth rate of 3 mm per month for both the species. One of the possible reason for shortage of livebait at Minicoy and other islands is the over exploitation of the resource by the increased effort (Pillai *et al*., 1986). The bluepuller, *Chromis caeruleus* has a monthly growth rate of 5.43 mm for the first year and 2.26 mm for the second year at Minicoy (Mohan *et al*., 1986). Gopakumar *et al*. (1991) calculated the length-weight relationship of 17 species of livebaits from Lakshadweep.

A review of the studies on population dynamics of baitfishes suggest that there is an urgent need to understand the various population parameters such as growth, mortality and maximum sustainable yield of commercial baitfishery. The present study concentrates on the length-weight relationship of 11 species of livebait from the pole-and-line fishery at Minicoy and S. delicatulus from the fishery at Agatti, Bangaram and Perumal Par. An attempt is also made to estimate the growth and mortality of S. delicatulus at Bangaram and Perumal Par. However, due to limited data, definite conclusions could not be drawn.

## MATERIALS AND METHODS

Baitfish samples were collected from pole-and-line fishing boats every month during the 1988-89 and 1989-90 fishing seasons at Minicoy and Agatti. Fish length (TL, mm), weight (+ or - 0.001 g) and sex were recorded for all the fish collected at Minicoy. A subsample was randomly collected from the total sample of S. delicatulus obtained in a month at Agatti. Length-weight relationships were computed by the method of least squares. An analysis of covariance was carried out to test if the regressions are significantly different for the two sexes.

Length-frequency time series data for Spratelloides delicatulus from Bangaram and Perumal Par for six months (Jan, Feb, Mar, Oct, Nov, Dec) were analyzed separately and by combining the data of the two areas. The length-frequency data were analyzed using the Compleat ELEFAN suite of computer programs (Pauly, 1987; Gayanilo _et al_., 1988). Growth parameter estimates were obtained using ELEFAN I. This is a programme that fits a von Bertlanffy growth functions (VBGF) to the length frequency data, arranged chronologically along a time axis. The growth curve is fixed to the time axis by $t_o$, i.e. the age of the fish at zero length assuming that the fish has always grown in the manner desired by the the curve. A $t_o$ of -0.023/yr was used based on sagittal increment data for _S. delicatulus_ in Fiji (Dalzell _et al_., 1987; Tiroba _et al_., 1990). ELEFAN I was run as many times as necessary on each data set until a satisfactory fit to the data was achieved. Values of $0'$, a dimensionless parameter used to compare the growth performance of fish when their growth is adequately described by the VBGF were calculated using the best fit values of $L_{oo}$ and K obtained from ELEFAN I (Pauly and Munro, 1984). $0'$ is calculated by :

$$0' = \log_{10}K + 2 \log_{10}L_{oo}$$

ELEFAN II estimates the total annual mortality from a length converted catch curve, where the slope of the right-hand, descending limp of the catch curve equates to total mortality, Z. A mean length equation also incorporated into ELEFAN II gives another estimate of Z. A third independent estimate of Z was obtained by multiplying the value of Z/K derived from a Wetherall Plot (Wetherall, 1986 as modified by Pauly, 1986) by K estimated from ELEFAN I.

Natural mortality (M) was calculated from Pauly's empirical formula in ELEFAN II (Pauly, 1980):

$$\log_{10} = 0.0066 - 2.279 \log_{10} L_{\infty} + 0.6543 \log_{10} K + 0.4643 \log_{10} T$$

where T = mean annual environmental temperature in degrees Centigrade. Temperature readings taken from the bait grounds at Bangaram and Perumal Par were used for this equation. Preliminary estimates of F was estimated by subtraction F = Z - M, while the exploitation rate (E) is estimated from E = F/Z. Recruitment patterns was also calculated for S. delicatulus at both the sites using a routine of ELEFAN II.

## RESULTS

The length-weight relationships of the various livebaits at Minicoy are presented in Table 1. While females weighed marginally more than males in the case of S. gracilis, males were heavier than females for S. delicatulus. Among caesionids, females weighed more than males in all the species and this distribution was more apparent in the case of P. chrysozona. Males were found to be heavier in both the pomacentrids; C. caeruleus and L. tapeinosoma, while females weighed more than males in all the three species of apogonids. Length-weight equations of S. delicatulus at the three locations of Agatti are given in Table 2. At Perumal Par, males were heavier than females while at Agatti and Bangaram the reverse was observed. The mean length and weight of male S. delicatulus

Table 1 : Length-weight relationships of livebaits at Minicoy

| Species | Sex | Equation | $r^2$ | N |
|---|---|---|---|---|
| *S. delicatulus* | M | $W = 8.48 \times 10^{-7} L^{3.53}$ | 0.98 | 42 |
| | F | $W = 1.09 \times 10^{-6} L^{3.46}$ | 0.98 | 51 |
| | P | $W = 9.68 \times 10^{-7} L^{3.49}$ | 0.98 | 93 |
| *S. gracilis* | M | $W = 1.51 \times 10^{-6} L^{3.33}$ | 0.96 | 94 |
| | F | $W = 1.34 \times 10^{-6} L^{3.36}$ | 0.98 | 107 |
| | P | $W = 1.42 \times 10^{-6} L^{3.35}$ | 0.96 | 201 |
| *G. argenteus* | M | $W = 1.37 \times 10^{-6} L^{3.39}$ | 0.96 | 87 |
| | F | $W = 9.96 \times 10^{-7} L^{3.46}$ | 0.96 | 90 |
| | P | $W = 1.15 \times 10^{-6} L^{3.43}$ | 0.96 | 177 |
| *C. striatus* | M | $W = 2.97 \times 10^{-6} L^{3.25}$ | 0.96 | 87 |
| | F | $W = 2.43 \times 10^{-6} L^{3.29}$ | 0.96 | 63 |
| | P | $W = 2.74 \times 10^{-6} L^{3.26}$ | 0.96 | 150 |
| *P. pisang* | I | $W = 3.68 \times 10^{-6} L^{3.23}$ | 0.92 | 45 |
| *P. chrysozona* | M | $W = 2.81 \times 10^{-5} L^{2.73}$ | 0.98 | 9 |
| | F | $W = 6.53 \times 10^{-6} L^{3.07}$ | 0.94 | 10 |
| | P | $W = 2.19 \times 10^{-5} L^{2.79}$ | 0.98 | 19 |
| *C. caeruleus* | M | $W = 1.52 \times 10^{-5} L^{2.99}$ | 0.98 | 18 |
| | F | $W = 2.09 \times 10^{-5} L^{2.91}$ | 0.98 | 29 |
| | P | $W = 1.98 \times 10^{-5} L^{2.92}$ | 0.98 | 47 |
| *L. tapeinosoma* | M | $W = 2.64 \times 10^{-6} L^{3.41}$ | 0.94 | 24 |
| | F | $W = 3.77 \times 10^{-6} L^{3.31}$ | 0.76 | 27 |
| | P | $W = 2.94 \times 10^{-6} L^{3.38}$ | 0.86 | 51 |
| *A. fucata* | M | $W = 2.41 \times 10^{-4} L^{2.21}$ | 0.67 | 17 |
| | F | $W = 1.65 \times 10^{-5} L^{2.86}$ | 0.92 | 25 |
| | P | $W = 3.33 \times 10^{-5} L^{2.71}$ | 0.86 | 42 |
| *A. thermalis* | M | $W = 5.91 \times 10^{-7} L^{3.79}$ | 0.94 | 34 |
| | F | $W = 1.91 \times 10^{-7} L^{4.10}$ | 0.94 | 35 |
| | P | $W = 4.01 \times 10^{-7} L^{3.90}$ | 0.94 | 69 |
| *R. gracilis* | M | $W = 3.64 \times 10^{-6} L^{3.29}$ | 0.96 | 22 |
| | F | $W = 1.22 \times 10^{-6} L^{3.62}$ | 0.98 | 13 |
| | P | $W = 2.57 \times 10^{-6} L^{3.39}$ | 0.96 | 35 |

M = Male, F = Female, P = Pooled, I = Indeterminate

Table 2 : Length-weight relationships of *S. delicatulus* at Agatti

| Location | Sex | Equation | $r^2$ | N |
|---|---|---|---|---|
| Agatti | M | $W = 1.40 \times 10^{-6} L^{3.38}$ | 0.92 | 70 |
| | F | $W = 5.09 \times 10^{-6} L^{3.63}$ | 0.86 | 65 |
| | P | $W = 7.29 \times 10^{-7} L^{3.55}$ | 0.88 | 135 |
| Bangaram | M | $W = 4.92 \times 10^{-6} L^{3.05}$ | 0.82 | 208 |
| | F | $W = 3.05 \times 10^{-6} L^{3.18}$ | 0.94 | 197 |
| | P | $W = 3.83 \times 10^{-6} L^{3.12}$ | 0.88 | 405 |
| Perumal Par | M | $W = 1.30 \times 10^{-6} L^{3.41}$ | 0.94 | 234 |
| | F | $W = 2.80 \times 10^{-6} L^{3.20}$ | 0.92 | 238 |
| | P | $W = 2.10 \times 10^{-6} L^{3.28}$ | 0.92 | 472 |

Table 3 : Mean length, weight and calculated weight of *S. delicatulus* at Agatti

| Sex | Length | | Weight | | Obs. Leng. (mm) | Obs. Wt. (g) | Cal. Wt. (g) |
|---|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | | | |
| AGATTI | | | | | | | |
| M | 40 | 26-59 | 0.36 | 0.06-1.52 | 44 | 0.53 | 0.50 |
| F | 39 | 26-61 | 0.29 | 0.05-1.43 | 45 | 0.54 | 0.52 |
| BANGARAM | | | | | | | |
| M | 41 | 23-56 | 0.40 | 0.05-1.30 | 40 | 0.35 | 0.39 |
| F | 40 | 24-56 | 0.38 | 0.07-1.21 | 48 | 0.63 | 0.68 |
| PERUMAL PAR | | | | | | | |
| M | 40 | 29-55 | 0.39 | 0.10-1.09 | 37 | 0.29 | 0.29 |
| F | 40 | 26-61 | 0.38 | 0.05-1.70 | 39 | 0.33 | 0.34 |

caught at Bangaram was higher than that of the other two sites (Table 3), while females obtained at Agatti had a lower mean length and weight. Among the sprats at Minicoy, S. gracilis showed a higher mean length and weight than S. delicatulus (Table 4). C. striatus was the largest fusilier in terms of mean length and weight followed by P. chrysozona and G. argenteus. L. tapeinosoma averaged a higher length and weight over that of C. caeruleus and A. fucata was the largest among cardinalfishes at Minicoy (Table 4).

Analysis of covariance to test the difference between sexes indicated that the length-weight relationship was significantly different ($P<0.05$) for males and females of S. delicatulus at Perumal Par (Table 5). At Minicoy, there was no significant variation between sexes for S. delicatulus and S. gracilis (Table 6), caesionids (Table 7), pomacentrids (Table 8) and apogonids (Table 9). The parabolic relationship between length and weight of various species is shown in Figures 1 to 8.

The number of specimens of S. delicatulus measured for ELEFAN and the results of analysis are presented in Table 10. The preliminary estimate of $L_{oo}$ using ELEFAN II indicated that it is around 70 mm. Further refinement of this value by ELEFAN I for the three sets of data showed that $L_{oo}$ is between 70 and 74 mm (Figs 9 to 11). The K values ranged from 4 to 4.25/yr. Total mortality estimates varied widely in the three methods employed and between sites. Natural mortality at both the sites

Table 4 : Mean length, weight and calculated weights of livebaits at Minicoy

| Sex | Length | | Weight | | Obs. Leng. (mm) | Obs. Wt. (g) | Cal. Wt. (g) |
|---|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | | | |
| *S. delicatulus* | | | | | | | |
| M | 34 | 20-61 | 0.22 | 0.03-1.80 | 30 | 0.15 | 0.14 |
| F | 35 | 21-61 | 0.23 | 0.04-1.64 | 24 | 0.07 | 0.07 |
| *S. gracilis* | | | | | | | |
| M | 44 | 31-60 | 0.45 | 0.15-1.24 | 41 | 0.32 | 0.37 |
| F | 45 | 29-61 | 0.49 | 0.11-1.28 | 33 | 0.20 | 0.17 |
| *G. argenteus* | | | | | | | |
| M | 67 | 46-96 | 2.09 | 0.71-6.78 | 66 | 2.45 | 2.03 |
| F | 67 | 45-99 | 2.13 | 0.68-7.32 | 67 | 2.81 | 2.09 |
| *C. striatus* | | | | | | | |
| M | 83 | 44-111 | 5.10 | 0.77-13.83 | 65 | 3.10 | 2.28 |
| F | 84 | 49-118 | 5.07 | 0.98-15.92 | 63 | 2.40 | 1.96 |
| *P. pisang* | | | | | | | |
| I | 36 | 30-45 | 0.49 | 0.23-0.82 | 34 | 0.33 | 0.33 |
| *P. chrysozona* | | | | | | | |
| M | 73 | 46-92 | 3.49 | 1.01-7.16 | 46 | 1.01 | 0.98 |
| F | 75 | 59-86 | 3.79 | 1.95-5.68 | 79 | 4.46 | 4.45 |
| *C. caeruleus* | | | | | | | |
| M | 38 | 28-63 | 0.80 | 0.31-3.30 | 42 | 1.05 | 1.08 |
| F | 35 | 22-69 | 0.64 | 0.17-4.40 | 53 | 2.10 | 2.20 |
| *L. tapeinosoma* | | | | | | | |
| M | 49 | 38-86 | 1.53 | 0.57-8.23 | 50 | 1.31 | 1.61 |
| F | 49 | 40-65 | 1.49 | 1.12-5.60 | 44 | 1.04 | 1.05 |
| *A. fucata* | | | | | | | |
| M | 54 | 49-60 | 1.82 | 1.17-2.21 | 54 | 1.82 | 1.61 |
| F | 53 | 41-62 | 1.34 | 0.73-2.57 | 50 | 1.34 | 1.32 |
| *A. thermalis* | | | | | | | |
| M | 39 | 27-58 | 0.64 | 0.18-2.85 | 41 | 0.96 | 0.78 |
| F | 39 | 31-47 | 0.64 | 0.24-1.37 | 38 | 0.51 | 0.57 |
| *R. gracilis* | | | | | | | |
| M | 32 | 21-50 | 0.34 | 0.08-1.57 | 22 | 0.08 | 0.09 |
| F | 32 | 25-49 | 0.34 | 0.13-1.54 | 25 | 0.13 | 0.14 |

M = Males, F = Females, I = Indeterminates

Table 5 : Analysis of covarience for length weight data of *S. delicatulus* at Agatti.

| Source | | df | SSx | Sxy | SSy | b | df | SS | MS | F |
|---|---|---|---|---|---|---|---|---|---|---|
| **Agatti** | | | | | | | | | | |
| Male | | 69 | 2.33 | 7.88 | 28.57 | 3.38 | 68 | 1.92 | 0.03 | |
| Female | | 64 | 3.51 | 12.76 | 53.25 | 3.63 | 63 | 6.86 | 0.11 | |
| Total | | | | | | | 131 | 8.78 | 0.07 | |
| Pooled | W | 133 | 5.84 | 20.65 | 81.82 | 3.53 | 132 | 8.87 | 0.07 | |
| Difference between slopes | | | | | | | 1 | 0.09 | 0.09 | 1.35 |
| Between | B | 1 | 0.03 | 0.20 | 1.23 | | | | | |
| W + B | | 134 | 5.88 | 20.85 | 83.05 | 3.55 | 133 | 9.09 | 0.07 | |
| Difference between corrected means | | | | | | | 1 | 0.22 | 0.22 | 3.25 |
| **Bangaram** | | | | | | | | | | |
| Male | | 207 | 4.02 | 12.29 | 44.39 | 3.06 | 206 | 6.85 | 0.03 | |
| Female | | 196 | 4.43 | 14.08 | 47.15 | 3.18 | 195 | 2.43 | 0.01 | |
| Total | | | | | | | 401 | 9.29 | 0.02 | |
| Pooled | W | 403 | 8.46 | 26.37 | 91.54 | 3.12 | 402 | 9.32 | 0.02 | |
| Difference between slopes | | | | | | | 1 | 0.03 | 0.03 | 1.34 |
| Between | B | 1 | 0.00 | 0.01 | 0.12 | | | | | |
| W + B | | 404 | 8.46 | 26.37 | 91.66 | 3.12 | 403 | 9.41 | 0.02 | |
| Difference between corrected means | | | | | | | 1 | 0.09 | 0.09 | 3.82 |
| **Perumal Par** | | | | | | | | | | |
| Male | | 233 | 3.97 | 13.55 | 48.87 | 3.41 | 232 | 2.63 | 0.01 | |
| Female | | 237 | 6.39 | 20.45 | 70.43 | 3.19 | 236 | 5.03 | 0.02 | |
| Total | | | | | | | 468 | 7.66 | 0.02 | |
| Pooled | W | 470 | 10.36 | 33.99 | 119.30 | 3.28 | 469 | 7.77 | 0.02 | |
| Difference between slopes | | | | | | | 1 | 0.11 | 0.11 | 6.90* |
| Between | B | 1 | 0.00 | -0.00 | 0.03 | | | | | |
| W + B | | 471 | 10.36 | 33.99 | 119.33 | 3.28 | 470 | 7.84 | 0.02 | |
| Difference between corrected means | | | | | | | 1 | 0.07 | 0.07 | 4.31* |

* $P < 0.05$

Table 6 : Analysis of covarience for length weight data of sprats at Minicoy.

| Source | df | SSx | Sxy | SSy | b | df | SS | MS | F |
|---|---|---|---|---|---|---|---|---|---|
| ***S. delicatulus*** | | | | | | | | | |
| Male | 41 | 3.71 | 13.14 | 47.15 | 3.53 | 40 | 0.69 | 0.02 | |
| Female | 50 | 3.93 | 13.59 | 47.60 | 3.46 | 49 | 0.62 | 0.01 | |
| Total | | | | | | 89 | 1.32 | 0.01 | |
| Pooled W | 91 | 7.65 | 26.73 | 92.75 | 3.50 | 90 | 1.32 | 0.01 | |
| Difference between slopes | | | | | | 1 | 0.01 | 0.01 | 0.77 |
| Between B | 1 | 0.01 | 0.03 | 0.08 | | | | | |
| W + B | 92 | 7.66 | 26.76 | 94.83 | 3.49 | 91 | 1.34 | 0.01 | |
| Difference between corrected means | | | | | | 1 | 0.02 | 0.02 | 1.04 |
| ***S. gracilis*** | | | | | | | | | |
| Male | 93 | 3.40 | 11.34 | 38.88 | 3.33 | 92 | 1.09 | 0.01 | |
| Female | 106 | 3.39 | 11.41 | 39.04 | 3.36 | 105 | 0.68 | 0.01 | |
| Total | | | | | | 197 | 1.77 | 0.01 | |
| Pooled W | 199 | 6.80 | 22.75 | 77.92 | 3.35 | 198 | 1.78 | 0.00 | |
| Difference between slopes | | | | | | 1 | 0.00 | 0.00 | 0.16 |
| Between B | 1 | 0.03 | 0.10 | 0.35 | | | | | |
| W + B | 200 | 6.83 | 22.85 | 78.27 | 3.35 | 199 | 1.78 | 0.01 | |
| Difference between corrected means | | | | | | 1 | 0.00 | 0.00 | 0.03 |

F values are not significant

Table 7 : Analysis of covariance of length weight data for caesionids at Minicoy

| Source | df | SSx | Sxy | SSy | b | df | SS | MS | F |
|---|---|---|---|---|---|---|---|---|---|
| *G. argenteus* | | | | | | | | | |
| Male | 86 | 2.26 | 7.64 | 26.92 | 3.39 | 85 | 1.06 | 0.01 | |
| Female | 89 | 2.66 | 9.21 | 32.88 | 3.46 | 88 | 0.99 | 0.01 | |
| Total | | | | | | 173 | 2.05 | 0.01 | |
| Pooled W | 175 | 4.92 | 16.85 | 59.81 | 3.43 | 174 | 2.06 | 0.01 | |
| Difference between slopes | | | | | | 1 | 0.01 | 0.01 | 0.62 |
| Between B | 1 | 0.00 | 0.00 | 0.01 | | | | | |
| W + B | 176 | 4.92 | 16.85 | 59.82 | 3.43 | 175 | 2.06 | 0.01 | |
| Difference between corrected means | | | | | | 1 | 0.00 | 0.00 | 0.11 |
| *C. striatus* | | | | | | | | | |
| Male | 86 | 2.81 | 9.14 | 30.42 | 3.25 | 85 | 0.76 | 0.01 | |
| Female | 62 | 2.18 | 7.16 | 24.02 | 3.28 | 61 | 0.50 | 0.01 | |
| Total | | | | | | 146 | 1.27 | 0.01 | |
| Pooled W | 148 | 4.99 | 16.29 | 54.44 | 3.26 | 147 | 1.27 | 0.01 | |
| Difference between slopes | | | | | | 1 | 0.00 | 0.00 | 0.22 |
| Between B | 1 | 0.00 | -0.00 | 0.00 | | | | | |
| W + B | 149 | 4.99 | 16.29 | 54.45 | 3.26 | 148 | 1.29 | 0.01 | |
| Difference between corrected means | | | | | | 1 | 0.02 | 0.02 | 2.66 |
| *P. chrysozona* | | | | | | | | | |
| Male | 8 | 0.57 | 1.56 | 4.31 | 2.73 | 7 | 0.04 | 0.01 | |
| Female | 9 | 0.11 | 0.36 | 1.15 | 3.08 | 8 | 0.05 | 0.01 | |
| Total | | | | | | 15 | 0.09 | 0.01 | |
| Pooled W | 17 | 0.69 | 1.92 | 5.46 | 2.79 | 16 | 0.10 | 0.01 | |
| Difference between slopes | | | | | | 1 | 0.01 | 0.01 | 1.84 |
| Between B | 1 | 0.00 | 0.01 | 0.03 | | | | | |
| W + B | 18 | 0.69 | 1.93 | 5.49 | 2.79 | 17 | 0.10 | 0.01 | |
| Difference between corrected means | | | | | | 1 | 0.00 | 0.00 | 0.14 |

F values are insignificant

Table 8 : Analysis of covarience - length weight data for pomacentrids at Minicoy

| Source | | df | SSx | Sxy | SSy | b | df | SS | MS | F |
|---|---|---|---|---|---|---|---|---|---|---|
| *C. caeruleus* | | | | | | | | | | |
| Male | | 17 | 0.79 | 2.35 | 7.14 | 2.99 | 16 | 0.09 | 0.01 | |
| Female | | 28 | 2.27 | 6.60 | 19.42 | 2.91 | 27 | 0.20 | 0.01 | |
| Total | | | | | | | 43 | 0.29 | 0.01 | |
| Pooled | W | 45 | 3.06 | 8.96 | 26.57 | 2.93 | 44 | 0.30 | 0.01 | |
| | Difference between slopes | | | | | | 1 | 0.00 | 0.00 | 0.58 |
| Between | B | 1 | 0.08 | 0.19 | 0.50 | | | | | |
| W + B | | 46 | 3.13 | 9.15 | 27.07 | 2.92 | 45 | 0.30 | 0.01 | |
| | Difference between corrected means | | | | | | 1 | 0.01 | 0.01 | 1.27 |
| *L. tapeinosoma* | | | | | | | | | | |
| Male | | 23 | 0.84 | 2.88 | 10.37 | 3.41 | 22 | 0.57 | 0.03 | |
| Female | | 26 | 0.37 | 1.24 | 5.41 | 3.31 | 25 | 1.30 | 0.05 | |
| Total | | | | | | | 47 | 1.88 | 0.04 | |
| Pooled | W | 49 | 1.22 | 4.12 | 15.78 | 3.38 | 48 | 1.88 | 0.04 | |
| | Difference between slops | | | | | | 1 | 0.00 | 0.00 | 0.06 |
| Between | B | 1 | 0.00 | 0.00 | 0.01 | | | | | |
| W + B | | 50 | 1.22 | 4.11 | 15.79 | 3.38 | 49 | 1.88 | 0.04 | |
| | Difference between corrected means | | | | | | 1 | 0.00 | 0.00 | 0.00 |

F values are insignificant

Table 9 : Analysis of covarience - length weight data for apogonids at Minicoy

| Source | df | SSx | Sxy | SSy | b | df | SS | MS | F |
|---|---|---|---|---|---|---|---|---|---|
| *A. fucata* | | | | | | | | | |
| Male | 16 | 0.06 | 0.15 | 0.47 | 2.21 | 15 | 0.15 | 0.01 | |
| Female | 24 | 0.22 | 0.63 | 1.93 | 2.89 | 23 | 0.13 | 0.01 | |
| Total | | | | | | 38 | 0.29 | 0.01 | |
| Pooled W | 40 | 0.28 | 0.77 | 2.40 | 2.73 | 39 | 0.30 | 0.01 | |
| Difference between slopes | | | | | | 1 | 0.02 | 0.02 | 3.18 |
| Between B | 1 | 0.01 | 0.02 | 0.04 | | | | | |
| W + B | 41 | 0.29 | 0.79 | 2.44 | 2.71 | 40 | 0.31 | 0.01 | |
| Difference between corrected means | | | | | | 1 | 0.00 | 0.00 | 0.55 |
| *A. thermalis* | | | | | | | | | |
| Male | 33 | 0.82 | 3.09 | 12.39 | 3.80 | 32 | 0.65 | 0.02 | |
| Female | 34 | 0.43 | 1.75 | 7.60 | 4.10 | 33 | 0.41 | 0.01 | |
| Total | | | | | | 65 | 1.06 | 0.02 | |
| Pooled W | 67 | 1.24 | 4.85 | 19.99 | 3.90 | 66 | 1.09 | 0.02 | |
| Difference between slopes | | | | | | 1 | 0.03 | 0.03 | 1.60 |
| Between B | 1 | 0.00 | -0.00 | 0.00 | | | | | |
| W + B | 68 | 1.24 | 4.85 | 19.99 | 3.90 | 67 | 1.09 | 0.02 | |
| Difference between corrected means | | | | | | 1 | 0.00 | 0.00 | 0.11 |
| *R. gracilis* | | | | | | | | | |
| Male | 21 | 1.42 | 4.67 | 15.68 | 3.29 | 20 | 0.35 | 0.02 | |
| Female | 12 | 0.70 | 2.53 | 9.25 | 3.62 | 11 | 0.09 | 0.01 | |
| Total | | | | | | 31 | 0.44 | 0.01 | |
| Pooled W | 33 | 2.12 | 7.20 | 24.93 | 3.40 | 32 | 0.49 | 0.02 | |
| Difference between slopes | | | | | | 1 | 0.05 | 0.05 | 3.64 |
| Between B | 1 | 0.00 | -0.00 | 0.00 | | | | | |
| W + B | 34 | 2.12 | 7.20 | 24.93 | 3.39 | 33 | 0.52 | 0.02 | |
| Difference between corrected means | | | | | | 1 | 0.03 | 0.03 | 1.75 |

F values are insignificant

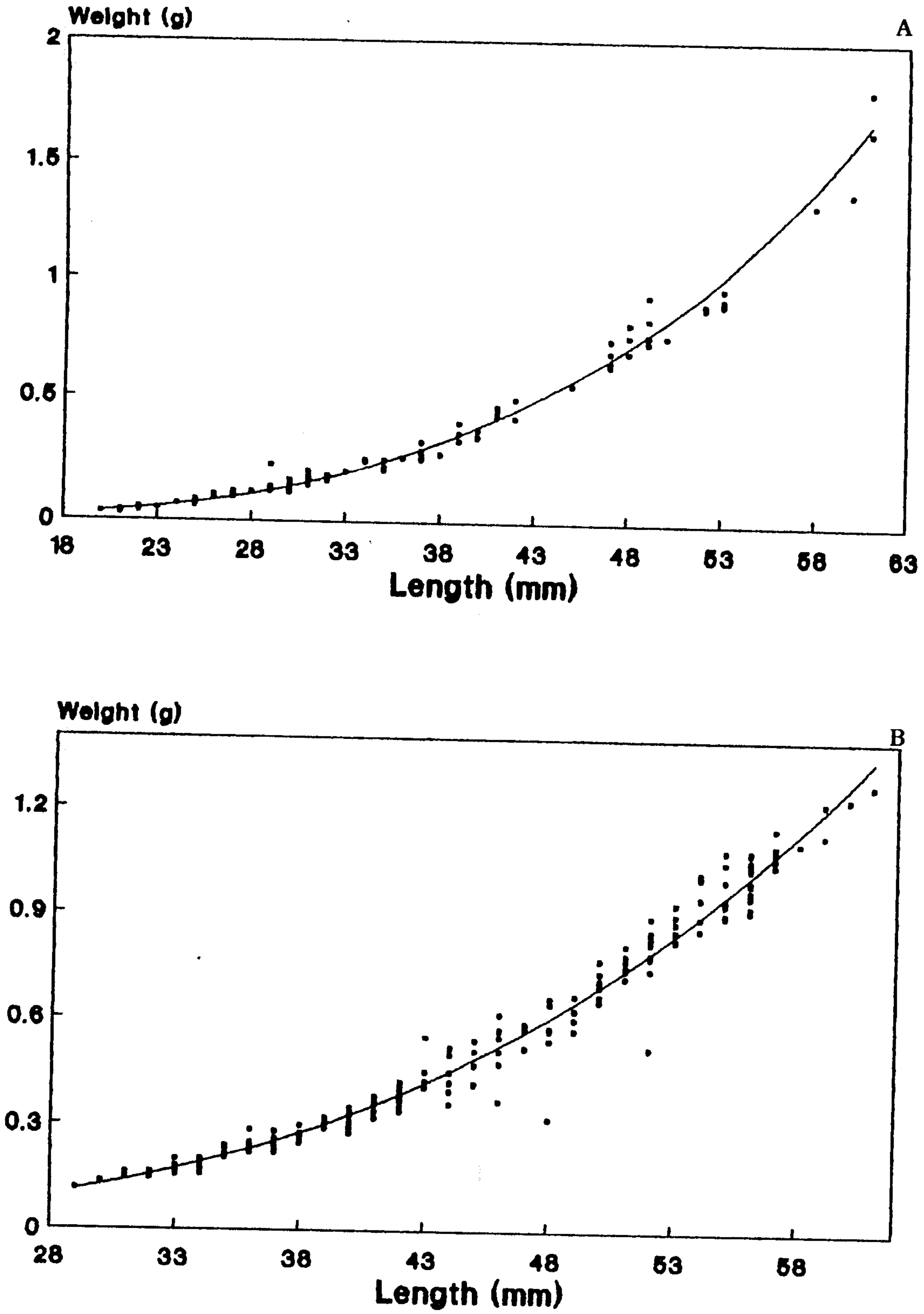


Fig. 1. Length-weight relationships of Clupeids at Minicoy. A. S. delicatulus B. S. gracilis.

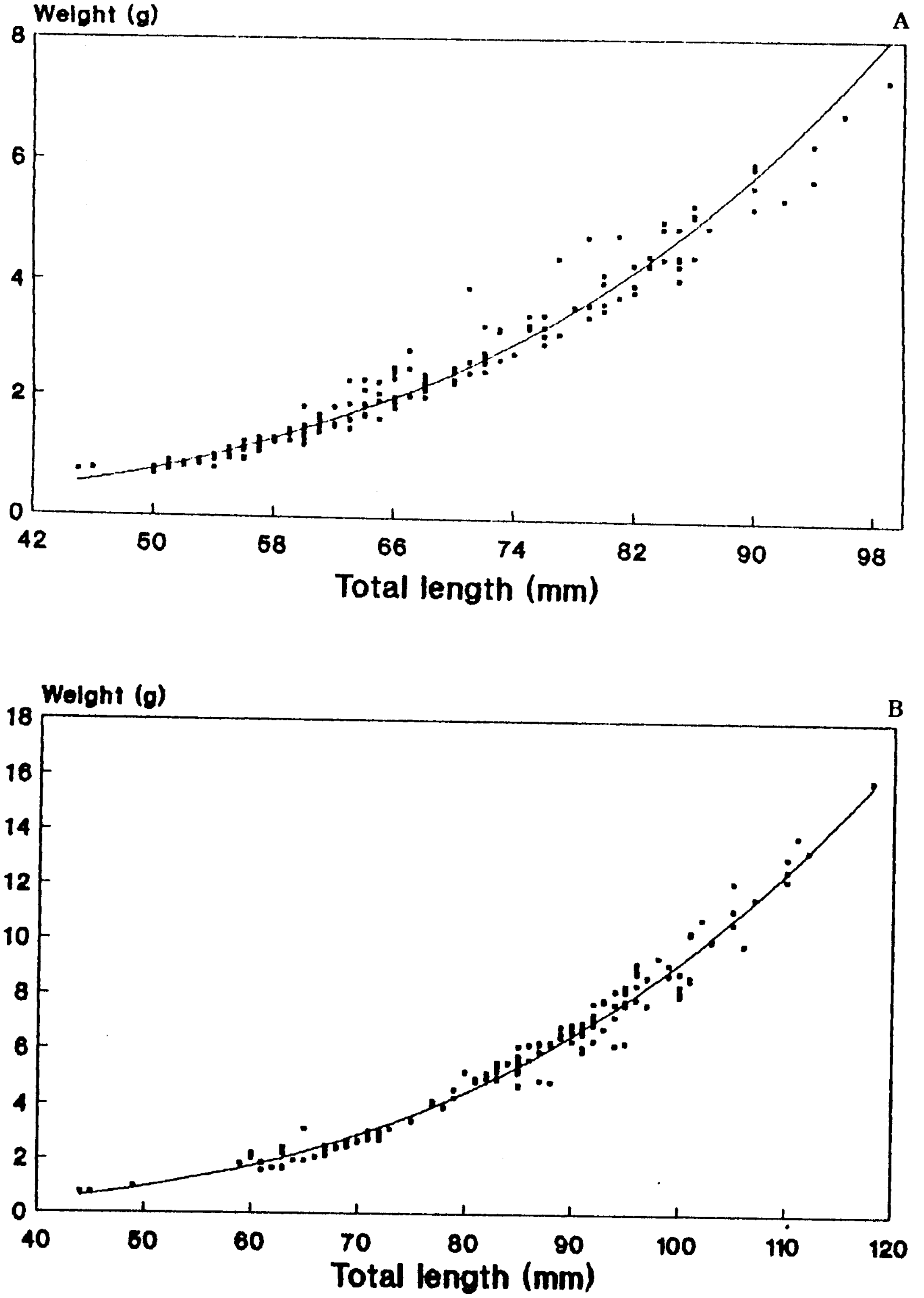


Fig. 2. Length-weight relationships of Caesionids at Minicoy. A. *G. argenteus* B. *C. striatus*.

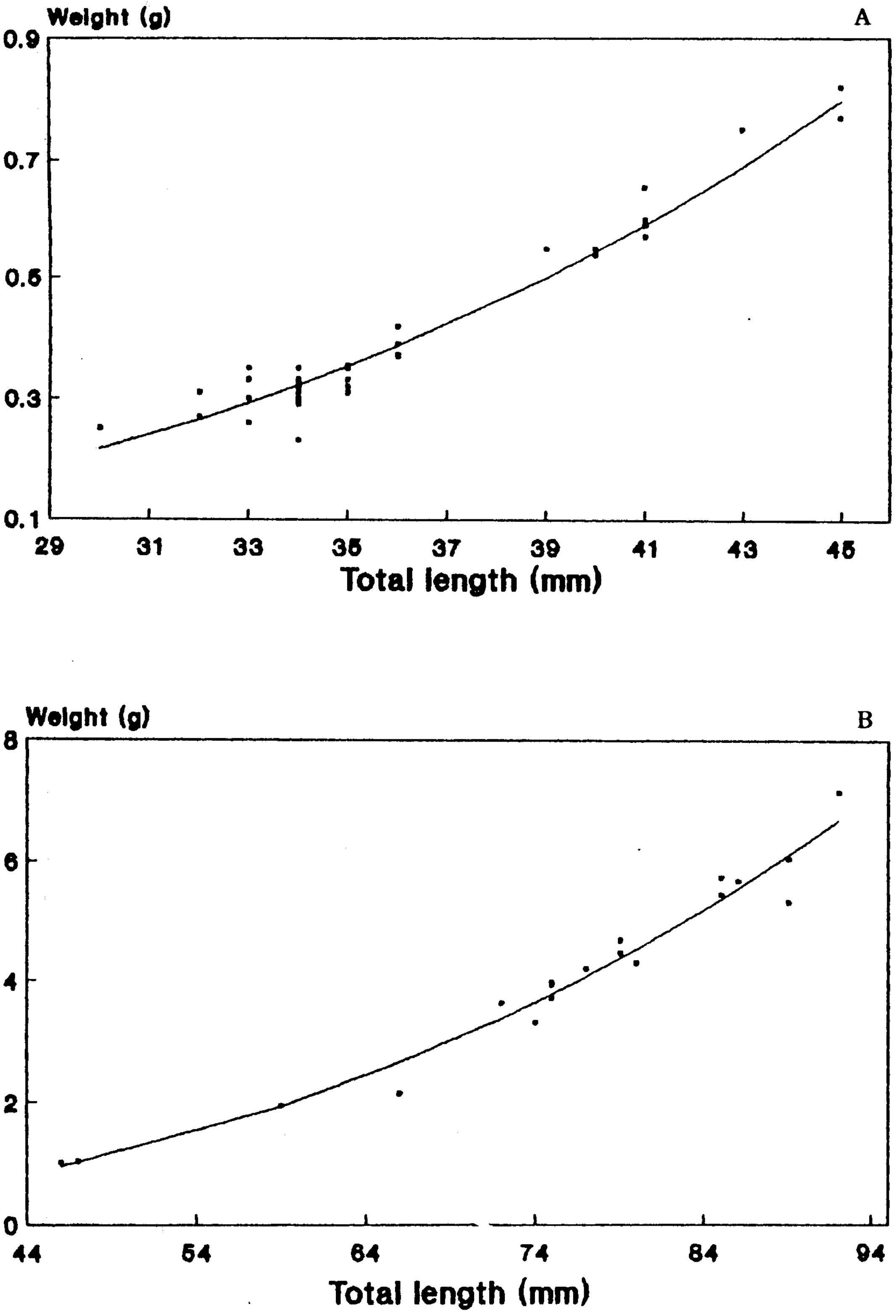


Fig. 3. Length-weight relationships of Caesionids at Minicoy. A. *P. pisang* B. *P. chrysozona*.

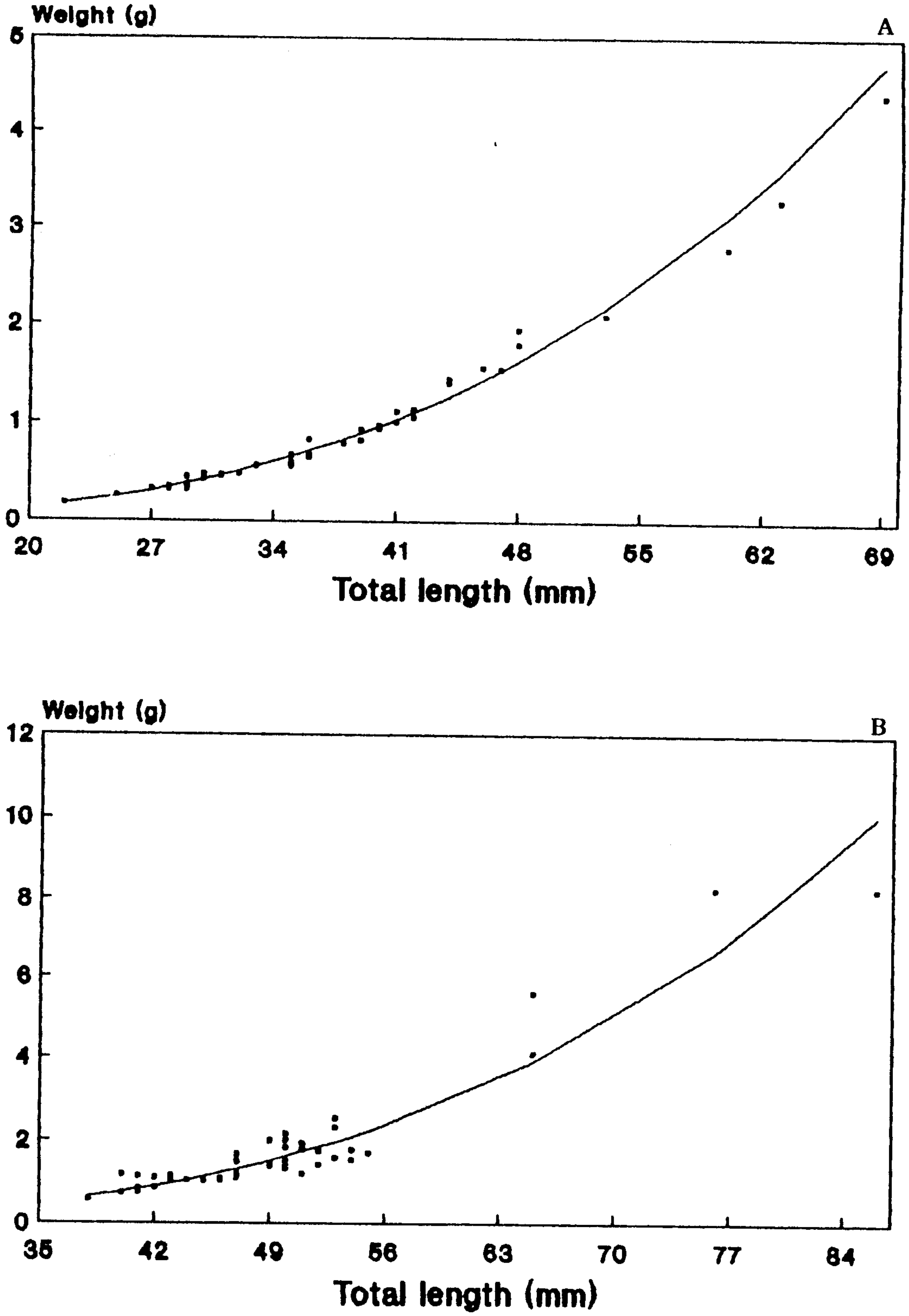


Fig. 4. Length-weight relationships of Pomacentrids at Minicoy. A. *C. caeruleus* B. *L. tapeinosoma*.

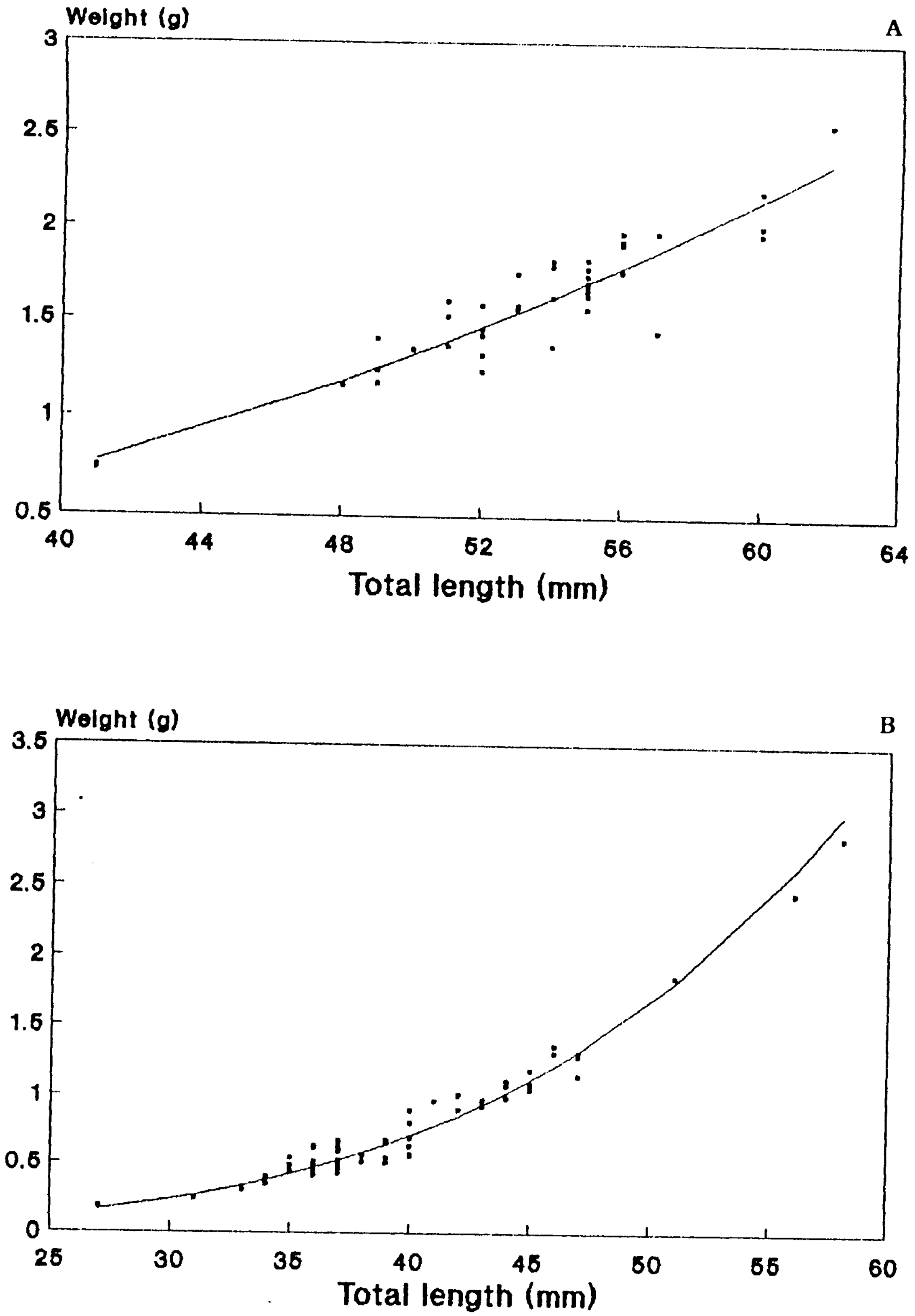


Fig. 5. Length-weight relationships of Apogonids at Minicoy. A. *A. fucata* B. *A. thermalis*.

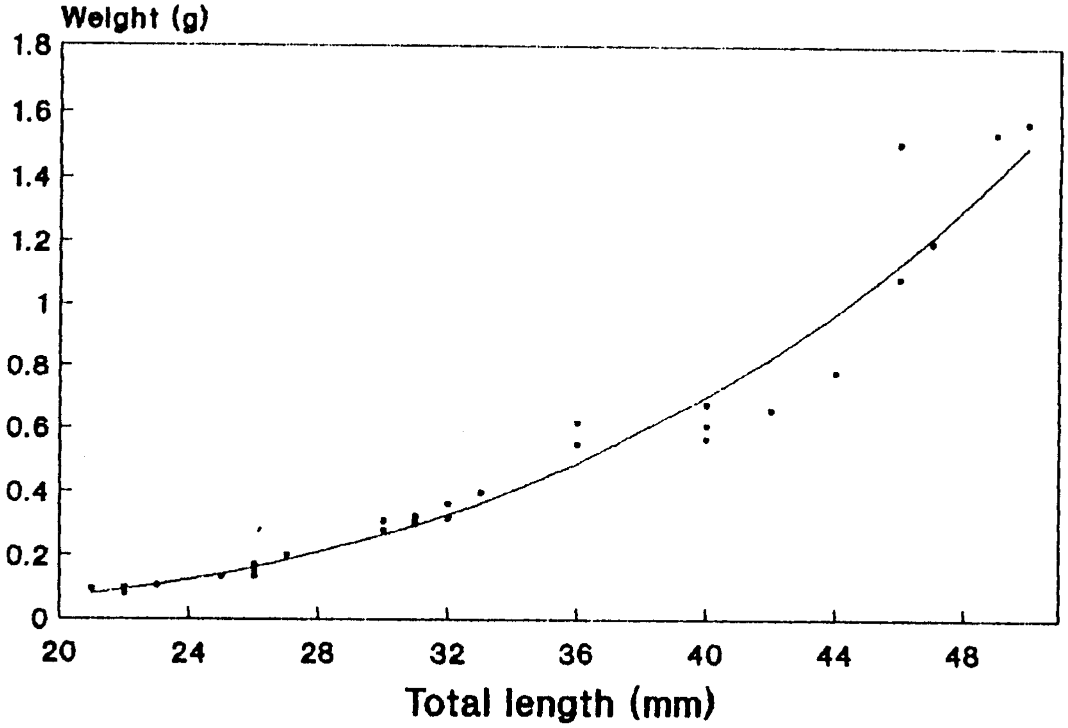


Fig. 6. Length-weight relationships of the Apogonid R. gracilis at Minicoy.

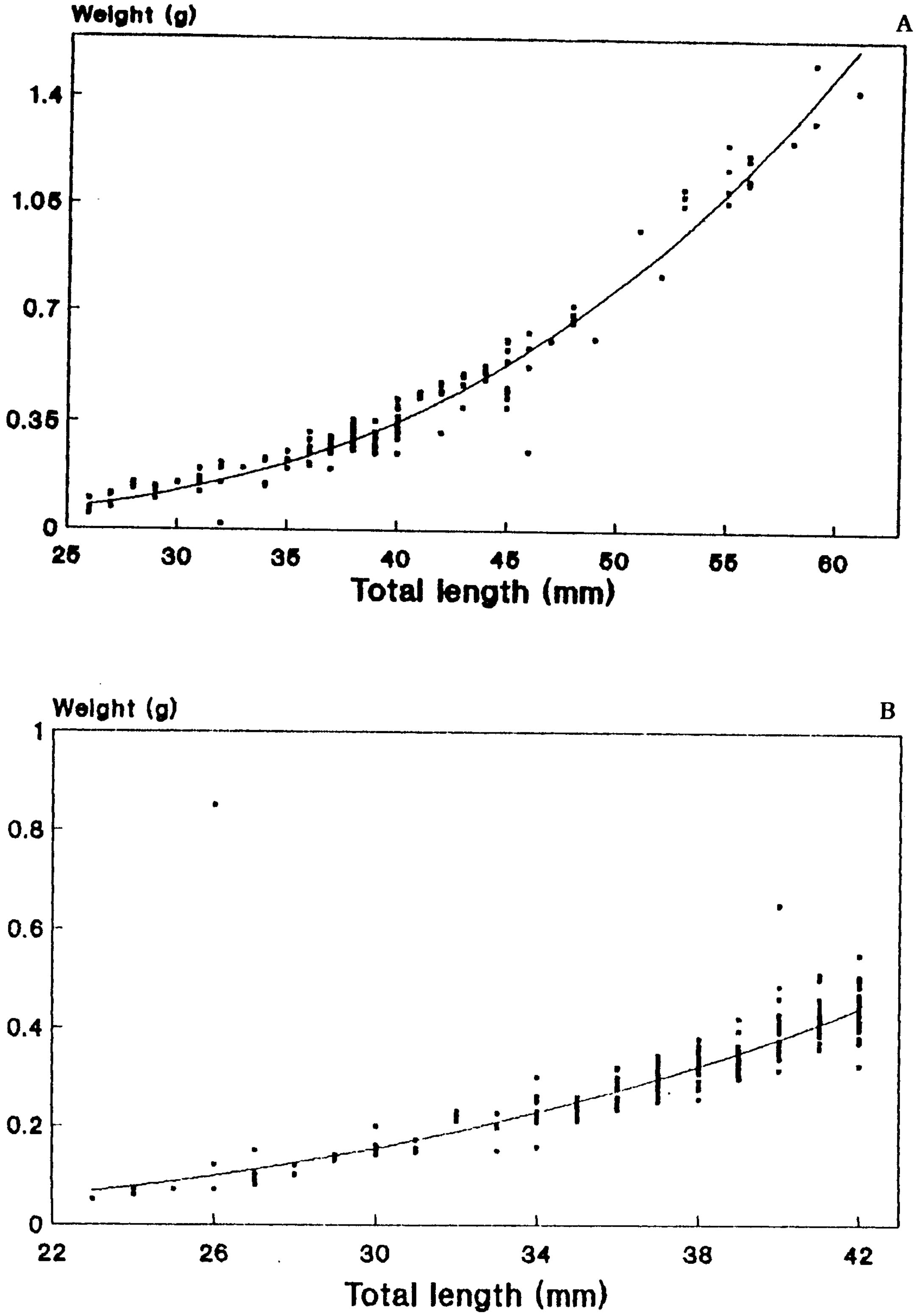


Fig. 7. Length-weight relationships of S. delicatulus at A. Agatti and B. Bangaram.

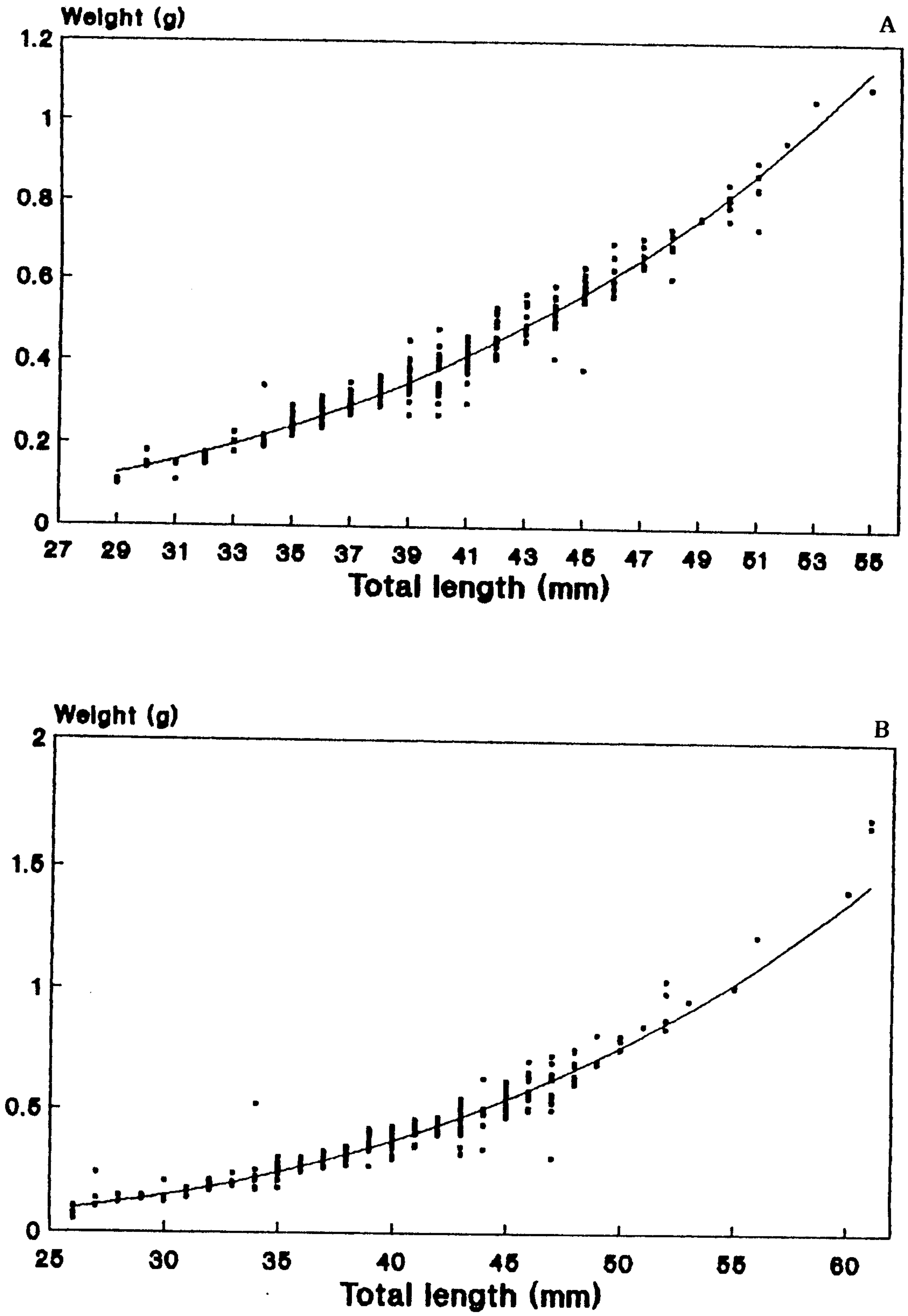
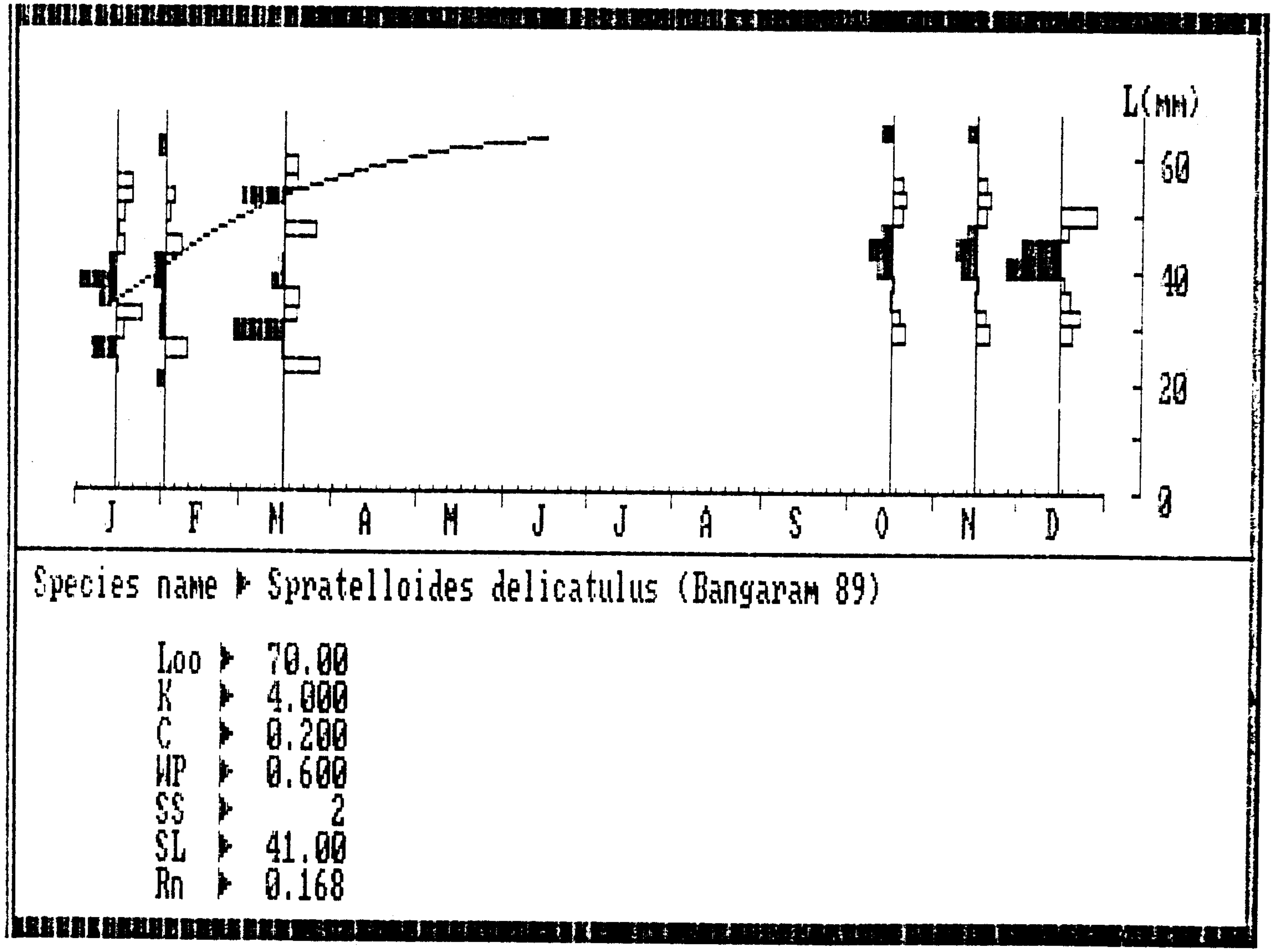
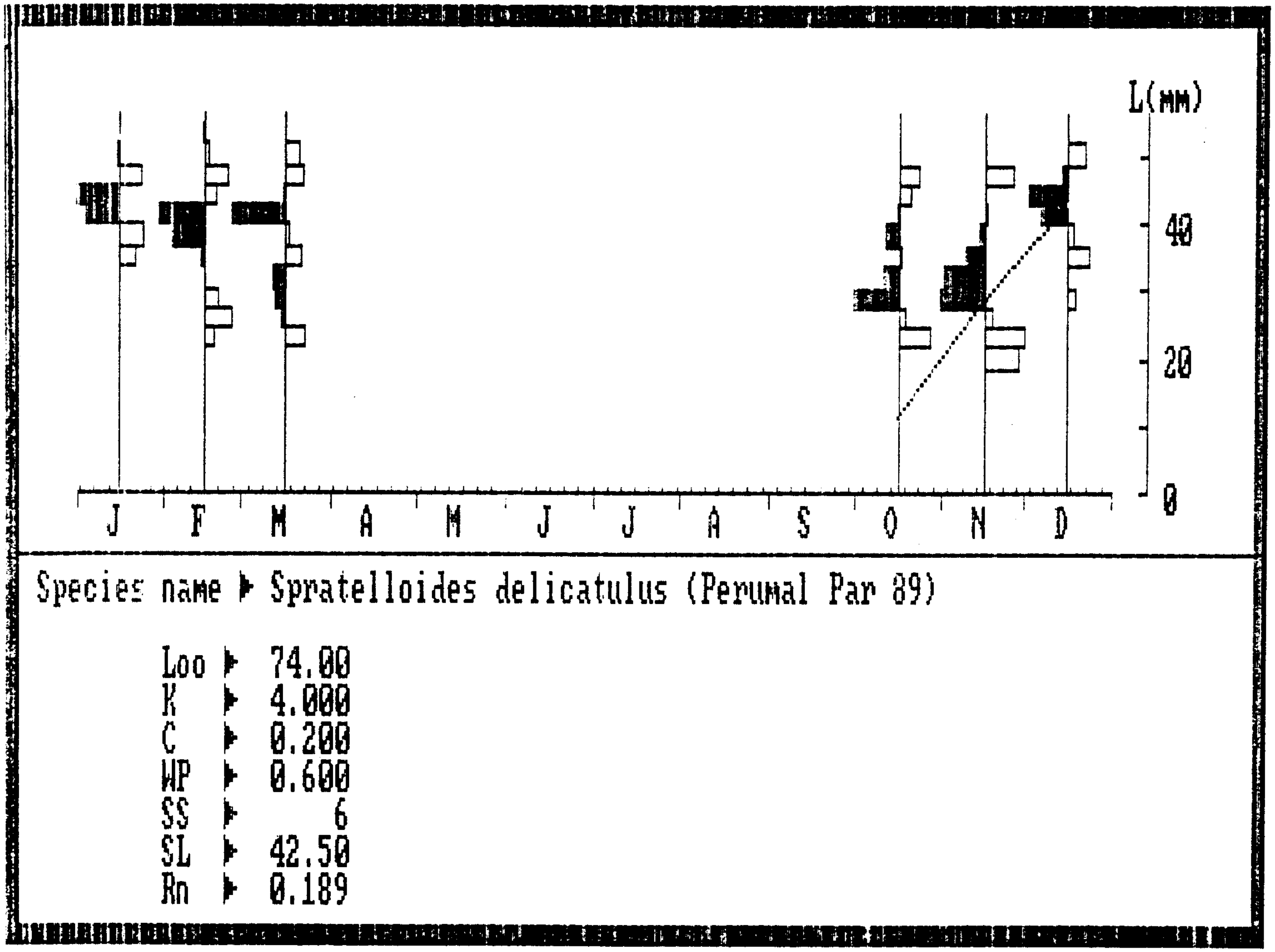


Fig. 8. Length-weight relationships of S. delicatulus at Perumal Par.
A. Male B. Female.



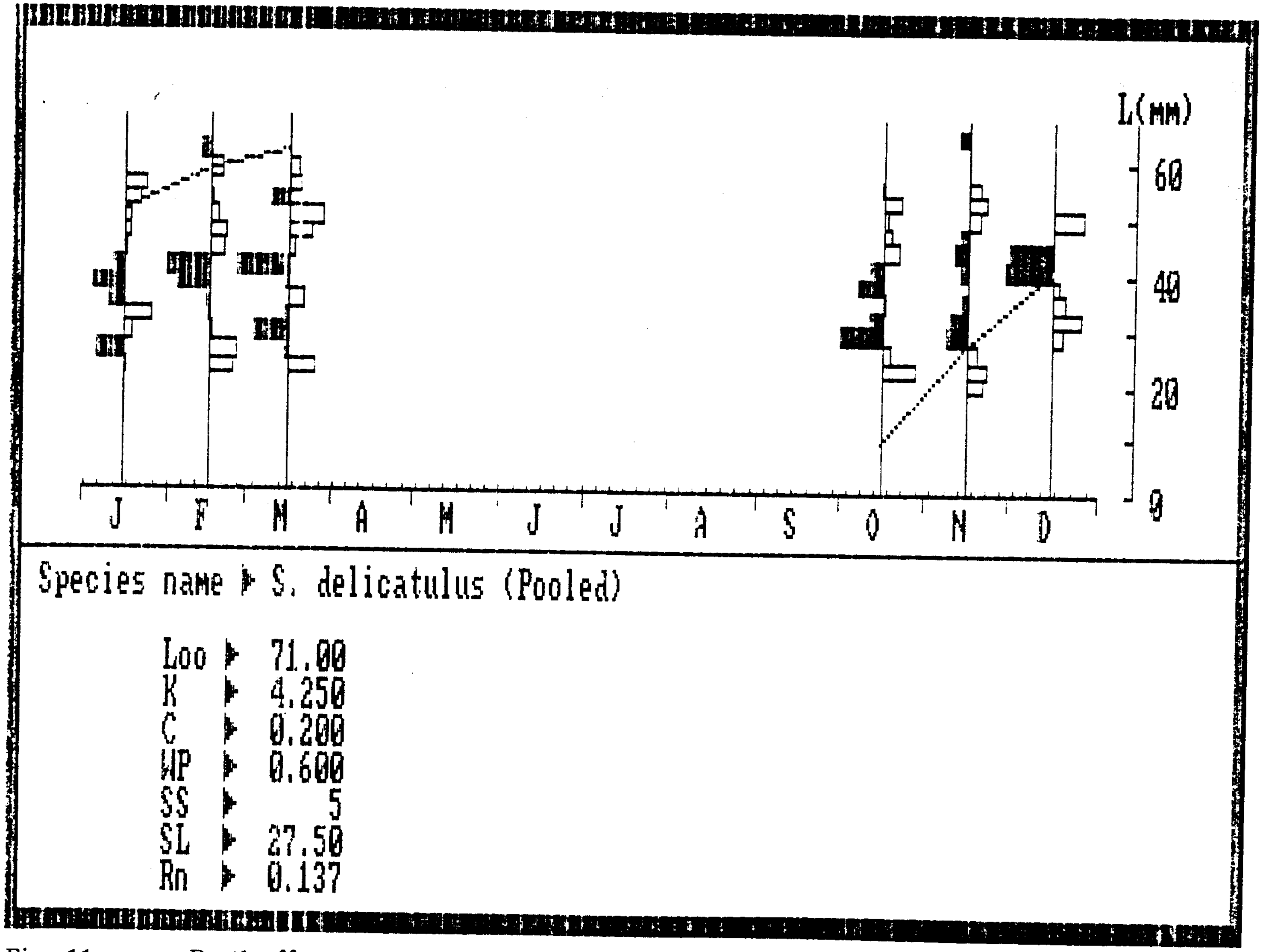
```
Species name ▶ Spratelloides delicatulus (Bangaram 89)

      Loo ▶  70.00
      K   ▶  4.000
      C   ▶  0.200
      WP  ▶  0.600
      SS  ▶      2
      SL  ▶  41.00
      Rn  ▶  0.168
```

Fig. 9. von Bertlanffy growth curves generated by ELEFAN I for *S. delicatulus* at Bangaram.



```
Species name ▶ Spratelloides delicatulus (Perumal Par 89)

        Loo ▶  74.00
        K   ▶  4.000
        C   ▶  0.200
        WP  ▶  0.600
        SS  ▶      6
        SL  ▶  42.50
        Rn  ▶  0.189
```

Fig. 10. von Bertlanffy growth curves generated by ELEFAN I for S. delicatulus at Perumal Par.



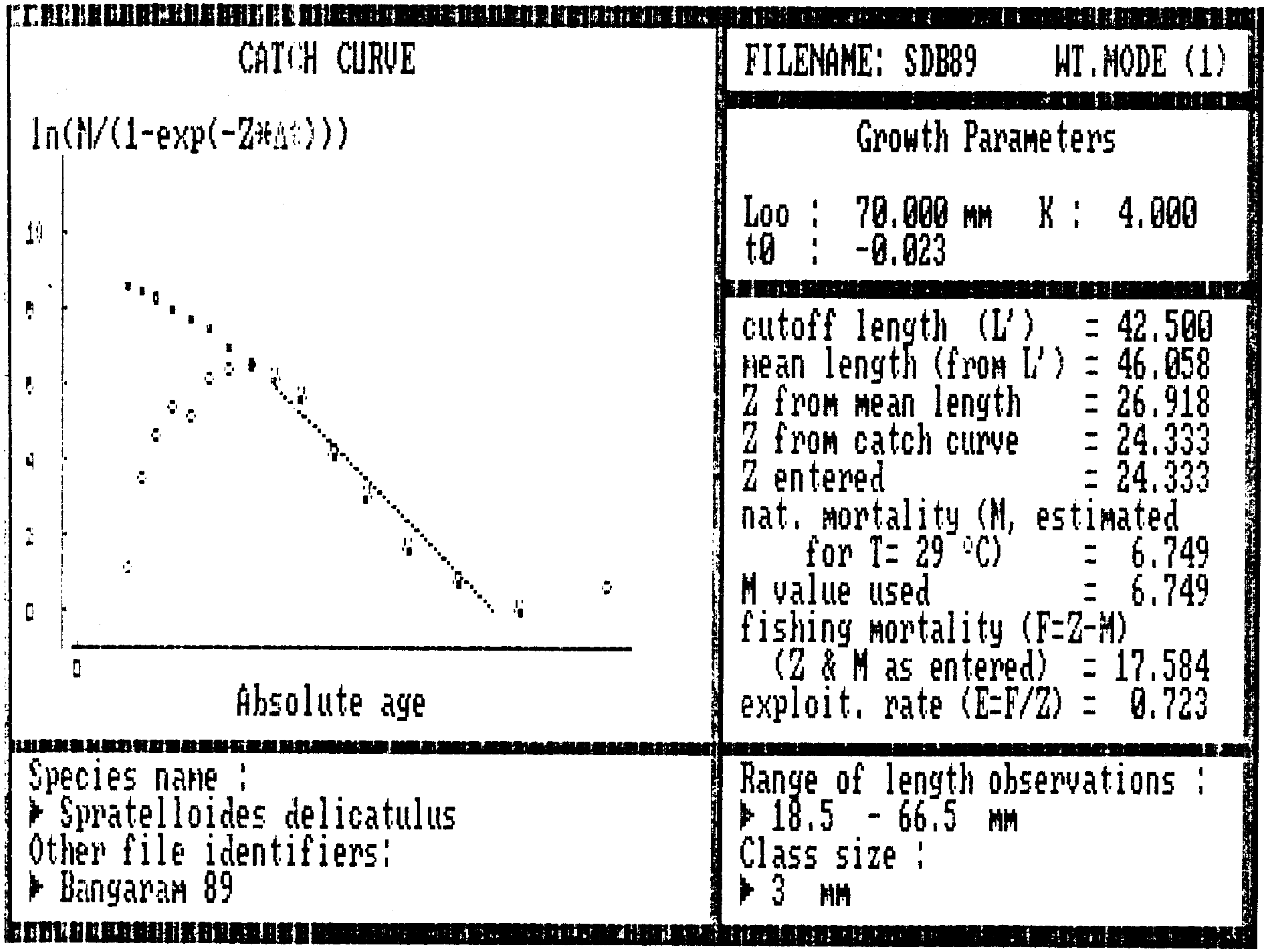
```
Species name ▶ S. delicatulus (Pooled)

        Loo ▶  71.00
        K   ▶  4.250
        C   ▶  0.200
        WP  ▶  0.600
        SS  ▶      5
        SL  ▶  27.50
        Rn  ▶  0.137
```

Fig. 11. von Bertlanffy growth curves generated by ELEFAN I for S. delicatulus for combined data (Bangaram & Perumal Par).

were almost similar while fishing mortality at Perumal Par was nearly double that of Bangaram (Figs 12 to 14). A higher exploitation rate of S. delicatulus was noticed at Perumal Par. Recruitment pattern showed a higher percentage during August and November at Bangaram. At Perumal Par the recruitment showed a delayed pulsing with maximum modes at September and December (Figs 15 to 17).

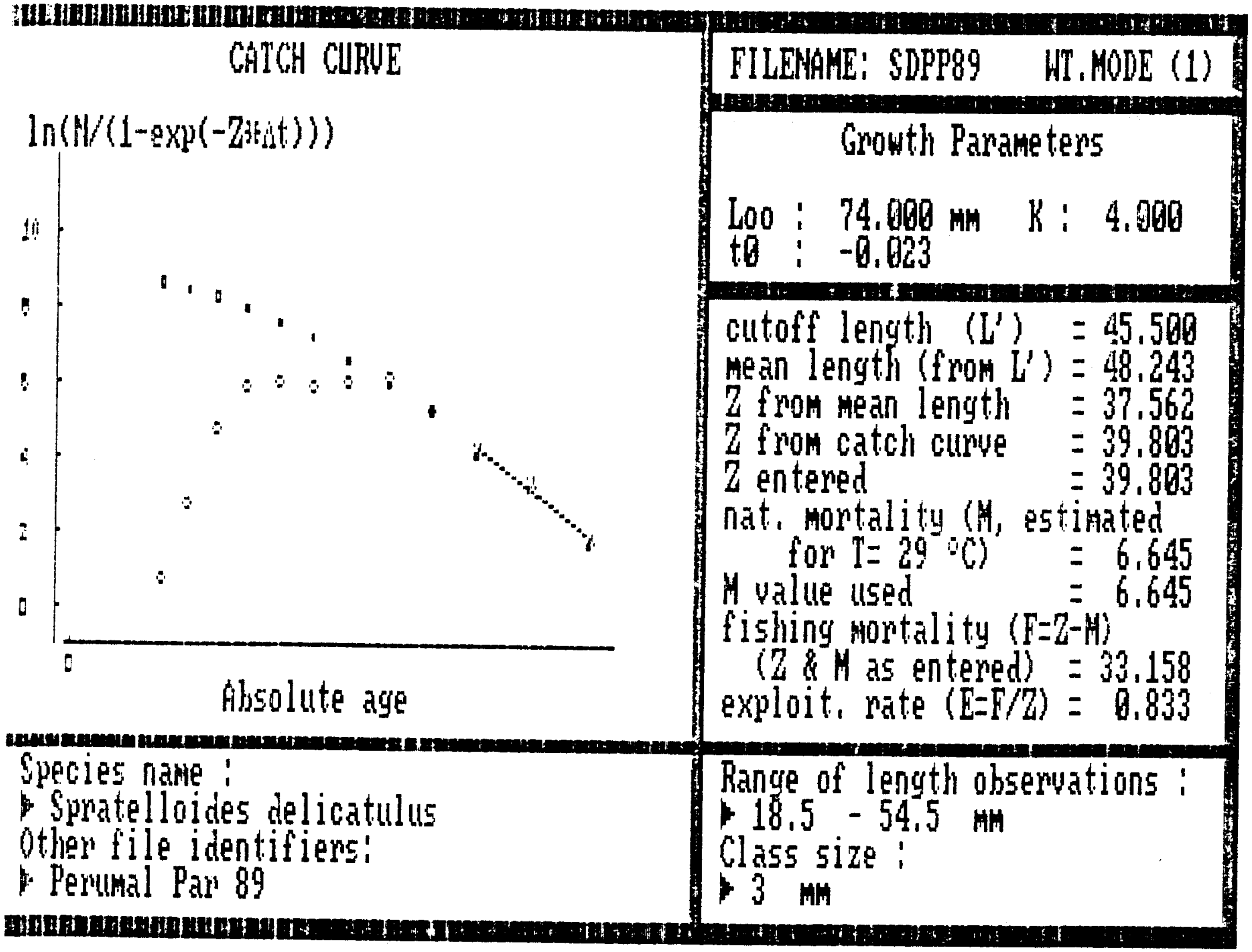
## DISCUSSION

Length-weight data are often used to study the indication of fatness, general well being or gonad development. It is also assumed that heavier fish of a given length are in better condition. S. delicatulus showed allometric growth at all the sites studied with weight increasing at a faster rate (b>3.0). Among the sites there was a wide variation with lowest b value at Bangaram. Similar variation between location for S. delicatulus has been reported (Milton et al., 1990b). They attributed the reduced weight at one site in Solomon Islands to less favorable conditions, and the variation between locations to the quantity and quality of food available at each site. S. gracilis at Minicoy also indicated a faster allometric growth. Dalzell and Wankowski (1980) reported isometric growth for this species at Papua New Guinea and pointed out that whether a radical change in body proportions takes place between juvenile and adult phases is not known. The results of Gopakumar et al.



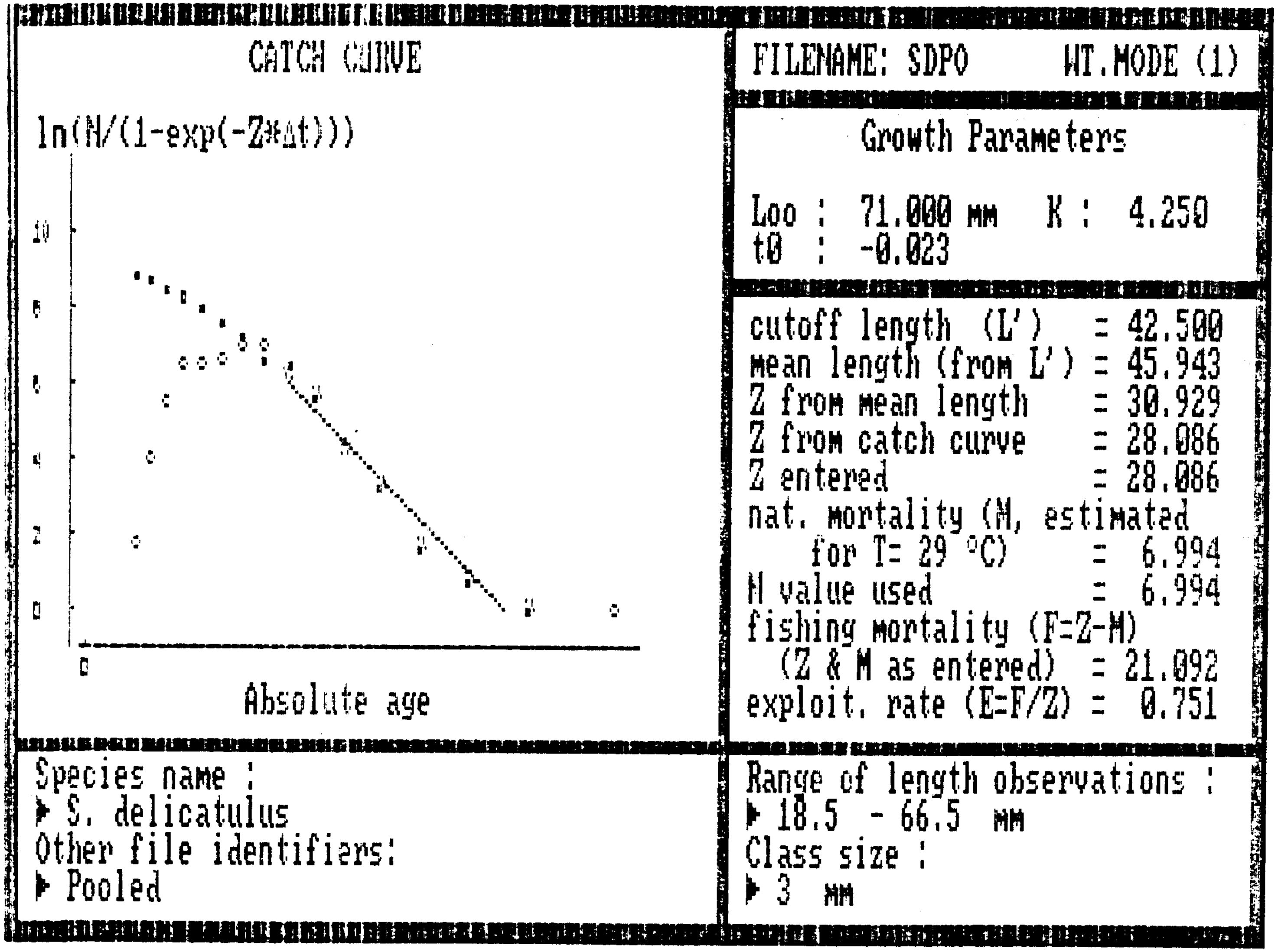
```
FILENAME: SDB89    WT.MODE (1)

       Growth Parameters

Loo :  70.000 mm   K :  4.000
t0  :  -0.023

cutoff length  (L')    = 42.500
mean length (from L') = 46.058
Z from mean length     = 26.918
Z from catch curve     = 24.333
Z entered              = 24.333
nat. mortality (M, estimated
    for T= 29 °C)      =  6.749
M value used           =  6.749
fishing mortality (F=Z-M)
  (Z & M as entered)  = 17.584
exploit. rate (E=F/Z) =  0.723

Species name :
▶ Spratelloides delicatulus
Other file identifiers:
▶ Bangaram 89

Range of length observations :
▶ 18.5  - 66.5  mm
Class size :
▶ 3  mm
```

Fig. 12. Length-converted catch curves generated by ELEFAN II for S. delicatulus at Bangaram.



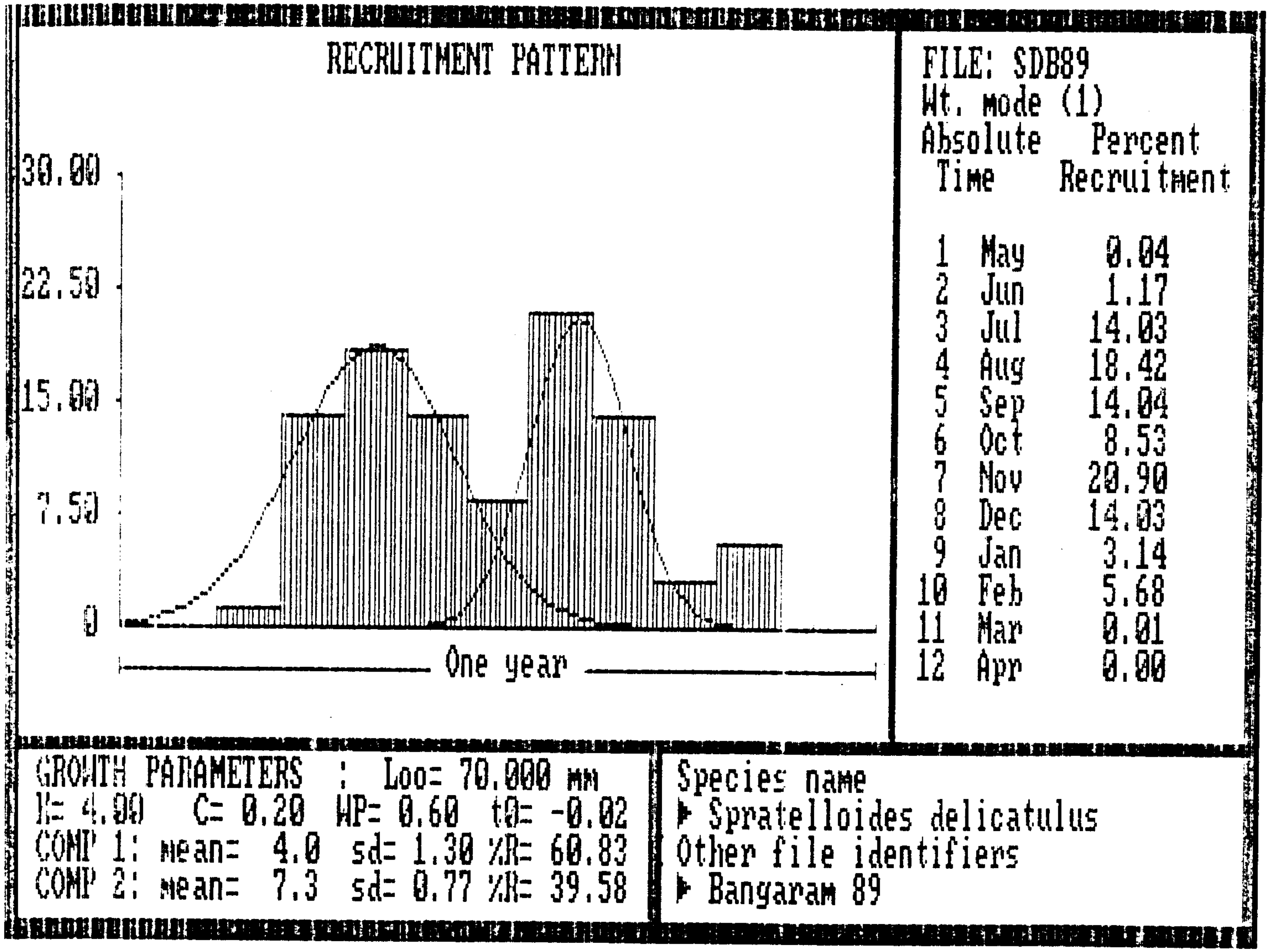
```
FILENAME: SDPP89    WT.MODE (1)

Growth Parameters

Loo :  74.000 mm   K :  4.000
t0  :  -0.023

cutoff length  (L')    = 45.500
mean length (from L') = 48.243
Z from mean length    = 37.562
Z from catch curve    = 39.803
Z entered             = 39.803
nat. mortality (M, estimated
    for T= 29 °C)     =  6.645
M value used          =  6.645
fishing mortality (F=Z-M)
  (Z & M as entered)  = 33.158
exploit. rate (E=F/Z) =  0.833

Species name :
▶ Spratelloides delicatulus
Other file identifiers:
▶ Perumal Par 89

Range of length observations :
▶ 18.5  - 54.5  mm
Class size :
▶ 3  mm
```

Fig. 13. Length-converted catch curves generated by ELEFAN II for S. delicatulus at Perumal Par.



```
FILENAME: SDPO          WT.MODE (1)

         Growth Parameters

Loo :  71.000 mm    K :  4.250
t0  :  -0.023

cutoff length  (L')    = 42.500
mean length (from L') = 45.943
Z from mean length     = 30.929
Z from catch curve     = 28.086
Z entered              = 28.086
nat. mortality (M, estimated
    for T= 29 °C)      =  6.994
M value used           =  6.994
fishing mortality (F=Z-M)
  (Z & M as entered)   = 21.092
exploit. rate (E=F/Z)  =  0.751

Species name :
▶ S. delicatulus
Other file identifiers:
▶ Pooled

Range of length observations :
▶ 18.5  - 66.5  mm
Class size :
▶ 3  mm
```

Fig. 14. Length-converted catch curves generated by ELEFAN II for S. delicatulus for combined data (Bangaram & Perumal Par).

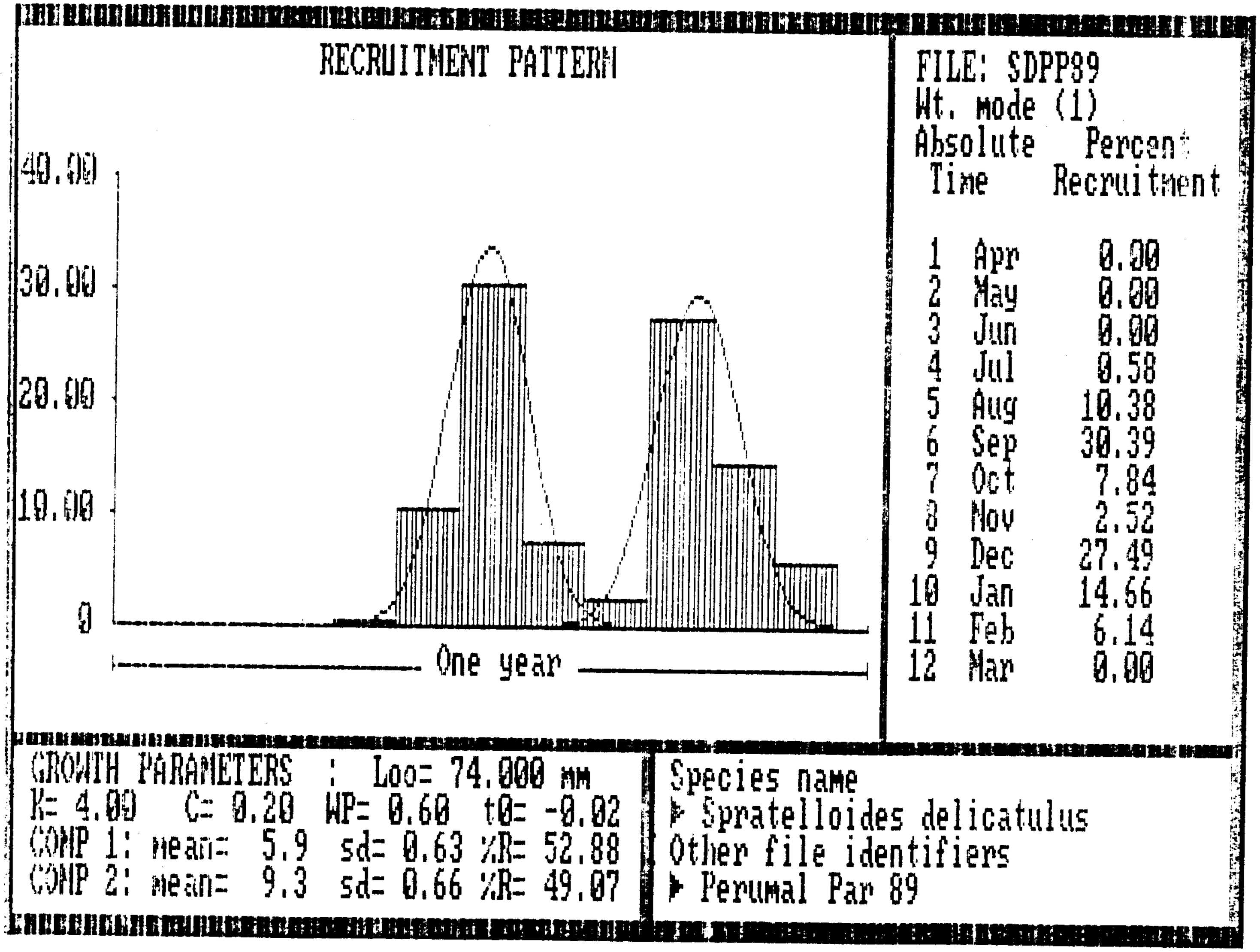


```
FILE: SDB89
Wt. mode (1)
Absolute   Percent
 Time    Recruitment

 1  May       0.04
 2  Jun       1.17
 3  Jul      14.03
 4  Aug      18.42
 5  Sep      14.04
 6  Oct       8.53
 7  Nov      20.90
 8  Dec      14.03
 9  Jan       3.14
10  Feb       5.68
11  Mar       0.01
12  Apr       0.00
```

```
GROWTH PARAMETERS  :  Loo= 70.000 mm
K= 4.00   C= 0.20  WP= 0.60  t0= -0.02
COMP 1: mean=  4.0  sd= 1.30 %R= 60.83
COMP 2: mean=  7.3  sd= 0.77 %R= 39.58
```

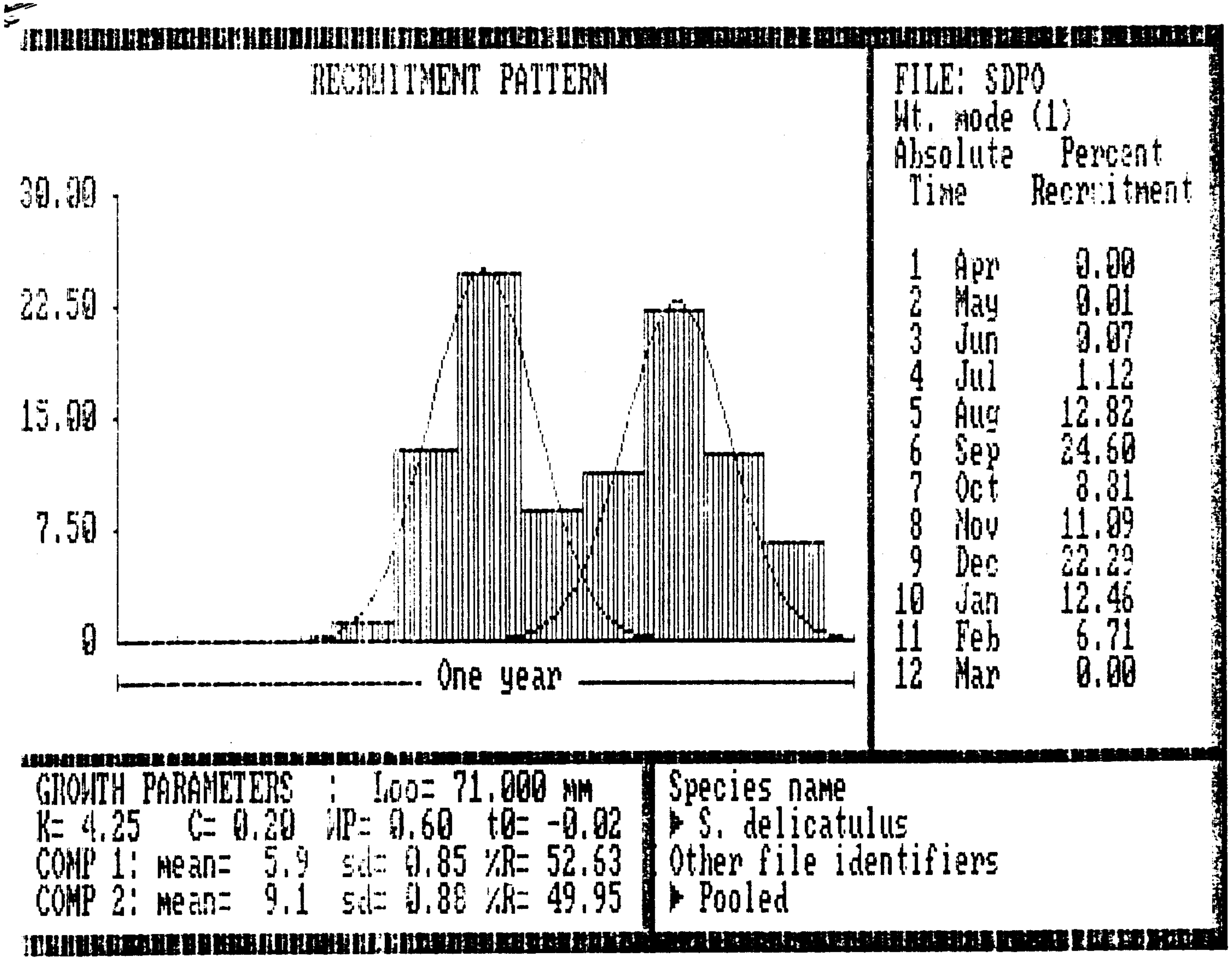
```
Species name
▶ Spratelloides delicatulus
Other file identifiers
▶ Bangaram 89
```

Fig. 15. Recruitment patterns obtained from ELEFAN II for *S. delicatulus* at Bangaram.



```
RECRUITMENT PATTERN

FILE: SDPP89
Wt. mode (1)
Absolute    Percent
 Time     Recruitment

 1  Apr      0.00
 2  May      0.00
 3  Jun      0.00
 4  Jul      0.58
 5  Aug     10.38
 6  Sep     30.39
 7  Oct      7.84
 8  Nov      2.52
 9  Dec     27.49
10  Jan     14.66
11  Feb      6.14
12  Mar      0.00

GROWTH PARAMETERS  :  Loo= 74.000 mm
K= 4.00   C= 0.20  WP= 0.60  t0= -0.02
COMP 1: mean=  5.9  sd= 0.63 %R= 52.88
COMP 2: mean=  9.3  sd= 0.66 %R= 49.07

Species name
▶ Spratelloides delicatulus
Other file identifiers
▶ Perumal Par 89
```

Fig. 16. Recruitment patterns obtained from ELEFAN II for S. delicatulus at Perumal Par.



```
FILE: SDPO
Wt. mode (1)
Absolute   Percent
 Time     Recruitment

 1  Apr      0.00
 2  May      0.01
 3  Jun      0.07
 4  Jul      1.12
 5  Aug     12.82
 6  Sep     24.60
 7  Oct      8.81
 8  Nov     11.09
 9  Dec     22.29
10  Jan     12.46
11  Feb      6.71
12  Mar      0.00
```

```
GROWTH PARAMETERS   :  Loo= 71.000 mm
K= 4.25   C= 0.20  WP= 0.60  t0= -0.02
COMP 1: mean=  5.9  sd= 0.85 %R= 52.63
COMP 2: mean=  9.1  sd= 0.88 %R= 49.95
```

```
Species name
▶ S. delicatulus
Other file identifiers
▶ Pooled
```

Fig. 17. Recruitment patterns obtained from ELEFAN II for S. delicatulus for combined data (Bangaram & Perumal Par).

(1991) for juvenile and adult S. gracilis from Lakshadweep seems to imply that juveniles have a slower rate of increasing weight than adults. The b values obtained in this study are higher than those reported for this species from other locations (Dalzell and Wankowski, 1980; Conand, 1988; Milton et al., 1990b; Gopakumar et al., 1991). It is also significant that the values reported earlier from Minicoy for this species (Mohan and Kunhikoya, 1985) are much lower than those obtained in this study. This may indicate the influence of changing environmental conditions on the general well being of the fish stock at Minicoy.

The higher b values for most caesionids seems to testify that reefs surrounding coral atolls are highly productive and hence support a higher biomass. Fusiliers are migrant forms (Gopakumar et al., 1991) which are found shoaling in the outer reef areas and temporarily associated with corals inside the lagoon. This migration is mainly a prey avoidance strategy coupled with active feeding. They are in a different category in contrast to the other livebaits with only juveniles used as bait in pole-and-line fishery and grows up to a length of about 25 cm (Carpenter 1984). Except for a few reports (Cabanban, 1984; Bell and Colin, 1986) there is practically no information of this group of livebaits. Caesionids form an important component of baitfishery at Minicoy during the various months that they are available. It is also the most significant group in the tuna baitfishery of Maldives with several species being involved (Maniku et al., 1990). The deep-bodied Pomacentrid, C. caeruleus have a slower weight gain with b values approaching isometry. This is in agreement with the findings of Mohan et al. (1986) who reported slightly lower values of 2.67 from Minicoy. Similar values were obtained for the relatively deep-bodied apogonids, A. fucata with growth constant considerably lower than 3.0. Gopakumar et al. (1991), however, observed values above 3.0 for this species from Lakshadweep. The length-weight studies on livebaits indicated that except in one case the relationship was not significantly different between sexes. Most of them have allometric growth rates and faster weight gain. The conclusion therefore could be that livebaits enjoy a favorable habit and habitat at the various locations.

Population dynamics does not feature as a prominent aspect of livebait biology. The data in most cases are wanting for lack of a continuous and long time series and also in the number of baitfish available for study. The results of S. delicatulus presented are based only on a single year, six month data, involving length of only about a thousand specimens from each site. The paucity of information in this field of livebait biology is however an allurement to make a few observations in spite of severe restrictions on the data. The growth parameter estimates of S. delicatulus is in broad agreement with published values for this species (Munch-Petersen, 1983; Dalzell et al., 1987; Tiroba et al., 1990; Milton et al., 1991). The sprats are a fast growing, short lived group of fishes. For example, the life expectancy of *S. delicatulus* is around 6 months (Dalzell *et al*., 1987) and it is generally less than 4 months for the genus *Spratelloides* (Milton *et al*., 1991). *S. delicatulus* is the smaller bait among sprats while $L_{oo}$ values of other species are much higher. Dalzell and Wankowski (1980) estimated $L_{oo}$ and K values for *S. gracilis* at 83 mm and 4.38 and Dalzell (1987a) calculated K value for *S. lewisi* at around 5.44/yr.

The high total and fishing mortalities observed at both Bangaram and Perumal Par indicate that there is an over exploitations of this species. Tiroba *et al*. (1990) reasoned that a relatively high fishing mortality of *S. delicatulus* over that of anchovies is because when this species is present in a baitground it is preferred and hence suffers a very high mortality. Livebait fishery in the northern group of islands of Lakshadweep, unlike Minicoy, depends only on *S. delicatulus* and this to an extent may explain the high mortalities observed. On the basis of life cycle strategies, sprats are classified as type 1 (Lewis, 1990). They are species with short life cycle, are relatively small in size, grow rapidly, attains sexual maturity in 3-4 months, spawn over an extended period and have batch fecundities of 500-1500 oocytes per gram of fish. Lewis (1990) also explains that recovery from periods of heavy exploitation of such species are rapid because of the fast population turnover, existence of unfished buffer zones and division of stocks into discrete but spatially overlapping units. The fishery to a large extend is self-regulatory due to the availability of a large number of alternative baiting sites. There has been instances when concentration of baitfishing at Perumal Par alone, resulted in complete depletion of the stock. Resumption of fishery was possible only after a delay of few months. The complete suspension of pole-and-line fishing during the southwest monsoon also helps in recovery of the stock. The mortality values are higher than those reported for the Solomon Islands fishery (Tiroba et al., 1990). Pauly (1987) cautions that assessment of whether a stock is overfished, based solely on length-frequency data is possible only in principle. In reality, the estimates of Z will be biased one way or the other by the sampling gear and by the behavior of the animals sampled. The ratio of fishing mortality to total mortality or exploitation rate (E) can be used as a measure of the exploitation of a fish stock. Gulland (1971) suggested that in a stock that is optimally exploited, fishing mortality should be about equal to natural mortality or $F_{opt}=M$ and $E_{opt}=0.5$. Pauly (1984) proposed a more conservative definition of optimum fishing mortality where $F_{opt}=0.4$ M and $E_{opt}=0.3$. The E values obtained for the baitfishery at Bangaram and Perumal Par far exceeds the suggested optima. The island of Agatti has in recent times emerged as an important contributor to the total tuna catch of Lakshadweep (Varghese and Shanmugham, 1983). The results of this study, therefore, indicates that the fishery of this area require close monitoring and further expansion in terms of increased effort must be viewed with extreme caution.

Recruitment patterns obtained by the ELEFAN program gives only approximate results because it is based on assumptions which will hardly ever be met in reality (Pauly, 1987). The results, however, suggest that recruitment pattern contain useful information, from which legitimate inferences on the dynamics of fish stocks can be drawn. The peak of recruitment observed during August-September at Bangaram and Perumal Par tallies with the major recruitment months of S. delicatulus at Solomon Islands (Tiroba et al., 1990). Milton and Blaber (1991) found that spawning of six species of baitfish correlated with particular environmental conditions, especially moon phase and less importantly, rainfall and temperature. They also point out that the lack of clear proximate stimuli for spawning makes it difficult to predict the timing of major spawning events. Lewis (1990) opined that the highly fecund sprats appear to spawn year round, with recruitment occurring on a much less predictable basis and the probability of success determined by stochastic processes. Milton et al. (1990b) established that a significant proportion of the livebait population at Solomon Islands are spawning at any given time. This means that even if there is heavy fishing during peak spawning, it will not seriously affect the overall fishery, as there will be some recruitment to the fishery from fish spawning at other sites. A similar mechanism may be operating at Bangaram and Perumal Par as is evident from the protracted recruitment and continued availability of S. delicatulus in spite of tremendous fishing pressure.

# CHAPTER 3

# FOOD AND FEEDING HABITS

## INTRODUCTION

In terms of their food and feeding behaviour two groups are widely recognised among coral reef fishes. They are the herbivores (feeding on the reef micro and marcrovegetation) and the planktivores. However, the classification into various trophic levels does not have uniformity and at times groups identified as herbivores by some authours are placed under coral feeders by others. The category omnivore is a flexible one, while planktivores, piscivores and crustacean-feeders are sometimes included as carnivores. Trophic classifications of coral reef fishes include those of Talbot (1965), Bakus (1966), Goldman and Talbot (1976), Parrish and Zimmerman (1977), Gladfelter and Gladfelter (1978) and Sale (1980). General descriptions of the feeding biology of reef fishes is provided by Fishelson et al., (1974), Hobson (1974), Hobson and Chess (1978) and Gladfelter et al., (1980). Detailed analysis of diets have been presented for fishes of the Marshall Islands (Hiatt and Strasburg, 1960) and Caribbean (Randall, 1967). Diets of particular groups of fishes have also been presented from many regions (Choat, 1968; Vivien and Peyrot-Clausade, 1974; Harmelin-Vivien and Bouchon, 1976).

Herbivores have attracted special attention because they are the consumers of primary production and help in channeling food materials and energy to other members of the food chain. Herbivorous fishes of coral reefs are among the most abundant and widespread groups of vertebrate herbivores. These fishes differ greatly in the morphology and power of their mouth-parts, their digestive physiologies, and their foraging rates and behaviour. As plants are sessile, procuring food poses few problems but the difficulties are in the quality of food materials which are highly variable and in their resistance to processing and digestion. Herbivorous fishes are involved in three important processes of reefs. They are i) trophodynamics, ii) effect on the distribution and composition of plant assemblages and iii) interactions among herbivorous fishes which have been used as a basis for developing demographic and behavioural models of reef fishes (Choat, 1991). Studies on trophodynamics are mainly those of Odum and Odum (1955), Hatcher (1981), Carpenter (1986), Klumpp _et al_., (1987) and Klumpp and Polunin (1989). Plant-herbivore interactions has received wide attention in areas such as plant assemblages and herbivore activity (Ogden and Lobel, 1978; Williams, 1983; Choat, 1983; Carpenter, 1986; Lewis, 1986) and plant defense mechanisms (Hay, 1981 and 1984; Hatcher and Larkum, 1983; Paul _et al_., 1990). Sale (1980), Robertson and Polunin (1981) and Doherty and Williams (1988) deal with the demography and behaviour of herbivorous reef fishes. The herbivores that are most characteristic of reef environments belong to the families Acanthuridae, Pomacentridae, Scaridae and Siganidae (Randall, 1961; Choat, 1991). Herbivores occur throughout the world's oceans but their distribution patterns are modified by striking gradients in diversity and abundance (Bouchon-Navaro and Harmelin-Vivien, 1981; Horn, 1989).

Fishes that feed on zooplankters are also major components of coral reef communities. Virtually every major family includes species that are specialized as planktivores and most of them feed with visually oriented strikes at individual prey. Incident light being an important factor aiding vision, these fishes are adapted to specific photic conditions and feed either strictly by day or by night. Most diurnal reef planktivores feed primarily on crustacea, particularly calanoid and cyclopoid copepods while larvaceans or fish eggs are favoured by others. The important modifications in day feeders have taken place in the region of the head and jaws, including dentition, which permits ever large individuals to prey on tiny organisms. Other features are the protrusible jaw and the oblique orientation of the mouth. Fishes that feed on zooplankters during night are strongly influenced by the difficulty of visually locating prey in dim light. Major prey of these fishes are plankton that are relatively large and semipelagic residents that rise into the water column during the night. Adaptations to nocturnal feeding include large eyes, deep compressed body and tendency to remain solitary. Planktivorous reef fishes that feed by day typically form aggregations in the water column, and from a distance it it often difficult to distinguish one species from another (Hobson, 1991). Most diurnal planktivores have a small mouth that in many is sharply upturned and with highly protrusible, often toothless jaws. Gill rakers tend to be long, numerous and closely spaced to prevent ingested prey from escaping through the gill openings. They are most abundant along reef edges adjacent to deeper water, probably because their major prey the holoplankters from open water are most accessible at outer reef areas (Hobson, 1974; Hobson and Chess, 1978). Twilight is a time of transition between distinctive diurnal and nocturnal feeding modes among planktivorous reef fishes. The crepuscular changeover is an orderly sequence of responses to specific levels of diminished daylight, with the morning and evening sequences being essentially mirror images of one another (Hobson, 1972). Nocturnal feeders emerge from their shelters in large numbers about 30 min after sunset and migrate to distant feeding grounds (Gosline, 1965; Hobson, 1972; Gladfelter, 1979). Similarly, a transition is also observed in the zooplankters when they emerge in large numbers during late twilight. They include the holoplankters that had been in swarms close to benthic substrata during the day, mostly copepods and mysids (Emery, 1968; Hamner and Carleton, 1979; Carleton and Hamner, 1989) and at nightfall disperse in the water column. Apart from these swarms a variety of bottom dwelling organisms such as polychaetes, ostracods, isopods, amphipods, and crustacean larvae also enter the water column (Alldredge and King, 1977; McWilliam _et al_., 1981). Nocturnal planktivores generally are more widespread in the reef area than their diurnal counterparts. This distinction may have developed because the nocturnal species feed mainly on reef residents that are themselves widespread over the reef, whereas the diurnal species take mainly open-water transits that are most available at reef edges (Hobson, 1991). Major nocturnal zooplankton feeders of reefs belong to the families of Clupeidae, Engraulidae, Athernidae, Holocentridae and Apogonidae.

Apart from studies on herbivores and planktivores, observations have also been made on other sources of food to reef fishes. Riley (1963), Johannes (1967) and Qasim and Shankaranarayan (1970) observed organic aggregates mostly composed of coral mucus, a food for many fishes and zooplankton. Coelenterate mucus is a complex mixture of macromolecular components which may provide nutrition or energy to a diverse assemblage of detritus feeders as it undergoes denaturation _in situ_ on coral surfaces and enters the particulate organic detritus (Coles and Strathmann, 1973; Benson and Muscatine, 1974; Ducklow and Mitchell, 1979 a, b). The unicellular algae, zooxanthellae, found in corals also produce soluble extracellular organic material that adds to the productivity of coral reefs (Muscatine, 1967). Detritus formed from these mucus, organic aggregates, algal filaments, pieces of phyto and zooplankton and faecal pellets produced in reefs is transported to lagoons where they form food of zooplankton and fishes (Marshall, 1965; Qasim, 1979; Gerber and Marshall, 1974 and 1982).

Although studies on food and trophic relationships of reef fishes are numerous, they seldom include fishes that are important as tuna livebait. The only exception being the many species of damselfishes belonging to the genus *Chromis* (Pomacentridae) on which a sizable literature exists (Coles and Strathmann, 1973; Fishelson *et al*., 1974; Gerber and Marshall, 1974; deBoer, 1978; Luckhurst and Luckhurst, 1978; Tribble and Nishikawa, 1982; Go and Jeon, 1983 b; Mohan *et al*., 1986; Coughlin and Strickler, 1990). The change in feeding habit from a diurnal mode to nocturnal one among Apogonids as they grow older has also received attention (Azeta *et al*., 1983; Robblee and Zieman, 1984; Hobson, 1991). Among the other livebaits, the food and feeding biology of *Herklotsichthys punctatus* and *Pranesus pinguis* from Marshall Islands (Hida and Uchiyama, 1977), *Stolephorus heterolobus*, *S. devisi* and *Spratelloides gracilis* from Papua New Guinea (Anon., 1982), *Lepidozygus tapeinosoma* of the Indo-Pacific (Emery, 1983) and *Stolephorus devisi*, *S. heterolobus*, *Spratelloides delicatulus*, *S. gracilis*, *S. lewisi*, *Archamia zosterophora* from Solomon Islands (Milton *et al*., 1990a) has been studied. From Lakshadweep, diet and feeding habit of *S. delicatulus* and *S. gracilis* (Mohan and Kunhikoya, 1985) and

Chromis caeruleus (Mohan et al., 1986) has been investigated. Gopakumar et al., (1991) examined the gut contents of 17 species of tuna livebaits. Mathew and Gopakumar (1986) observed the influence of zooplankton biomass on tuna catch indirectly through the abundance of livebaits.

As a part of biological studies on tuna livebaits of Lakshadweep, the feeding condition and the quantitative and qualitative estimation of the gut contents of livebaits were carried out. The object of the study was to understand the state of feeding when the livebaits are caught and the major prey of the various species.

## MATERIALS AND METHODS

Baitfish samples were collected from commercial fishery at Minicoy, Agatti, Bangaram and Perumal Par. At Minicoy, Spratelloides delicatulus is caught by an encircling net while all the other baits are harvested by a lift net. S. delicatulus the only species of bait used in the other areas of study is also harvested by an encircling net. A sample collected from the net before they are transferred to the bait tanks was preserved in 5% formalin. In the laboratory, the fish were measured, weighed, sexed and their stomach and gut removed for further analysis. To ascertain the condition of feeding, the degree of fullness of stomach was noted before the stomach was actually opened. A stomach was designated 'full' when it was completely gorged with food and considered '3/4 full' when it was in a partly collapsed condition. Similarly, they were classified '1/2 full' and '1/4 full' depending on the relative fullness and the space occupied by the stomach contents. Those stomachs which were termed 'empty' contained practically nothing in them. Fishes withe stomachs classified as 'full' and '3/4 full' were considered to have actively fed, '1/2 full' moderately fed and '1/4 full' as poorly fed.

The gut contents were then teased out carefully and examined under a light microscope. Prey items were identified and the number of each prey in the gut were counted. The total length and diameter of each prey (body only in the case of zooplankton) were measured with an ocular micrometer and converted to millimeters. Prey volume was calculated assuming that prey shape approximated a cylinder of length equal to the prey length and a diameter of prey width. A ranking based on these measurements was constructed for the various food items as follows :

| Rank | Prey | Volume ($mm^3$) |
|---|---|---|
| 1. | Semidigested matter | 0.070 |
| 2. | Fish egg | 0.065 |
| 3. | Copepod | 0.055 |
| 4. | Zoea | 0.054 |
| 5. | Megalopa | 0.053 |
| 6. | Other Decapod Larvae | 0.051 |
| 7. | Mysis | 0.050 |
| 8. | Amphipod | 0.048 |

| | | |
|---|---|---|
| 9. | Ostracod | 0.045 |
| 10. | Isopod | 0.042 |
| 11. | Cumacean | 0.040 |
| 12. | Plant material | 0.030 |
| 13. | Crustacean remains | 0.010 |
| 14. | Fish scale | 0.009 |
| 15. | Bivalve larvae | 0.007 |
| 16. | Polychaete larvae | 0.005 |
| 17. | Invertebrate eggs | 0.002 |

These volumes were multiplied by the number of the particular prey in the gut to determine its total volume. The percentage frequency of occurrence of each prey item was also calculated.

Apart from the zooplankton which were identified the remaining gut contents were classified into groups for easy comparison. In almost all the cases the gut contained partly digested food and this was classified as 'semidigested matter'. Decapod larvae other than zoea and megalopa such as the mysis stage of crustaceans were grouped as 'other decapod larvae'. 'Plant material' comprised mostly fragments of macrophytic algae, seagrasses and phytoplankton. The broken appendages of crustacean larvae, copepod and other zooplankton were grouped as 'crustacean remains'. 'Invertebrate eggs' was constituted mainly by copepod eggs which may have detached from the copepod after its ingestion by the fish.

A grading of the gut contents was made based on the 'Index of Preponderance' proposed by Natarajan and Jhingran (1961). If $v_i$ and $o_i$ are the volume and occurrence index of food item i (as indicated by their percentages) the combined index (I) for food i may be represented as :

$$I_i = \frac{v_i o_i}{E\ v_i o_i} \times 100$$

Another index that was followed is the 'Index of Relative Importance' (Pinkas et al., 1971) in which the percent volume and percent number are added up and weighted by the frequency of occurrence :

$$= (v_i + n_i)\ f_i$$

where $v_i$ is the percent volume of food i

$n_i$ is the percent number of food i

and $f_i$ is the percentage frequency of occurrence of food i.

## RESULTS

The diet of 1059 fish belonging to 11 species at Minicoy and 1031 S. delicatulus from Agatti, Bangaram and Perumal Par were analysed. All species ate a similar range of prey items, although the proportions varied considerably between species. Copepods had the highest frequency of occurrence of all prey in all species and were the major prey item by numbers in all species.

In the five months that Spratelloides delicatulus were observed in the fishery, active feeding was noticed in only two months. During April 89, a majority were in moderately fed condition while in December 88 and October 89 poorly fed conditions prevailed (Table 1). Copepod were the most important food item and the group 'other decapod larvae' and fish eggs also dominated in certain months (Table 6). Apart from an active feeding mode in January 89 in the case of S. gracilis, most of the other months had fish predominantly in a poorly fed state (Table 1). Copepods dominated the diet of S. gracilis and in its absence mysids and cumacean were found to predominate (Table 7). Higher diversity of prey was observed during December 88 with as many as 10 various food items observed in the gut.

Poor to moderate feeding prevailed in G. argenteus with active feeding of about 50% observed only in January 90 (Table 2). Copepods were again the major food item and 'other decapod larvae', mysid, amphipod and crustacean remains in the next order of importance (Table 8). C. striatus showed low to moderate feeding rates but most of the months also had 20% or higher active feeding conditions. Percentage of fishes in actively fed condition were higher in this species when compared to the other caesionids (Table 2). Copepods ranked as the number one food item in all the months followed by 'other decapod larvae' and isopod (Table 9). Fish scales were observed in higher numbers during November 88 and hence ranked only next to copepod. Pterocaesio pisang and P. chrysozona formed only a minor portion of the total live bait fishery and showed poor to moderate feeding states (Table 2). While copepods were the dominant food of P. pisang; isopod, amphipod and mysid were predominant in the diet of P. chrysozona (Tables 10 & 11).

Table 1 : Condition of feed in percentage by sprats

| Month & Year | Poorly fed | Moderately fed | Actively fed |
|---|---|---|---|
| *S. delicatulus* | | | |
| Nov 88 | - | 10.53 | 89.47 |
| Dec | 100.00 | - | - |
| Apr 89 | - | 66.67 | 33.33 |
| Sep | 12.50 | 31.25 | 56.25 |
| Oct | 50.00 | 16.67 | 33.33 |
| *S. gracilis* | | | |
| Nov 88 | 55.56 | 22.22 | 22.22 |
| Dec | 56.25 | 18.75 | 25.00 |
| Jan 89 | - | 10.00 | 90.00 |
| Dec | 3.39 | 45.76 | 50.85 |
| Feb 90 | 66.67 | 33.33 | - |
| Mar | 100.00 | - | - |
| Apr | 100.00 | - | - |

Table 2 : Condition of feed in percentage by caesionids

| Month & Year | Poorly fed | Moderately fed | Actively fed |
|---|---|---|---|
| *G. argenteus* | | | |
| Jan 89 | 50.00 | 10.00 | 40.00 |
| Feb | 50.00 | 50.00 | - |
| Mar | 100.00 | - | - |
| Nov | 27.45 | 37.26 | 35.29 |
| Dec | 70.83 | 29.17 | - |
| Jan 90 | 14.81 | 37.04 | 48.15 |
| Mar | 100.00 | - | - |
| *C. striatus* | | | |
| Nov 88 | 69.23 | - | 30.77 |
| Dec | 23.08 | 38.46 | 38.46 |
| Nov 89 | 59.38 | 25.00 | 15.62 |
| Dec | 22.22 | 44.44 | 33.34 |
| Jan 90 | 74.19 | 12.90 | 12.91 |
| Feb | 11.76 | 70.59 | 17.65 |
| Mar | 100.00 | - | - |
| *P. pisang* | | | |
| Nov 88 | 25.00 | 50.00 | 25.00 |
| Dec | 100.00 | - | - |
| Mar 89 | 80.00 | 20.00 | - |
| *P. chrysozona* | | | |
| Nov 88 | 40.00 | 60.00 | - |
| Feb 90 | 87.50 | 12.50 | - |
| Mar | 100.00 | - | - |

le 6 : The percent number (n), percentage frequency of occurrence (f), percent volume (v), Index of Preponderance (IOP) and Index of relative importance (IRI) of prey eaten by *S. delicatulus* at Minicoy. Sample size is given in parenthesis.

| d item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| ember 88 (19) | | | | | | | |
| idigested matter | 3.05 | 14.42 | 3.95 | 3.44 | III | 100.94 | III |
| h eggs | 2.30 | 7.69 | 2.77 | 1.28 | V | 38.99 | V |
| epod | 59.63 | 18.27 | 60.59 | 66.95 | I | 2196.42 | I |
| a | 2.33 | 9.62 | 2.32 | 1.50 | IV | 44.73 | IV |
| er Decapod Larvae | 29.06 | 15.38 | 27.39 | 25.48 | II | 868.20 | II |
| id | 1.09 | 7.69 | 1.00 | 0.47 | VII | 16.07 | VII |
| hipod | 1.36 | 9.62 | 1.21 | 0.70 | VI | 24.72 | VI |
| pod | 0.94 | 6.73 | 0.73 | 0.30 | VIII | 11.24 | VIII |
| stacean fragments | 0.24 | 10.58 | 0.04 | 0.03 | IX | 2.96 | IX |
| ember 88 (19) | | | | | | | |
| idigested matter | 13.51 | 6.25 | 19.13 | 8.33 | IV | 204.00 | V |
| h egg | 18.92 | 16.67 | 24.86 | 28.87 | II | 729.81 | II |
| er Decapod Larvae | 21.62 | 25.00 | 22.27 | 38.78 | I | 2097.25 | I |
| id | 10.14 | 8.33 | 10.25 | 5.94 | VI | 169.85 | VI |
| hipod | 13.51 | 10.42 | 13.11 | 9.52 | III | 277.38 | III |
| pod | 10.81 | 12.50 | 9.15 | 7.97 | V | 249.50 | IV |
| stacean fragments | 4.73 | 4.16 | 0.96 | 0.28 | VIII | 23.67 | VIII |
| ertebrate eggs | 6.76 | 16.67 | 0.27 | 0.31 | VII | 117.19 | VII |
| il 89 (19) | | | | | | | |
| h eggs | 69.26 | 26.67 | 75.25 | 82.95 | I | 3854.08 | I |
| a | 10.82 | 20.00 | 9.77 | 8.07 | II | 411.80 | II |
| alopa | 4.33 | 13.33 | 3.84 | 2.12 | V | 108.91 | V |
| hipod | 9.52 | 13.33 | 7.67 | 4.23 | III | 229.14 | III |
| racod | 5.19 | 20.00 | 3.04 | 2.51 | IV | 164.60 | IV |
| nt material | 0.88 | 6.67 | 0.43 | 0.12 | VI | 8.73 | VI |
| tember 89 (18) | | | | | | | |
| idigested matter | 3.73 | 11.84 | 5.12 | 3.38 | IV | 104.78 | V |
| matopod larvae | 0.45 | 2.63 | 0.53 | 0.08 | VII | 2.58 | IX |
| epod | 56.92 | 21.05 | 61.33 | 71.91 | I | 2489.16 | I |
| alopa | 1.49 | 7.89 | 1.55 | 0.68 | VI | 23.99 | VII |
| er Decapod Larvae | 19.02 | 14.47 | 19.00 | 15.31 | II | 550.15 | II |
| hipod | 7.91 | 13.16 | 7.44 | 5.45 | III | 202.00 | III |
| racod | 6.79 | 11.84 | 4.66 | 3.07 | V | 135.57 | IV |
| ychaete | 0.56 | 3.95 | 0.22 | 0.05 | IX | 3.08 | VIII |
| tropod larvae | 0.30 | 3.95 | 0.04 | 0.01 | X | 1.34 | X |
| ertebrate eggs | 2.83 | 9.22 | 0.11 | 0.06 | VIII | 27.11 | VI |
| ober 89 (18) | | | | | | | |
| idigested matter | 3.61 | 18.46 | 5.15 | 4.03 | IV | 161.71 | IV |
| h eggs | 1.64 | 4.62 | 2.18 | 0.43 | VI | 17.65 | VI |
| epod | 49.25 | 27.69 | 55.29 | 64.87 | I | 2894.71 | I |
| id | 1.64 | 6.15 | 1.68 | 0.44 | V | 20.42 | V |
| pod | 17.05 | 18.46 | 14.62 | 11.44 | III | 584.63 | III |
| acean | 25.18 | 21.54 | 20.56 | 18.77 | II | 985.24 | II |
| ychaete | 0.98 | 1.54 | 0.40 | 0.03 | VII | 2.13 | VII |
| h scale | 0.65 | 1.54 | 0.12 | 0.01 | VIII | 1.19 | VIII |

Table 7 : The percent number (n), percentage frequency of occurrence (f), percent volume (v), Index of Preponderance (IOP) and Index of Relative Importance (IRI) of prey eaten by S. gracilis at Minicoy. Sample size is given in parenthesis.

| od item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| ovember 88 (11) | | | | | | | |
| emidigested matter | 8.09 | 18.53 | 10.99 | 7.96 | IV | 353.55 | IV |
| opepod | 44.53 | 33.33 | 47.53 | 61.93 | I | 3068.36 | I |
| ther Decapod Larvae | 22.67 | 22.22 | 22.47 | 19.52 | II | 1003.01 | II |
| sopod | 19.83 | 14.81 | 16.18 | 9.37 | III | 533.31 | III |
| lant material | 4.87 | 11.11 | 2.83 | 1.23 | V | 85.55 | V |
| ecember 88 (19) | | | | | | | |
| emidigested matter | 6.10 | 13.73 | 8.80 | 4.57 | II | 204.58 | II |
| opepod | 67.52 | 31.37 | 76.55 | 90.80 | I | 4519.48 | I |
| oea | 2.33 | 1.96 | 2.58 | 0.19 | V | 9.62 | VII |
| ther Decapod Larvae | 0.55 | 5.88 | 0.59 | 0.13 | VII | 6.70 | VIII |
| mphipod | 6.65 | 11.76 | 6.58 | 2.93 | III | 155.58 | III |
| ladoceran | 5.32 | 7.84 | 3.52 | 1.04 | IV | 69.31 | V |
| rustacean fragments | 4.00 | 5.88 | 0.82 | 0.18 | VI | 28.34 | VI |
| ish scale | 1.11 | 3.92 | 0.21 | 0.03 | IX | 5.17 | X |
| ivalve larvae | 1.32 | 3.92 | 0.14 | 0.02 | X | 5.72 | IX |
| nvertebrate eggs | 5.10 | 13.74 | 0.21 | 0.10 | VIII | 72.96 | IV |
| anuary 89 (20) | | | | | | | |
| emidigested matter | 1.90 | 9.30 | 2.84 | 1.52 | V | 44.08 | VII |
| opepod | 50.57 | 20.93 | 59.51 | 71.80 | I | 2303.97 | I |
| ysid | 11.29 | 13.95 | 12.08 | 9.71 | III | 326.01 | III |
| mphipod | 17.02 | 11.63 | 17.48 | 11.72 | II | 401.24 | II |
| ladoceran | 8.34 | 11.63 | 5.73 | 3.84 | IV | 163.63 | IV |
| olychaete | 3.62 | 10.47 | 1.55 | 0.94 | VI | 54.13 | VI |
| rustacean fragments | 2.95 | 9.30 | 0.63 | 0.34 | VII | 33.29 | VIII |
| nvertebrate eggs | 4.31 | 12.80 | 0.18 | 0.13 | VIII | 57.47 | V |
| ecember 89 (62) | | | | | | | |
| emidigested matter | 2.96 | 7.86 | 4.24 | 1.94 | VI | 56.59 | VI |
| opepod | 35.32 | 21.07 | 39.76 | 48.88 | I | 1581.94 | I |
| ther Decapod Larvae | 27.38 | 17.14 | 28.59 | 28.59 | II | 959.33 | II |
| mphipod | 12.01 | 14.29 | 11.81 | 9.85 | III | 340.39 | III |
| sopod | 9.57 | 13.21 | 8.23 | 6.34 | IV | 235.14 | IV |
| umacean | 5.64 | 10.71 | 4.62 | 2.89 | V | 109.88 | V |
| stracod | 3.66 | 10.00 | 2.62 | 1.53 | VII | 6.28 | VIII |
| nvertebrate eggs | 3.46 | 5.72 | 0.13 | 0.04 | VIII | 20.53 | VII |

Continued...

le 7 : Continued...

| d item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| <u>ruary 90 (7)</u> | | | | | | | |
| midigested matter | 10.42 | 10.00 | 14.23 | 6.51 | IV | 246.50 | IV |
| sh egg | 7.81 | 15.00 | 9.86 | 6.78 | III | 265.05 | III |
| pepod | 46.88 | 30.00 | 50.30 | 69.05 | I | 2915.40 | I |
| her Decapod Larvae | 7.81 | 10.00 | 7.83 | 3.58 | V | 156.40 | V |
| sid | 14.58 | 20.00 | 14.23 | 13.02 | II | 576.20 | II |
| ant material | 4.17 | 5.00 | 2.43 | 0.56 | VI | 33.00 | VII |
| stropod larvae | 8.33 | 10.00 | 1.12 | 0.51 | VII | 94.50 | VI |
| <u>rch 90 (54)</u> | | | | | | | |
| midigested matter | 8.74 | 12.90 | 14.56 | 11.65 | IV | 300.57 | IV |
| sid | 19.67 | 22.58 | 23.41 | 32.78 | I | 972.75 | I |
| phipod | 17.49 | 19.35 | 20.02 | 24.02 | II | 725.82 | II |
| opod | 8.20 | 16.13 | 8.19 | 8.19 | V | 264.37 | VI |
| macean | 14.21 | 9.68 | 13.52 | 8.12 | VI | 268.43 | V |
| tracod | 21.31 | 12.90 | 17.82 | 14.25 | III | 504.78 | III |
| stacean fragments | 10.38 | 6.46 | 2.48 | 0.99 | VII | 83.08 | VII |
| <u>ril 90 (30)</u> | | | | | | | |
| macean | 31.43 | 23.53 | 40.74 | 50.07 | I | 1698.16 | I |
| tracod | 14.29 | 11.76 | 16.20 | 9.95 | III | 358.56 | IV |
| adoceran | 27.14 | 17.65 | 28.24 | 26.04 | II | 977.46 | II |
| ant material | 8.57 | 11.76 | 8.33 | 5.12 | V | 198.74 | V |
| lychaete | 1.43 | 5.88 | 0.93 | 0.28 | VI | 13.88 | VI |
| rustacean fragments | 17.14 | 29.42 | 5.56 | 8.53 | IV | 667.83 | III |

e 8: The percent number (n), percentage frequency of occurrence (f), percent volume volume (v), Index of Preponderance (IOP) and Index of Relative Importance (IRI) of prey eaten by <u>*G. argenteus*</u> at Minicoy. Sample size is given in parenthesis.

| item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| <u>ary 89 (10)</u> | | | | | | | |
| digested matter | 8.39 | 11.36 | 11.36 | 6.56 | III | 229.70 | III |
| pod | 62.44 | 23.25 | 66.42 | 76.72 | I | 2996.00 | I |
| | 0.49 | 2.33 | 0.51 | 0.06 | VII | 2.33 | VII |
| d | 12.20 | 13.95 | 11.79 | 8.17 | II | 334.66 | II |
| ipod | 4.88 | 16.28 | 4.53 | 3.66 | V | 153.19 | V |
| oceran | 7.61 | 18.60 | 4.72 | 4.36 | IV | 229.34 | IV |
| scale | 4.00 | 13.96 | 0.67 | 0.46 | VI | 65.19 | VI |
| <u>uary 89 (20)</u> | | | | | | | |
| digested matter | 9.63 | 13.89 | 21.21 | 14.72 | II | 428.37 | III |
| pod | 38.50 | 22.22 | 66.67 | 74.03 | I | 2336.88 | I |
| tacean fragments | 21.39 | 22.22 | 6.73 | 7.47 | III | 624.83 | II |
| scale | 13.10 | 15.28 | 3.70 | 2.83 | IV | 256.74 | IV |
| lve larvae | 5.88 | 11.11 | 0.93 | 0.52 | V | 77.66 | VI |
| chaete larvae | 1.07 | 2.78 | 0.08 | 0.01 | VII | 3.20 | VII |
| rtebrate eggs | 10.43 | 2.50 | 0.68 | 0.42 | VI | 138.88 | V |
| <u>l 89 (12)</u> | | | | | | | |
| ligested matter | 18.10 | 12.50 | 30.91 | 23.28 | II | 612.63 | III |
| itopod larvae | 2.71 | 6.25 | 3.97 | 1.50 | VII | 41.75 | VII |
| r Decapod larvae | 32.58 | 21.88 | 40.51 | 53.42 | I | 1599.21 | I |
| ean | 5.43 | 15.63 | 5.30 | 5.00 | V | 167.71 | V |
| icod | 7.24 | 9.37 | 6.18 | 3.49 | VI | 125.75 | VI |
| iceran | 9.05 | 12.50 | 7.06 | 5.32 | IV | 201.38 | IV |
| acean fragments | 24.89 | 21.87 | 6.07 | 8.00 | III | 677.10 | II |
| <u>ber 89 (56)</u> | | | | | | | |
| ligested matter | 3.44 | 11.76 | 4.72 | 2.31 | III | 95.96 | III |
| od | 64.19 | 30.00 | 69.24 | 86.30 | I | 4002.90 | I |
| Decapod Larvae | 9.57 | 16.47 | 9.58 | 6.55 | II | 315.40 | II |
| | 6.44 | 7.06 | 6.32 | 1.85 | IV | 90.09 | IV |
| d | 7.35 | 5.88 | 6.06 | 1.48 | V | 78.85 | V |
| cod | 5.35 | 8.24 | 3.68 | 1.26 | VI | 74.41 | VI |
| scale | 1.99 | 17.65 | 0.33 | 0.24 | VII | 39.54 | VII |
| tebrate eggs | 1.75 | 2.94 | 0.07 | 0.01 | VIII | 5.35 | VIII |

Continued...

able 8 : Continued...

| ood item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| ecember 89 (31) | | | | | | | |
| emidigested matter | 8.84 | 16.67 | 14.05 | 9.72 | II | 381.58 | II |
| opepod | 45.92 | 31.94 | 57.37 | 76.06 | I | 3299.08 | I |
| mphipod | 14.97 | 11.11 | 16.29 | 7.51 | III | 347.30 | III |
| ladoceran | 10.88 | 13.89 | 7.88 | 4.54 | IV | 260.58 | IV |
| olychaete | 4.08 | 9.72 | 1.85 | 0.75 | VI | 57.64 | VI |
| ish scale | 7.14 | 8.33 | 1.47 | 0.51 | VII | 71.72 | V |
| astropod larvae | 2.72 | 4.17 | 0.46 | 0.80 | V | 13.26 | VIII |
| ivalve larvae | 5.45 | 14.17 | 0.63 | 0.11 | VIII | 25.35 | VII |
| anuary 90 (30) | | | | | | | |
| emidigested matter | 9.66 | 11.22 | 12.36 | 5.83 | II | 247.06 | II |
| ish egg | 3.05 | 9.18 | 3.62 | 1.40 | III | 61.23 | V |
| pepod | 76.43 | 27.55 | 76.86 | 88.98 | I | 4223.14 | I |
| phipod | 2.48 | 15.31 | 2.17 | 1.40 | IV | 71.19 | III |
| opod | 2.86 | 12.24 | 2.20 | 1.13 | VI | 61.93 | IV |
| macean | 3.30 | 10.20 | 2.42 | 1.04 | VII | 58.34 | VI |
| ish scale | 2.22 | 14.30 | 0.37 | 0.22 | V | 37.04 | VII |
| rch 90 (16) | | | | | | | |
| midigested matter | 11.82 | 12.70 | 17.99 | 13.44 | III | 378.59 | III |
| pepod | 37.16 | 22.22 | 44.42 | 58.04 | I | 1812.71 | I |
| her Decapod Larvae | 15.20 | 15.87 | 16.89 | 15.76 | II | 509.27 | II |
| sid | 8.78 | 11.11 | 9.54 | 6.23 | IV | 203.54 | IV |
| opod | 6.08 | 9.52 | 5.58 | 3.12 | V | 111.00 | VI |
| tracod | 4.05 | 7.94 | 3.08 | 1.44 | VII | 56.61 | VII |
| ustacean fragments | 10.14 | 14.29 | 2.20 | 1.85 | VI | 176.34 | V |
| vertebrate eggs | 6.77 | 6.35 | 0.30 | 0.11 | VIII | 44.89 | VIII |

Table 9: The percent number (n), percentage frequency of occurrence (f), percent volume (v), Index of Preponderance (IOP) and Index of Relative Importance (IRI) of prey eaten by <u>C. striatus</u> at Minicoy. Sample size is given in parenthesis.

| Food item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| <u>November 88 (13)</u> | | | | | | | |
| Semidigested matter | 14.81 | 10.00 | 22.75 | 11.43 | II | 375.60 | III |
| Copepod | 39.51 | 30.00 | 47.66 | 71.81 | I | 2615.10 | I |
| Zoea | 12.35 | 10.00 | 14.62 | 7.34 | III | 269.70 | IV |
| Mysid | 9.88 | 10.00 | 10.83 | 5.44 | IV | 207.10 | V |
| Fish scale | 19.75 | 20.00 | 3.79 | 3.81 | V | 470.80 | II |
| Gastropod larvae | 2.47 | 10.00 | 0.27 | 0.14 | VI | 27.40 | VI |
| Polychaete larvae | 1.23 | 10.00 | 0.08 | 0.04 | VII | 13.10 | VII |
| <u>December 88 (16)</u> | | | | | | | |
| Semidigested matter | 12.46 | 9.09 | 16.77 | 8.45 | III | 265.70 | III |
| Copepod | 53.63 | 22.73 | 56.74 | 71.51 | I | 2508.71 | I |
| Zoea | 2.60 | 4.54 | 2.70 | 0.68 | VI | 24.06 | VII |
| Other Decapod Larvae | 11.25 | 18.18 | 11.05 | 11.14 | II | 405.41 | II |
| Amphipod | 7.61 | 13.64 | 7.02 | 5.31 | IV | 199.55 | IV |
| Cladoceran | 8.48 | 9.09 | 5.22 | 2.63 | V | 124.53 | V |
| Polychaete | 1.04 | 9.09 | 0.40 | 0.20 | VII | 13.09 | VIII |
| Invertebrate eggs | 2.93 | 13.64 | 0.10 | 0.08 | VIII | 41.33 | VI |
| <u>November 89 (38)</u> | | | | | | | |
| Semidigested matter | 14.25 | 13.28 | 19.48 | 14.35 | IV | 447.93 | IV |
| Copepod | 24.07 | 25.00 | 25.88 | 35.89 | I | 1248.75 | I |
| Other Decapod Larvae | 17.81 | 23.44 | 17.76 | 23.09 | II | 833.76 | II |
| Mysid | 15.67 | 11.72 | 15.31 | 9.95 | V | 363.09 | V |
| Amphipod | 21.79 | 14.06 | 20.43 | 15.93 | III | 593.61 | III |
| Fish scale | 6.41 | 12.50 | 1.14 | 0.79 | VI | 94.38 | VI |
| <u>December 89 (43)</u> | | | | | | | |
| Semidigested matter | 13.62 | 11.11 | 22.07 | 13.21 | II | 396.52 | II |
| Copepod | 38.18 | 24.44 | 48.64 | 64.06 | I | 2121.88 | I |
| Cumacean | 10.68 | 19.26 | 9.89 | 10.27 | III | 396.18 | III |
| Ostracod | 10.41 | 8.89 | 8.45 | 4.04 | V | 167.58 | VI |
| Cladoceran | 9.22 | 14.81 | 6.83 | 5.45 | IV | 237.55 | V |
| Crustacean fragments | 15.89 | 14.07 | 3.68 | 2.80 | VI | 275.35 | IV |
| Fish scale | 2.00 | 7.42 | 0.42 | 0.17 | VII | 18.01 | VII |

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ble 9 : Continued...

| od item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| nuary 90 (37) | | | | | | | |
| idigested matter | 7.25 | 11.01 | 9.74 | 5.60 | III | 187.06 | IV |
| pepod | 47.29 | 28.44 | 49.90 | 74.16 | I | 2764.08 | I |
| ea | 11.22 | 3.67 | 11.63 | 2.23 | VII | 83.86 | VII |
| her Decapod Larvae | 12.74 | 11.01 | 12.46 | 7.17 | II | 277.45 | II |
| sid | 5.42 | 9.17 | 5.20 | 2.49 | VI | 97.39 | VI |
| phipod | 6.87 | 13.76 | 6.33 | 4.55 | IV | 181.63 | V |
| adoceran | 7.44 | 15.60 | 4.57 | 3.73 | V | 187.36 | III |
| valve larvae | 1.77 | 7.34 | 0.17 | 0.07 | VIII | 14.17 | VIII |
| bruary 90 (17) | | | | | | | |
| idigested matter | 8.68 | 6.45 | 13.56 | 5.02 | IV | 143.45 | V |
| pepod | 36.79 | 22.58 | 45.18 | 58.60 | I | 1850.88 | I |
| her Decapod Larvae | 16.98 | 19.35 | 19.33 | 21.49 | II | 702.60 | II |
| opod | 10.38 | 12.90 | 9.73 | 7.21 | III | 259.42 | III |
| tracod | 11.32 | 9.68 | 8.84 | 4.92 | V | 195.15 | IV |
| ustacean fragments | 8.49 | 12.90 | 1.89 | 1.40 | VI | 133.90 | VII |
| sh scale | 7.36 | 16.14 | 1.47 | 1.36 | VII | 142.43 | VI |
| rch 90 (16) | | | | | | | |
| idigested matter | 9.41 | 10.53 | 15.63 | 8.03 | III | 263.67 | IV |
| pepod | 41.18 | 26.32 | 53.77 | 69.04 | I | 2499.08 | I |
| opod | 21.96 | 15.79 | 21.86 | 16.84 | II | 691.92 | II |
| tracod | 4.71 | 10.53 | 3.91 | 2.01 | V | 90.77 | V |
| lychaete | 2.75 | 10.53 | 1.30 | 0.67 | VI | 42.65 | VI |
| istacean fragments | 13.73 | 21.05 | 3.26 | 3.35 | IV | 357.64 | III |
| ertebrate eggs | 6.26 | 5.26 | 0.28 | 0.07 | VII | 34.45 | VII |

ble 10: The percent number (n), percentage frequency of occurrence (f), percent volume (v), Index of Preponderance (IOP) and Index of Relative Importance (IRI) of prey taken by *P. pisang* at Minicoy. Sample size is shown in parenthesis.

| ood item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| ovember 88 (10) | | | | | | | |
| emidigested matter | 4.78 | 9.10 | 7.65 | 4.55 | V | 112.99 | VI |
| ish egg | 7.42 | 11.36 | 10.98 | 8.16 | III | 209.02 | IV |
| opepod | 33.49 | 18.18 | 42.05 | 50.01 | I | 1373.32 | I |
| oea | 7.18 | 11.36 | 8.85 | 6.58 | IV | 182.10 | V |
| ther Decapod Larvae | 22.25 | 15.91 | 25.89 | 26.93 | II | 765.43 | II |
| rustacean fragments | 16.51 | 13.63 | 3.77 | 3.36 | VI | 276.42 | III |
| ish scale | 0.96 | 6.82 | 0.22 | 0.09 | VIII | 8.04 | IX |
| ivalve larvae | 3.83 | 9.10 | 0.44 | 0.26 | VII | 38.81 | VII |
| nvertebrate eggs | 3.59 | 4.54 | 0.16 | 0.05 | IX | 17.03 | VIII |
| ecember 88 (25) | | | | | | | |
| emidigested matter | 9.09 | 16.13 | 13.27 | 8.59 | II | 360.67 | II |
| opepod | 53.79 | 32.26 | 61.77 | 79.98 | I | 3727.97 | I |
| mphipod | 11.36 | 12.90 | 11.37 | 5.89 | III | 293.22 | III |
| umacean | 12.12 | 9.68 | 10.11 | 3.93 | IV | 215.19 | IV |
| olychaete | 4.55 | 6.45 | 1.90 | 0.49 | VI | 41.60 | VI |
| ish scale | 7.58 | 19.35 | 1.42 | 1.10 | V | 174.15 | V |
| ivalve larvae | 1.51 | 3.23 | 0.16 | 0.02 | VII | 5.39 | VII |
| arch 89 (11) | | | | | | | |
| emidigested matter | 7.89 | 11.76 | 11.45 | 6.72 | III | 227.44 | III |
| opepod | 43.86 | 29.43 | 50.00 | 73.39 | I | 2762.30 | I |
| ther Decapod Larvae | 4.39 | 11.76 | 4.73 | 2.77 | V | 107.25 | VI |
| ysid | 12.28 | 5.88 | 12.73 | 3.73 | IV | 147.06 | IV |
| mphipod | 11.40 | 17.65 | 11.27 | 9.92 | II | 400.13 | II |
| sopod | 8.77 | 5.88 | 7.64 | 2.24 | VI | 96.49 | VII |
| rustacean fragments | 9.65 | 11.76 | 2.00 | 1.17 | VII | 137.00 | V |
| astropod larvae | 1.76 | 5.88 | 0.18 | 0.06 | VIII | 11.41 | VIII |

ble 11: Percent number (n), percentage frequency of occurrence (f), percent volume (v), Index of Preponderance (IOP) and Index of Relative Importance (IRI) of *P. chrysozona* at Minicoy. Number of fish examined is given in parenthesis.

| od item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| vember 88 (14) | | | | | | | |
| emidigested matter | 7.66 | 7.69 | 15.95 | 10.01 | V | 181.56 | V |
| opepod | 9.36 | 11.54 | 15.32 | 14.44 | IV | 284.81 | IV |
| ysid | 12.77 | 13.46 | 18.99 | 20.09 | III | 427.49 | III |
| sopod | 16.17 | 15.38 | 20.13 | 25.28 | I | 558.29 | I |
| stracod | 19.57 | 13.46 | 20.38 | 22.40 | II | 537.72 | II |
| olychaete | 5.11 | 11.54 | 3.03 | 2.85 | VI | 93.94 | VII |
| rustacean fragments | 11.06 | 9.62 | 3.29 | 2.58 | VII | 138.05 | VI |
| ish scale | 6.38 | 7.69 | 1.77 | 1.11 | VIII | 62.67 | VIII |
| astropod larvae | 3.40 | 3.85 | 0.63 | 0.19 | X | 15.52 | X |
| nvertebrate eggs | 8.52 | 5.77 | 0.51 | 0.24 | IX | 52.10 | IX |
| ebruary 90 (12) | | | | | | | |
| emidigested matter | 12.09 | 8.82 | 23.39 | 13.19 | IV | 312.93 | V |
| mphipod | 21.77 | 23.53 | 28.73 | 43.24 | I | 1188.27 | I |
| umacean | 16.13 | 11.76 | 17.82 | 13.40 | III | 399.25 | IV |
| stracod | 16.94 | 14.71 | 16.48 | 15.50 | II | 491.61 | III |
| olychaete | 19.35 | 17.65 | 10.69 | 12.07 | V | 530.21 | II |
| ish scale | 8.87 | 17.65 | 2.00 | 2.26 | VI | 191.86 | VI |
| astropod larvae | 4.85 | 5.88 | 0.89 | 0.33 | VII | 33.75 | VII |
| arch 90 (12) | | | | | | | |
| emidigested matter | 10.79 | 10.00 | 18.36 | 11.67 | IV | 291.50 | V |
| ysid | 25.18 | 20.00 | 30.59 | 38.88 | I | 1115.40 | I |
| sopod | 23.02 | 10.00 | 23.43 | 14.89 | III | 464.50 | III |
| stracod | 20.86 | 20.00 | 17.83 | 22.66 | II | 773.80 | II |
| ladoceran | 11.51 | 20.00 | 8.92 | 11.34 | V | 408.60 | IV |
| ivalve larvae | 5.76 | 10.00 | 0.70 | 0.44 | VI | 64.60 | VI |
| olychaete larvae | 2.88 | 10.00 | 0.17 | 0.12 | VII | 30.50 | VII |

Chromis caeruleus showed poor to moderate feeding with actively fed condition only in November 88 (Table 3). Copepod, 'other decapod larvae' and mysid were the chief food items with polychaete, bivalve and gastropod larvae and fish scale in minor percentages (Table 12). With the exception of moderate to high feeding in November 89, Lepidozygus tapeinosoma also showed poor to moderately fed conditions (Table 3). Amphipod, 'other decapod larvae', copepod and ostracod were the dominant prey (Table 13). fish scale and plant material were observed during most of the months in the gut.

There was an almost complete absence of actively fed guts in the case of the three Apogonids studied (Table 4). Only Rhabdamia gracilis had actively fed gut in low percentage during February 90. While R. gracilis showed copepod as the major food item, 'other decapod larvae', mysid, amphipod and zoea ranked high in the case of Archamia fucata and Apogon thermalis (Tables 14, 15 & 16).

S. delicatulus at Agatti and Bangaram showed similar feeding conditions ranging from poor to moderate with only certain months in actively fed condition (Table 5). At Perumal Par active feeding varying from 15 to 65% was observed in almost all the months. Copepod, 'other decapod larvae' and amphipod formed the major prey at Agatti (Table 17) while copepod, cumacean, fish eggs, mysid and 'other decapod larvae' were the

Table 3 : Condition of feed in percentage by pomacentrids

| nth & Year | Poorly fed | Moderately fed | Actively fed |
|---|---|---|---|
| *caeruleus* | | | |
| Nov 88 | 20.00 | 20.00 | 60.00 |
| Dec | 57.14 | 42.86 | - |
| Feb 89 | 72.73 | 27.27 | - |
| Feb 90 | 81.82 | 9.09 | 9.09 |
| *tapeinosoma* | | | |
| Nov 89 | - | 50.00 | 50.00 |
| Dec | 42.86 | 57.14 | - |
| Jan 90 | 23.08 | 53.85 | 23.07 |
| Feb | 84.62 | 15.38 | - |

Table 4 : Condition of feed in percentage by apogonids

| Month & Year | Poorly fed | Moderately fed | Actively fed |
|---|---|---|---|
| *A. fucata* | | | |
| Mar 89 | 38.89 | 61.11 | - |
| Feb 90 | 37.50 | 62.50 | - |
| Apr | 100.00 | - | - |
| *A. thermalis* | | | |
| Jan 90 | 80.00 | 20.00 | - |
| Feb | 83.33 | 16.67 | - |
| Mar | 43.75 | 56.25 | - |
| Apr | 54.17 | 45.83 | - |
| *R. gracilis* | | | |
| Mar 89 | 100.00 | - | - |
| Feb 90 | 60.00 | 24.00 | 16.00 |

Table 5 : Condition of feed in percentage by <u>S. delicatulus</u> at Agatti, Bangaram and Perumal Par.

| Month & Year | Poorly fed | Moderately fed | Actively fed |
|---|---|---|---|
| **Agatti** | | | |
| Dec 88 | 13.79 | 20.69 | 65.52 |
| Feb 89 | 29.41 | 35.29 | 35.30 |
| Mar | 95.65 | 4.35 | - |
| Nov | 100.00 | - | - |
| **Bangaram** | | | |
| Nov 88 | 37.04 | 7.40 | 55.56 |
| Jan 89 | 37.25 | 25.49 | 37.26 |
| Feb | 3.51 | 7.02 | 89.47 |
| Mar | 83.33 | 16.67 | - |
| Oct | 80.00 | 20.00 | - |
| Nov | 72.73 | 27.27 | - |
| Dec | 50.00 | 50.00 | - |
| Jan 90 | 14.29 | 39.29 | 46.42 |
| Feb | 50.00 | 31.82 | 18.18 |
| **Perumal Par** | | | |
| Nov 88 | 42.86 | 12.24 | 44.90 |
| Dec | 50.00 | 35.00 | 15.00 |
| Jan 89 | 29.27 | 46.34 | 24.39 |
| Feb | 29.26 | 4.88 | 65.85 |
| Mar | 64.86 | 13.51 | 21.62 |
| Oct | 50.00 | 20.00 | 30.00 |
| Nov | 31.58 | 21.05 | 47.37 |
| Dec | 35.29 | 29.41 | 35.30 |
| Jan 90 | 80.00 | 20.00 | - |
| Feb | 54.55 | 27.27 | 18.18 |

able 12: Percent number (n), percentage frequency of occurrence (f), percent volume (v), Index of Preponderance (IOP) and Index of Relative Importance (IRI) of <u>C. caeruleus</u> at Minicoy. Sample size is indicated in parenthesis.

| ood item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| <u>ovember 88 (15)</u> | | | | | | | |
| emidigested matter | 10.85 | 10.53 | 16.48 | 10.07 | III | 287.78 | IV |
| opepod | 32.54 | 26.31 | 38.89 | 59.36 | I | 1879.32 | I |
| ysid | 11.90 | 15.79 | 12.92 | 11.84 | II | 391.91 | III |
| sopod | 13.73 | 5.26 | 12.52 | 3.82 | VI | 138.23 | VI |
| stracod | 8.73 | 10.53 | 6.66 | 4.07 | V | 162.06 | V |
| lant material | 16.40 | 15.49 | 10.68 | 9.78 | IV | 427.59 | II |
| olychaete | 3.70 | 10.53 | 1.61 | 0.98 | VII | 55.91 | VII |
| ivalve larvae | 2.12 | 5.26 | 0.24 | 0.08 | VIII | 12.41 | VIII |
| <u>ecember 88 (14)</u> | | | | | | | |
| emidigested matter | 12.12 | 6.67 | 22.22 | 6.12 | III | 229.05 | V |
| opepod | 37.88 | 33.33 | 54.76 | 74.32 | I | 3087.69 | I |
| ysid | 13.64 | 20.00 | 17.86 | 14.74 | II | 630.00 | II |
| rustacean fragments | 15.15 | 20.00 | 3.97 | 3.28 | IV | 382.40 | III |
| astropod larvae | 3.03 | 6.67 | 0.40 | 0.11 | VI | 3.88 | VI |
| nvertebrate eggs | 18.18 | 13.33 | 0.79 | 0.43 | V | 252.87 | IV |
| <u>ebruary 89 (11)</u> | | | | | | | |
| emidigested matter | 8.46 | 18.18 | 13.58 | 9.69 | II | 400.69 | III |
| ish egg | 3.08 | 6.06 | 4.59 | 1.09 | V | 46.48 | VI |
| opepod | 46.54 | 33.33 | 58.73 | 76.85 | I | 3508.65 | I |
| stracod | 16.15 | 15.15 | 12.96 | 7.71 | III | 441.02 | II |
| lant material | 13.46 | 12.13 | 9.26 | 4.41 | IV | 275.59 | IV |
| ish scale | 1.54 | 9.09 | 0.35 | 0.12 | VII | 17.18 | VII |
| nvertebrate eggs | 10.77 | 6.06 | 0.53 | 0.13 | VI | 68.18 | V |
| <u>ebruary 90 (27)</u> | | | | | | | |
| emidigested matter | 7.15 | 9.60 | 10.91 | 7.04 | V | 173.38 | V |
| opepod | 23.05 | 16.00 | 27.65 | 29.73 | II | 811.20 | II |
| ther Decapod Larvae | 26.87 | 17.60 | 29.87 | 35.33 | I | 998.62 | I |
| mphipod | 11.13 | 14.40 | 11.64 | 11.27 | III | 327.89 | III |
| stracod | 7.79 | 10.40 | 5.44 | 3.80 | VI | 127.59 | VI |
| ladoceran | 5.56 | 8.80 | 3.88 | 2.29 | VII | 83.07 | VII |
| lant material | 15.26 | 15.20 | 9.98 | 10.20 | IV | 303.65 | IV |
| ish scale | 3.13 | 8.00 | 0.62 | 0.33 | VIII | 30.48 | VIII |

Table 13: Percent number (n), percentage frequency of occurrence (f), percent volume (v), Index of Preponderance (IOP), and Index of Relative Importance (IRI) of Lepidozygous tapeinosoma at Minicoy. Sample size is indicated in parenthesis.

| Food item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| November 89 (12) | | | | | | | |
| Semidigested matter | 13.27 | 12.50 | 19.03 | 13.41 | III | 403.75 | III |
| Copepod | 31.46 | 25.00 | 35.48 | 50.00 | I | 1678.50 | I |
| Other Decapod Larvae | 10.20 | 12.50 | 10.67 | 7.52 | V | 260.88 | V |
| Amphipod | 16.16 | 12.50 | 15.89 | 11.20 | IV | 400.63 | IV |
| Ostracod | 18.37 | 18.75 | 13.18 | 10.93 | II | 591.56 | II |
| Plant material | 8.84 | 12.50 | 5.44 | 3.83 | VI | 178.50 | VI |
| Fish scale | 1.70 | 6.25 | 0.31 | 0.11 | VII | 12.56 | VII |
| December 89 (24) | | | | | | | |
| Semidigested matter | 9.59 | 8.04 | 16.03 | 8.30 | V | 209.98 | V |
| Copepod | 34.89 | 18.75 | 45.79 | 55.30 | I | 1511.81 | I |
| Amphipod | 10.36 | 16.96 | 11.88 | 12.95 | II | 377.19 | III |
| Cumacean | 12.31 | 13.39 | 11.76 | 10.14 | IV | 322.30 | IV |
| Plant material | 14.12 | 16.07 | 10.12 | 10.47 | III | 389.54 | II |
| Polychaete | 6.22 | 10.71 | 2.97 | 2.05 | VI | 98.42 | VI |
| Fish scale | 5.05 | 8.93 | 1.08 | 0.62 | VII | 54.74 | VIII |
| Invertebrate eggs | 7.51 | 7.15 | 0.37 | 0.17 | VIII | 56.34 | VII |
| January 90 (16) | | | | | | | |
| Semidigested matter | 6.65 | 13.33 | 10.58 | 7.53 | IV | 229.68 | V |
| Fish egg | 3.91 | 5.00 | 5.78 | 1.54 | VI | 48.45 | VI |
| Copepod | 47.59 | 21.67 | 59.47 | 68.83 | I | 2319.99 | I |
| Other Decapod Larvae | 10.43 | 18.33 | 12.09 | 11.84 | II | 412.79 | II |
| Plant material | 12.65 | 16.67 | 8.63 | 7.68 | III | 354.74 | III |
| Crustacean fragments | 13.56 | 15.00 | 3.08 | 2.47 | V | 249.60 | IV |
| Fish scale | 0.65 | 3.34 | 0.15 | 0.03 | VIII | 2.67 | VIII |
| Invertebrate eggs | 4.56 | 6.66 | 0.22 | 0.08 | VII | 31.83 | VII |
| February 90 (19) | | | | | | | |
| Semidigested matter | 7.21 | 8.70 | 10.91 | 5.07 | V | 157.64 | V |
| Copepod | 27.88 | 26.09 | 33.16 | 46.23 | I | 1592.53 | I |
| Other Decapod Larvae | 18.75 | 21.73 | 20.69 | 24.02 | II | 857.03 | II |
| Amphipod | 20.19 | 13.04 | 20.99 | 14.63 | III | 536.99 | III |
| Ostracod | 8.65 | 8.70 | 6.55 | 3.05 | VI | 132.24 | VI |
| Plant material | 11.54 | 17.40 | 7.48 | 6.95 | IV | 330.95 | IV |
| Invertebrate eggs | 5.78 | 4.34 | 0.22 | 0.05 | VII | 26.04 | VII |

Table 14: The percent number (n), percentage frequency of occurrence (f), percent volume, Index of Preponderance (IOP) and Index of Relative Importance (IRI) of diet of *A. fucata* at Minicoy. Sample size is given in parenthesis.

| Food item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| March 89 (18) | | | | | | | |
| Semidigested matter | 7.95 | 9.09 | 11.15 | 6.78 | VI | 173.62 | VI |
| Copepod | 13.76 | 12.12 | 15.20 | 12.32 | IV | 350.99 | IV |
| Zoea | 15.90 | 15.15 | 17.22 | 17.45 | III | 501.77 | III |
| Other Decapod Larvae | 19.57 | 24.24 | 19.98 | 32.40 | I | 958.69 | I |
| Mysid | 14.68 | 18.18 | 14.71 | 17.89 | II | 534.31 | II |
| Amphipod | 11.93 | 12.12 | 11.46 | 9.29 | V | 283.49 | V |
| Ostracod | 12.54 | 6.06 | 8.82 | 3.58 | VII | 129.44 | VII |
| Polychaete | 3.67 | 3.04 | 1.47 | 0.30 | VIII | 15.63 | VIII |
| February 90 (10) | | | | | | | |
| Semidigested matter | 7.78 | 9.68 | 14.55 | 7.37 | III | 216.15 | V |
| Other Decapod Larvae | 32.68 | 25.81 | 44.49 | 60.06 | I | 1991.76 | I |
| Mysid | 13.23 | 19.35 | 17.67 | 17.88 | II | 597.92 | II |
| Isopod | 8.56 | 12.90 | 9.56 | 6.45 | IV | 233.75 | IV |
| Cladoceran | 10.51 | 9.68 | 8.94 | 4.53 | V | 188.28 | VI |
| Crustacean fragments | 15.56 | 16.13 | 4.16 | 3.51 | VI | 318.08 | III |
| Invertebrate eggs | 11.68 | 6.45 | 0.63 | 0.20 | VII | 79.40 | VII |
| April 90 (24) | | | | | | | |
| Semidigested matter | 9.24 | 12.50 | 15.30 | 10.35 | III | 306.75 | V |
| Other Decapod Larvae | 30.12 | 25.00 | 36.41 | 49.26 | I | 1663.25 | I |
| Amphipod | 16.87 | 18.75 | 19.20 | 19.48 | II | 676.31 | II |
| Cumacean | 14.86 | 12.50 | 14.07 | 9.52 | IV | 361.63 | IV |
| Ostracod | 11.24 | 18.75 | 9.32 | 9.46 | V | 385.50 | III |
| Polychaete | 7.63 | 6.25 | 3.61 | 1.22 | VI | 70.25 | VI |
| Crustacean fragments | 8.84 | 6.25 | 2.09 | 0.71 | VII | 68.31 | VII |

le 15: Percent number (n), percentage frequency of occurrence (f), percent volume (v), Index of Preponderance (IOP) and Index of Relative Importance (IRI) for prey consumed by *A. thermalis* at Minicoy. Number of fish examined is given in parenthesis.

| od item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| uary 90 (22) | | | | | | | |
| midigested matter | 8.66 | 7.46 | 13.25 | 5.65 | V | 163.45 | VI |
| pepod | 21.65 | 14.93 | 26.02 | 22.19 | III | 711.71 | III |
| ea | 23.81 | 22.39 | 28.09 | 35.93 | I | 1162.04 | I |
| phipod | 19.91 | 20.90 | 20.91 | 24.97 | II | 853.14 | II |
| adoceran | 12.99 | 17.91 | 9.27 | 9.49 | IV | 398.68 | IV |
| ustacean fragments | 10.39 | 13.43 | 2.27 | 1.74 | VI | 170.02 | V |
| lychaete larvae | 2.60 | 2.99 | 0.19 | 0.03 | VII | 23.27 | VII |
| bruary 90 (17) | | | | | | | |
| midigested matter | 9.85 | 10.53 | 16.55 | 8.74 | III | 277.99 | V |
| her Decapod Larvae | 36.36 | 26.32 | 44.36 | 58.57 | I | 2124.55 | I |
| phipod | 13.64 | 21.05 | 15.64 | 16.52 | II | 616.34 | II |
| opod | 9.09 | 10.52 | 9.09 | 4.76 | V | 191.25 | VI |
| tracod | 11.36 | 15.79 | 9.64 | 7.64 | IV | 331.59 | IV |
| ustacean fragments | 19.70 | 15.79 | 4.72 | 3.74 | VI | 385.59 | III |
| rch 90 (18) | | | | | | | |
| midigested matter | 5.78 | 6.89 | 8.22 | 3.19 | VI | 96.46 | VI |
| sh egg | 7.48 | 10.34 | 9.88 | 5.75 | V | 179.50 | V |
| pepod | 12.93 | 17.24 | 14.43 | 13.99 | III | 471.68 | III |
| her Decapod Larvae | 30.27 | 24.15 | 31.35 | 42.58 | I | 1488.12 | I |
| sid | 21.77 | 20.69 | 22.09 | 25.71 | II | 907.46 | II |
| tracod | 14.63 | 13.79 | 10.43 | 8.09 | IV | 345.58 | IV |
| adoceran | 5.10 | 3.45 | 3.31 | 0.64 | VII | 29.01 | VIII |
| stropod larvae | 2.04 | 3.45 | 0.29 | 0.06 | VIII | 8.04 | VII |
| ril 90 (32) | | | | | | | |
| midigested matter | 7.90 | 9.09 | 11.87 | 5.75 | V | 179.71 | VI |
| pepod | 11.69 | 14.77 | 13.82 | 10.88 | III | 376.78 | III |
| her Decapod Larvae | 36.55 | 27.27 | 40.08 | 58.24 | I | 2089.70 | I |
| sid | 9.65 | 13.64 | 10.36 | 7.53 | IV | 272.94 | IV |
| phipod | 12.87 | 17.05 | 13.25 | 12.04 | II | 445.35 | II |
| tracod | 11.11 | 11.36 | 8.35 | 5.05 | VI | 221.06 | V |
| lychaete | 4.68 | 4.55 | 2.01 | 0.49 | VII | 30.44 | VII |
| vertebrate eggs | 5.55 | 2.27 | 0.26 | 0.03 | VIII | 13.19 | VIII |

ble 16: Percent number (n), percentage frequency of occurrence (f), percent volume (v), Index of Preponderance (IOP) and Index of Relative Importance (IRI) of prey taken by R. *gracilis* at Minicoy. Sample size is given in parenthesis.

| od item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| rch 89 (17) | | | | | | | |
| midigested matter | 14.64 | 15.38 | 19.63 | 16.04 | III | 527.07 | III |
| pepod | 24.39 | 23.08 | 25.70 | 31.52 | I | 1156.07 | I |
| ea | 18.29 | 15.38 | 18.93 | 15.47 | IV | 572.44 | IV |
| phipod | 24.39 | 23.08 | 22.43 | 27.51 | II | 1080.61 | II |
| opod | 12.20 | 15.38 | 9.81 | 8.02 | V | 338.51 | V |
| lant material | 6.09 | 7.70 | 3.50 | 1.43 | VI | 73.84 | VI |
| bruary 90 (28) | | | | | | | |
| pepod | 29.79 | 23.58 | 34.46 | 39.94 | I | 1515.02 | I |
| galopa | 3.90 | 5.66 | 4.36 | 1.22 | VI | 46.75 | VI |
| her Decapod Larvae | 30.85 | 23.58 | 33.08 | 38.34 | II | 1507.47 | II |
| phipod | 15.25 | 16.98 | 15.40 | 12.85 | III | 520.44 | III |
| macean | 9.75 | 14.15 | 8.21 | 5.71 | IV | 254.13 | IV |
| ladoceran | 5.85 | 9.43 | 3.95 | 1.83 | V | 92.41 | V |
| stropod larvae | 3.01 | 4.73 | 0.45 | 0.10 | VII | 16.37 | VII |
| vertebrate eggs | 1.60 | 1.89 | 0.09 | 0.01 | VIII | 3.19 | VIII |

ble 17: The percent number (n), percentage frequency of occurrence (f), percent volume (v), Index of Preponderance (IOP) and Index of Relative importance (IRI) of food consumed by *S. delicatulus* at Agatti. The number of fish examined is shown in parenthesis.

| od item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| cember 88 (30) | | | | | | | |
| midigested matter | 15.44 | 9.28 | 20.56 | 11.15 | III | 334.08 | III |
| sh eggs | 9.74 | 4.12 | 12.06 | 2.90 | V | 89.82 | V |
| pepod | 28.68 | 29.90 | 30.00 | 52.40 | I | 1754.53 | I |
| ea | 8.27 | 4.12 | 8.50 | 2.04 | VI | 69.09 | VII |
| her Decapod Larvae | 18.01 | 21.65 | 17.48 | 22.11 | II | 768.36 | II |
| sid | 11.40 | 14.43 | 10.84 | 9.14 | IV | 320.92 | IV |
| sh scale | 1.84 | 6.19 | 0.32 | 0.12 | VIII | 13.37 | VIII |
| vertebrate eggs | 6.62 | 10.31 | 0.24 | 0.14 | VII | 70.73 | VI |
| bruary 89 (34) | | | | | | | |
| midigested matter | 13.69 | 12.61 | 21.37 | 12.22 | III | 442.11 | IV |
| pepod | 36.15 | 28.57 | 44.36 | 57.44 | I | 2300.17 | I |
| her Decapod Larvae | 21.54 | 21.01 | 24.49 | 23.32 | II | 967.09 | II |
| ant material | 7.69 | 10.08 | 5.15 | 2.35 | V | 129.43 | V |
| ustacean fragments | 19.38 | 23.53 | 4.32 | 4.61 | IV | 557.66 | III |
| sh scale | 1.55 | 4.20 | 0.31 | 0.06 | VI | 7.81 | VI |
| rch 89 (37) | | | | | | | |
| midigested matter | 13.27 | 17.24 | 17.87 | 12.97 | II | 536.85 | II |
| sh eggs | 32.23 | 39.66 | 40.29 | 67.26 | I | 2876.14 | I |
| pepod | 9.48 | 6.90 | 10.03 | 2.91 | V | 134.62 | V |
| opod | 16.59 | 12.07 | 13.40 | 6.80 | IV | 361.98 | IV |
| tracod | 20.85 | 13.80 | 14.04 | 8.16 | III | 481.48 | III |
| ant material | 7.58 | 10.33 | 4.37 | 1.90 | VI | 123.44 | VI |
| vember 89 (38) | | | | | | | |
| midigested matter | 9.79 | 15.56 | 17.66 | 14.76 | III | 427.12 | III |
| phipod | 36.08 | 22.22 | 44.62 | 53.25 | I | 1793.15 | I |
| macean | 17.01 | 20.00 | 17.53 | 18.83 | II | 690.80 | II |
| adoceran | 8.76 | 13.33 | 7.17 | 5.13 | IV | 212.35 | V |
| ant material | 11.34 | 8.89 | 8.77 | 4.19 | V | 178.78 | VI |
| ustacean fragments | 15.46 | 17.78 | 3.98 | 3.80 | VI | 345.64 | IV |
| valve larvae | 1.56 | 2.22 | 0.27 | 0.04 | VII | 4.06 | VII |

main prey at Bangaram (Table 18). The important food item of *S. delicatulus* at Perumal Par were copepod, amphipod, 'other decapod larvae', fish eggs, mysid, ostracod and cumacean (Table 19).

The percentage of empty stomachs from specieswise pooled data indicate that the lowest value of 10.79 is for *S. delicatulus* from Agatti and the highest of 50.00 for *P. pisang* at Minicoy (Figure 1). Values greater than 25% were observed for *S. delicatulus*, *S. gracilis*, *P. chrysozona*, *A. fucata* and *R. gracilis* at Minicoy and for *S. delicatulus* from Bangaram and Perumal Par.

The variation in feeding between months, species and locations were compared by two-way ANOVA after logarithmic transformations. Percent number, percentage frequency of occurrence and percent volume (all replicates) differed significantly in all the baitfishes ($P < 0.01$). Monthly deviations (treatments) were also significant except in *P. chrysozona* and *A. fucata* (Table 20). Although the overall variance in feeding by the different species at Minicoy were significant ($P < 0.01$), individual comparisons did not show much diversification (Table 21). The feeding of *S. delicatulus* were different from those of *P. pisang*, *P. chrysozona* and *Archamia fucata*, while that of *S. gracilis* and *G. argenteus* varied from that of *P. chrysozona*. There was no significant change in feeding by *S. delicatulus* at the four locations (Table 21).

le 18 :Percent number (n), percentage frequency of occurrence (f), percent volume (v), Index of Preponderance (IOP) and Index of Relative Importance (IRI) of prey ingested by *S. delicatulus* at Bangaram.

| item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| mber 88 (30) | | | | | | | |
| digested matter | 4.98 | 12.90 | 7.85 | 5.20 | III | 165.51 | IV |
| epod | 40.89 | 26.88 | 50.64 | 69.92 | I | 2487.21 | I |
| a | 5.83 | 6.45 | 7.08 | 2.35 | V | 83.27 | VI |
| er Decapod Larvae | 16.10 | 17.21 | 18.49 | 16.34 | II | 595.29 | II |
| hipod | 3.18 | 4.30 | 3.44 | 0.76 | VII | 28.47 | VIII |
| acean | 8.26 | 8.60 | 7.44 | 3.29 | IV | 135.02 | V |
| racod | 5.40 | 7.53 | 4.27 | 1.65 | VI | 72.82 | VII |
| h scale | 0.64 | 2.15 | 0.12 | 0.01 | IX | 1.63 | IX |
| ertebrate eggs | 14.72 | 3.98 | 0.67 | 0.48 | VII | 215.15 | III |
| uary 89 (57) | | | | | | | |
| digested matter | 9.59 | 10.58 | 12.35 | 7.24 | IV | 232.13 | IV |
| h egg | 14.02 | 15.38 | 16.78 | 14.30 | III | 473.70 | III |
| epod | 31.47 | 25.00 | 31.87 | 44.15 | I | 1583.50 | I |
| a | 6.29 | 9.62 | 6.27 | 3.34 | V | 120.83 | V |
| er Decapod Larvae | 28.33 | 19.23 | 26.60 | 28.35 | II | 1056.30 | II |
| pod | 7.44 | 7.69 | 5.74 | 2.45 | VI | 101.35 | VI |
| h scale | 1.72 | 9.62 | 0.29 | 0.15 | VII | 19.34 | VII |
| alve larvae | 1.14 | 2.88 | 0.10 | 0.02 | VIII | 3.57 | VIII |
| ruary 89 (57) | | | | | | | |
| digested matter | 6.72 | 12.33 | 9.34 | 6.04 | III | 198.02 | III |
| h egg | 2.44 | 2.74 | 3.15 | 0.45 | VII | 15.32 | VIII |
| epod | 55.75 | 23.29 | 60.81 | 74.28 | I | 2714.68 | I |
| a | 1.84 | 7.53 | 1.97 | 0.78 | VI | 28.69 | VII |
| er Decapod Larvae | 9.78 | 20.55 | 9.89 | 10.66 | II | 404.22 | II |
| id | 7.33 | 9.59 | 7.27 | 3.66 | V | 140.01 | V |
| hipod | 7.58 | 10.27 | 7.23 | 3.89 | IV | 152.10 | IV |
| ertebrate eggs | 8.56 | 13.70 | 0.34 | 0.24 | VIII | 121.93 | VI |
| ch 89 (42) | | | | | | | |
| digested matter | 6.47 | 11.11 | 9.65 | 7.37 | IV | 179.09 | V |
| eggs | 9.05 | 7.41 | 12.59 | 6.41 | V | 160.35 | VI |
| epod | 17.24 | 14.81 | 20.22 | 20.59 | II | 554.78 | II |
| er Decapod Larvae | 24.14 | 22.22 | 26.29 | 40.16 | I | 1120.55 | I |
| pod | 11.21 | 18.52 | 10.02 | 12.76 | III | 393.18 | III |
| acean | 10.34 | 7.41 | 8.83 | 4.50 | VII | 142.05 | VII |
| racod | 9.91 | 11.11 | 7.44 | 5.68 | VI | 192.76 | IV |
| chaete larvae | 11.64 | 7.41 | 4.96 | 2.53 | VIII | 123.01 | VIII |

Continued...

Table 18: Continued...

| Food item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| October 89 (38) | | | | | | | |
| Semidigested matter | 9.14 | 8.33 | 15.74 | 8.93 | V | 207.25 | VI |
| Fish egg | 1.48 | 2.08 | 2.37 | 0.34 | VIII | 8.01 | VIII |
| Copepod | 13.58 | 12.50 | 18.41 | 15.67 | III | 399.88 | III |
| Mysid | 19.75 | 16.67 | 24.31 | 27.60 | II | 734.48 | II |
| Cumacean | 22.72 | 20.83 | 22.34 | 31.69 | I | 938.60 | I |
| Cladoceran | 11.85 | 14.58 | 9.36 | 9.29 | IV | 309.24 | V |
| Plant material | 4.44 | 10.43 | 3.28 | 2.32 | VII | 80.52 | VII |
| Crustacean fragments | 17.04 | 14.58 | 4.19 | 4.16 | VI | 309.53 | IV |
| November 89 (57) | | | | | | | |
| Semidigested matter | 5.99 | 10.71 | 9.67 | 8.53 | V | 167.72 | VI |
| Fish egg | 18.43 | 8.93 | 27.63 | 20.32 | II | 411.32 | II |
| Copepod | 22.12 | 12.50 | 28.06 | 28.88 | I | 627.25 | I |
| Cumacean | 13.83 | 14.29 | 12.75 | 15.01 | IV | 379.83 | III |
| Ostracod | 11.98 | 10.71 | 9.67 | 8.53 | III | 231.87 | IV |
| Cladoceran | 14.75 | 19.64 | 10.84 | 17.53 | IV | 182.97 | V |
| Gastropod larvae | 5.53 | 7.15 | 0.85 | 0.50 | VII | 45.62 | VIII |
| Polychaete larvae | 7.37 | 16.17 | 0.53 | 0.70 | VI | 119.29 | VII |
| December 89 (40) | | | | | | | |
| Semidigested matter | 8.93 | 11.76 | 9.64 | 5.87 | V | 218.38 | V |
| Copepod | 35.71 | 23.53 | 43.22 | 52.66 | I | 1857.22 | I |
| Mysid | 13.39 | 17.65 | 14.73 | 13.46 | | | |
| Cumacean | 17.86 | 17.65 | 15.72 | 14.37 | III | 496.32 | III |
| Cladoceran | 16.07 | 17.65 | 11.39 | 10.41 | II | 592.69 | II |
| Plant material | 8.04 | 1.76 | 5.30 | 3.23 | IV | 484.67 | IV |
| | | | | | VI | 156.88 | VI |
| January 90 (39) | | | | | | | |
| Semidigested matter | 5.73 | 9.72 | 9.39 | 5.21 | IV | 146.97 | VI |
| Fish egg | 5.05 | 8.74 | 7.67 | 3.69 | VI | 111.17 | VII |
| Copepod | 31.19 | 27.18 | 40.13 | 62.17 | I | 1938.48 | I |
| Other Decapod Larvae | 12.84 | 12.62 | 15.34 | 11.03 | II | 355.63 | II |
| Isopod | 16.51 | 10.68 | 16.20 | 9.86 | III | 349.34 | III |
| Ostracod | 8.03 | 11.65 | 6.60 | 4.38 | V | 170.44 | V |
| Crustacean fragments | 18.36 | 14.56 | 4.29 | 3.56 | VII | 329.78 | IV |
| Gastropod larvae | 2.29 | 4.85 | 0.38 | 0.10 | VIII | 12.95 | VIII |
| February 90 (57) | | | | | | | |
| Semidigested matter | 8.19 | 17.31 | 12.42 | 12.05 | III | 356.76 | III |
| Copepod | 39.41 | 21.15 | 46.17 | 55.70 | I | 1826.94 | I |
| Other Decapod Larvae | 13.84 | 19.23 | 15.30 | 16.50 | II | 560.36 | II |
| Cumacean | 12.15 | 9.62 | 10.53 | 5.68 | IV | 218.18 | V |
| Ostracod | 11.16 | 11.54 | 8.48 | 5.49 | V | 226.65 | IV |
| Plant material | 9.18 | 13.46 | 5.97 | 4.51 | VI | 203.92 | VI |
| Fish scale | 0.42 | 2.88 | 0.09 | 0.01 | VIII | 1.47 | VIII |
| Invertebrate eggs | 5.65 | 4.81 | 0.24 | 0.06 | VII | 28.33 | VII |

Table 19: Percent number (n), percentage frequency of occurrence (f), percent volume (v), Index of Preponderance (IOP) and Index of Relative Importance (IRI) of _S. delicatulus_ from Perumal Par. Sample size in parenthesis.

| Food item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| <u>November 88 (52)</u> | | | | | | | |
| Fish egg | 2.47 | 5.00 | 3.44 | 0.72 | VI | 29.55 | VI |
| Copepod | 42.33 | 35.00 | 49.97 | 73.24 | I | 3230.50 | I |
| Other Decapod Larvae | 13.15 | 7.14 | 14.41 | 4.31 | IV | 196.78 | IV |
| Amphipod | 16.44 | 17.14 | 16.93 | 12.15 | II | 571.96 | II |
| Isopod | 12.19 | 18.57 | 10.99 | 8.55 | III | 430.45 | III |
| Ostracod | 5.07 | 5.71 | 3.82 | 0.89 | V | 50.76 | V |
| Fish scale | 0.55 | 1.44 | 0.12 | 0.01 | VIII | 0.96 | VIII |
| Invertebrate eggs | 7.80 | 10.00 | 0.32 | 0.13 | VII | 81.20 | VII |
| <u>December 88 (44)</u> | | | | | | | |
| Semidigested matter | 4.61 | 16.67 | 6.45 | 5.94 | IV | 184.37 | IV |
| Fish egg | 5.87 | 4.17 | 7.64 | 1.76 | V | 56.34 | V |
| Copepod | 31.80 | 15.00 | 34.96 | 28.99 | II | 1001.40 | II |
| Zoea | 0.45 | 0.83 | 0.49 | 0.02 | VII | 0.78 | VIII |
| Other Decapod Larvae | 36.68 | 22.50 | 37.40 | 46.51 | I | 1666.80 | I |
| Mysid | 3.43 | 5.83 | 3.43 | 1.11 | VI | 39.99 | VI |
| Ostracod | 13.46 | 30.00 | 9.43 | 15.64 | III | 686.70 | III |
| Fish scale | 0.36 | 1.67 | 0.07 | 0.01 | VIII | 0.72 | IX |
| Invertebrate eggs | 3.34 | 3.33 | 0.13 | 0.02 | VII | 11.55 | VII |
| <u>January 89 (45)</u> | | | | | | | |
| Semidigested matter | 11.94 | 11.46 | 15.77 | 10.66 | V | 317.56 | V |
| Fish egg | 26.72 | 20.83 | 32.77 | 40.26 | I | 1239.18 | I |
| Copepod | 21.03 | 17.72 | 21.85 | 22.84 | II | 759.83 | II |
| Zoea | 0.75 | 2.08 | 0.76 | 0.09 | VII | 3.14 | IX |
| Other Decapod Larvae | 2.69 | 6.25 | 2.59 | 0.96 | VI | 33.00 | VI |
| Amphipod | 16.42 | 14.58 | 14.86 | 12.78 | III | 456.06 | IV |
| Cladoceran | 18.51 | 18.75 | 11.18 | 12.36 | IV | 556.69 | III |
| Fish scale | 0.45 | 6.25 | 0.08 | 0.03 | VIII | 3.31 | VIII |
| Bivalve larvae | 1.49 | 2.08 | 0.14 | 0.02 | IX | 3.39 | VII |
| <u>February 89 (48)</u> | | | | | | | |
| Semidigested matter | 6.60 | 10.96 | 11.19 | 7.60 | IV | 194.98 | VI |
| Copepod | 23.39 | 28.08 | 31.18 | 54.22 | I | 1532.33 | I |
| Other Decapod Larvae | 8.24 | 3.42 | 10.21 | 2.16 | VII | 43.16 | VII |
| Mysid | 14.69 | 9.59 | 17.81 | 10.58 | III | 311.68 | III |
| Amphipod | 15.74 | 13.71 | 18.31 | 15.55 | II | 466.83 | II |
| Plant material | 9.60 | 15.07 | 6.98 | 6.51 | V | 249.86 | V |
| Crustacean fragments | 16:79 | 13.01 | 4.07 | 3.28 | VI | 271.39 | IV |
| Invertebrate eggs | 4.95 | 6.16 | 0.25 | 0.10 | VIII | 32.03 | VIII |

Continued...

able 19 : Continued...

| ood item | n | f | v | IOP | Rank | IRI | Rank |
|---|---|---|---|---|---|---|---|
| arch 89 (46) | | | | | | | |
| emidigested matter | 7.92 | 13.56 | 10.35 | 8.10 | IV | 247.74 | IV |
| ish egg | 13.49 | 22.03 | 16.38 | 20.81 | III | 658.04 | III |
| opepod | 31.79 | 21.19 | 32.65 | 39.90 | I | 1365.48 | I |
| oea | 6.43 | 4.24 | 6.46 | 1.58 | VI | 54.65 | VI |
| ther Decapod Larvae | 8.58 | 9.32 | 8.17 | 4.39 | V | 156.11 | V |
| ysid | 27.36 | 16.95 | 24.53 | 24.96 | II | 896.49 | II |
| ish scale | 0.47 | 0.85 | 0.09 | 0.01 | VIII | 0.48 | VIII |
| ivalve larvae | 3.96 | 11.86 | 0.37 | 0.25 | VII | 51.35 | VII |
| ctober 89 (45) | | | | | | | |
| emidigested matter | 7.05 | 9.09 | 9.43 | 5.58 | V | 49.80 | V |
| ish egg | 3.62 | 11.36 | 4.61 | 3.41 | VI | 93.49 | VI |
| opepod | 47.20 | 18.18 | 50.92 | 60.20 | I | 1783.82 | I |
| ther Decapod Larvae | 9.76 | 4.55 | 9.85 | 2.89 | VII | 88.77 | VII |
| ysid | 10.49 | 20.45 | 10.28 | 13.67 | II | 424.75 | II |
| sopod | 8.14 | 15.91 | 6.70 | 6.93 | IV | 236.10 | IV |
| stracod | 11.93 | 13.64 | 8.19 | 7.27 | III | 274.44 | III |
| olychaete larvae | 1.81 | 6.82 | 0.12 | 0.05 | VIII | 13.16 | VIII |
| ovember 89 (37) | | | | | | | |
| emidigested matter | 11.29 | 8.93 | 15.71 | 8.58 | VI | 241.11 | VI |
| ish egg | 7.12 | 19.64 | 9.22 | 11.07 | V | 320.92 | V |
| opepod | 29.83 | 19.64 | 32.63 | 39.19 | I | 1217.88 | I |
| ther Decapod Larvae | 15.86 | 14.29 | 16.29 | 14.06 | II | 456.57 | IV |
| sopod | 16.80 | 16.07 | 14.03 | 13.79 | III | 495.44 | III |
| stracod | 17.47 | 17.86 | 12.16 | 13.28 | IV | 529.19 | II |
| ivalve larvae | 1.61 | 3.57 | 0.16 | 0.03 | VII | 6.32 | VII |
| ecember 89 (52) | | | | | | | |
| emidigested matter | 6.98 | 7.06 | 9.39 | 4.00 | III | 115.57 | VII |
| ish egg | 34.41 | 20.00 | 42.98 | 51.86 | I | 1547.80 | I |
| opepod | 26.39 | 18.82 | 27.88 | 31.66 | II | 1021.36 | II |
| mphipod | 7.17 | 9.41 | 6.61 | 3.75 | V | 129.67 | V |
| umacean | 7.65 | 10.59 | 5.88 | 3.76 | IV | 143.28 | III |
| ladoceran | 6.31 | 11.76 | 3.88 | 2.75 | VI | 119.83 | VI |
| lant material | 3.25 | 8.24 | 1.87 | 0.93 | VIII | 42.19 | VIII |
| rustacean fragments | 7.84 | 14.12 | 1.51 | 1.29 | VII | 132.02 | IV |
| anuary 90 (54) | | | | | | | |
| emidigested matter | 14.74 | 11.54 | 23.11 | 11.44 | II | 436.79 | III |
| opepod | 44.74 | 30.77 | 55.19 | 72.83 | I | 3074.85 | I |
| sopod | 2.63 | 11.54 | 2.48 | 1.23 | V | 58.97 | VI |
| stracod | 7.89 | 15.38 | 6.25 | 4.12 | IV | 217.47 | IV |
| lant material | 18.42 | 19.23 | 12.38 | 10.21 | III | 592.28 | II |
| astropod larvae | 1.05 | 3.85 | 0.12 | 0.02 | VII | 4.50 | VII |
| nvertebrate eggs | 10.53 | 7.69 | 0.47 | 0.15 | VI | 84.59 | V |
| ebruary 90 (52) | | | | | | | |
| emidigested matter | 6.44 | 10.45 | 9.52 | 4.91 | V | 166.78 | VI |
| opepod | 41.65 | 28.36 | 48.38 | 67.59 | I | 2553.25 | I |
| ther Decapod Larvae | 10.06 | 13.43 | 10.83 | 7.16 | IV | 280.55 | IV |
| mphipod | 13.48 | 11.98 | 13.68 | 8.05 | III | 324.29 | III |
| umacean | 16.10 | 14.93 | 13.59 | 9.99 | II | 443.27 | II |
| rustacean fragments | 11.07 | 17.90 | 2.34 | 2.06 | VI | 240.04 | V |

Table 20: Variation in feeding compared by two-way ANOVA. Treatments are months and replicates are the estimates of feeding by number, frequency of occurrence and volume.

| Species | | Source | df | SS | MS | F |
|---|---|---|---|---|---|---|
| *Spratelloides delicatulus* | | Treatment | 4 | 16.950 | 4.237 | 11.62** |
| | | Replicate | 2 | 28.038 | 14.019 | 38.43** |
| | | Error | 8 | 2.918 | 0.365 | |
| *S. gracilis* | | Treatment | 6 | 24.776 | 4.129 | 37.38** |
| | | Replicate | 2 | 36.950 | 18.475 | 167.22** |
| | | Error | 12 | 1.306 | 0.110 | |
| *Gymnocaesio argenteus* | | Treatment | 6 | 11.453 | 1.909 | 9.60** |
| | | Replicate | 2 | 35.315 | 17.657 | 88.81** |
| | | Error | 12 | 2.386 | 0.199 | |
| *Caesio striatus* | | Treatment | 6 | 16.531 | 2.755 | 22.04** |
| | | Replicate | 2 | 36.331 | 18.166 | 145.31** |
| | | Error | 12 | 1.500 | 0.125 | |
| *Pterocaesio pisang* | | Treatment | 2 | 2.143 | 1.072 | 21.78** |
| | | Replicate | 2 | 14.322 | 7.161 | 145.53** |
| | | Error | 4 | 0.197 | 0.049 | |
| *P. chrysozona* | | Treatment | 2 | 1.071 | 0.536 | 2.72 |
| | | Replicate | 2 | 16.392 | 8.196 | 41.63** |
| | | Error | 4 | 0.787 | 0.197 | |
| *Chromis caeruleus* | | Treatment | 3 | 7.795 | 2.598 | 15.35** |
| | | Replicate | 2 | 20.296 | 10.148 | 59.95** |
| | | Error | 6 | 1.016 | 0.169 | |
| *Lepidozygus tapeinosoma* | | Treatment | 3 | 3.437 | 1.146 | 5.90* |
| | | Replicate | 2 | 21.980 | 10.990 | 56.60** |
| | | Error | 6 | 1.165 | 0.194 | |
| *Archamia fucata* | | Treatment | 2 | 0.352 | 0.176 | 3.98 |
| | | Replicate | 2 | 16.142 | 8.071 | 182.44** |
| | | Error | 4 | 0.177 | 0.044 | |
| *Apogon thermalis* | | Treatment | 3 | 2.215 | 0.738 | 8.32* |
| | | Replicate | 2 | 19.113 | 9.556 | 107.68** |
| | | Error | 6 | 0.532 | 0.089 | |
| *Rhabdamia gracilis* | | Treatment | 1 | 5.726 | 5.726 | 641.25** |
| | | Replicate | 2 | 9.085 | 4.543 | 508.68** |
| | | Error | 2 | 0.018 | 0.009 | |
| *S. delicatulus* | Agatti | Treatment | 3 | 3.067 | 1.022 | 48.04** |
| | | Replicate | 2 | 18.776 | 9.380 | 441.14** |
| | | Error | 6 | 0.128 | 0.021 | |
| | Bangaram | Treatment | 8 | 12.254 | 1.532 | 41.08** |
| | | Replicate | 2 | 43.385 | 21.692 | 581.80** |
| | | Error | 16 | 0.597 | 0.037 | |
| | Perumal Par | Treatment | 9 | 7.078 | 0.786 | 16.65** |
| | | Replicate | 2 | 48.027 | 24.014 | 447.17** |
| | | Error | 18 | 0.967 | 0.054 | |

* <0.05     ** P<0.01

Table 21: ANOVA tables for devaition in feeding between species at Minicoy and feeding of *S. delicatulus* at the four locations. Specieswise comparison of feeding at Minicoy is also presented.

| | Source | df | SS | MS | F |
|---|---|---|---|---|---|
| Between species | Treatment | 10 | 11.057 | 1.106 | $11.20^{**}$ |
| | Replicate | 2 | 55.269 | 27.634 | $279.86^{**}$ |
| | Error | 20 | 1.975 | 0.099 | |
| Between locations | Treatment | 3 | 1.511 | 0.504 | 2.42 |
| | Replicate | 2 | 19.562 | 9.781 | $46.99^{**}$ |
| | Error | 6 | 1.249 | 0.208 | |

$^{**}$ P<0.01

TREATMENT MEAN COMPARISON FOR BETWEEN SPECIES

| No. | Species | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *S. delicatulus* | - | - | * | * | - | - | * | - | - | - |
| 2 | *S. gracilis* | | - | - | * | - | - | - | - | - | - |
| 3 | *G. argenteus* | | | - | * | - | - | - | - | - | - |
| 4 | *C. striatus* | | | | - | - | - | - | - | - | - |
| 5 | *P. pisang* | | | | | - | - | - | - | - | - |
| 6 | *P. chrysozona* | | | | | | - | - | - | - | - |
| 7 | *C. caeruleus* | | | | | | | - | - | - | - |
| 8 | *L. tapeinosoma* | | | | | | | | - | - | - |
| 9 | *A. fucata* | | | | | | | | | - | - |
| 0 | *A. thermalis* | | | | | | | | | | - |
| 1 | *R. gracilis* | | | | | | | | | | |

( * indicates significance )

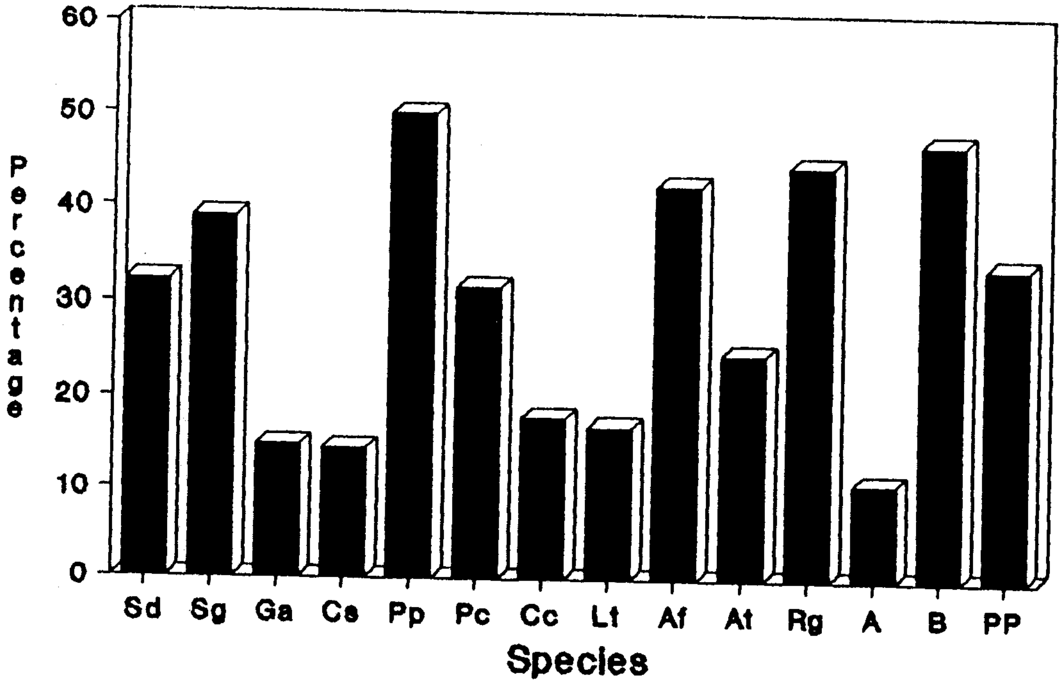


Fig. 1. Percentage of empty stomachs for the various species of livebaits. Species names is abbreviated (eg. Ga - *Gymnocaesio argenteus*). A, B, & PP indicates *S. delicatulus* at Agatti, Bangaram and Perumal Par.

# DISCUSSION

All the species of baitfish studied showed poor to moderate feeding states with actively fed stomachs in low percentages. Feeding rate depends on the availability of zooplankton, the feeding behaviour (diurnal or nocturnal), the time of bait caught, prey selectivity and size of prey and feeding method employed by the particular baitfish. Mathew and Gopakumar (1986) reports an indirect influence of zooplankton on tuna catch by the abundance of livebaits. They opine that a higher secondary production resulted in greater biomass of bait fishes at Minicoy which in turn increased the abundance and catch of tuna. Emery (1968) also observed a variety of reef fishes feeding on resident zooplankton and added that these zooplankters are an important energy source for planktivorous fishes. It is therefore evident that the various species eat prey in proportion to its density in the environment. In general clupeids and apogonids are nocturnal in feeding habit while pomacentrids and caesionids are diurnal. Studies have shown that nocturnal feeders cease feeding one hour before sunrise and diurnal feeders start feeding one hour after sunrise. Therefore the time when bait fishes are caught, which is generally early morning (between 0600 and 0800 hrs) is a period when the nocturnal fishes have stopped feeding and the diurnal ones are yet to enter an active feeding mode. This may explain the high percentage of empty and low to moderately fed condition in a majority of the guts mined. Likewise the percentage of food in advanced stages of estion as shown by semidigested matter implies preceded ding activity. Milton *et al*., (1990a) based on field ervations and diet data concluded that *S. delicatulus* is a rnal feeder. Jones (1960) observed the sprat in large numbers racted to light off Bitra and Mohan and Kunhikoya (1985) also und a large number of empty stomachs in samples collected at icoy. These findings seem to indicate that *S. delicatulus* at shadweep is predominantly a nocturnal feeder.

The diets of the baitfishes were similar to those ported for the species from elsewhere or other species in the e families. Zooplankton, especially copepods were the major m. Only in two species of Apogonids, *Archamia fucata* and *gon thermalis* did other food items dominate. Milton *et al*., 990a) also observed significant negative selectivity for lanoids by *Archamia zosterophora* at Solomon Islands and ggested that it is a visual predator which pursues the prey em that appears largest at the start of the search. Another ecies which did not have a high percentage of copepod in the t was *P. chrysozona*. But *P. pisang* collected from the same cation and at about the same period had copepod as a major em. Species comparisons also showed significant difference in eding habits of *G. argenteus* and *P. chrysozona*. This implies at there may exist competition for favoured food among esionids occupying same area. The argument gets further support albeit a weak one from the comparison of feeding of S. delicatulus. S. delicatulus, an inhabitant of the sandy area of the Minicoy lagoon had a significant deviation in feeding from that of the reef and outer reef dwelling of P. pisang and P. chrysozona and the coral resident Archamia fucata of the lagoon. Furthermore, S. delicatulus found in similar sandy habitats but at different locations did not show significant variation in diet. Inter-specific competition and the habitat may therefore influence the diet of livebaits.

A surprising prey item observed in some cases were fish scales in thick clumps about the size of scales of the predatory fishes themselves. Although Milton et al., (1990a) reported fish as a prey of certain baitfishes, apart from the scales there were no indication that bait at Minicoy are piscivorous. An explanation for their presence could be that scales entangled in coral mucus are inadvertently consumed by the bait fishes when they feed on coral mucus. It is interesting to note that fish scales are abundant in bait found in areas of high coral mucus production and turbulence such as reefs.

Plant material may also have found its way into the gut of planktivores in a similar manner. Algal contents in guts of C. caeruleus (Gerber and Marshall, 1974; Mohan et al., 1986) and S. delicatulus (Mohan and Kunhikoya, 1985) have been reported. Bait fishes may be opportunistic feeders since the most frequently occurring food organisms, with the exception of copepod, changes from month to month. Quite often the presence of multiple prey in the stomach may be the result of the incomplete digestion of a previous meal, rather than the predator taking multiple prey during a meal (Crow, 1979).

# CHAPTER 4

# REPRODUCTION

## INTRODUCTION

Studies on life history characteristics of coral reef fishes have concentrated mainly on the pelagic egg and larval stages (Leis, 1991b), settlement strategies and biogeography (Victor, 1991), spatial and temporal patterns in recruitment (Doherty, 1991), postrecruitment processes (Jones, 1991) and spawning patterns (Robertson, 1991). Abel (1972) described coral reef fishes very restrictively as only those species which prey upon coral polyps. To most workers, however, they are fishes found associated with coralline structures and only rarely are Scombridae, Carangidae, or other typically pelagic forms treated as a part of the reef fish community although species of these families do occur in the vicinity of reefs (Sale, 1980). The majority of work on reef fishes has been concerned with the smaller, relatively sedentary forms. This explains why the pelagic species of Clupeidae, Engraulidae and Caesionidae which form the major tuna livebaits are excluded from studies of the nature mentioned above. Coral reef fishes of the families Pomacentridae and Apogonidae, which contribute to the livebait fishery in some countries, however, being in the category of typical reef fishes have received attention. Prominent among them are the reproductive behaviour of fishes of the genus *Chromis* (Myrberg *et al*., 1967; Swerdloff, 1970; Russel, 1971; Sale, 1971; Fishelson *et al*., 1974; deBoer, 1980; Go and Jeon, 1983a; Moosleitner, 1983; Mohan *et al*., 1986) and the mouth-breeding habits of the apogonids (Charney, 1976; Garnaud, 1977; Omori and Takahashi, 1980; Kuwamura, 1983).

Major coral reef fishes have a pelagic, usually larval stage resulting in a life history with two distinct and very different phases. The pelagic and benthic stages differ in almost all characteristics and morphology to size, habitat, food and behaviour (Leis, 1991b). Although reef fishes are highly fecund they have a high mortality rate which mostly takes place in the pelagic stage (Doherty, 1981, 1983; Doherty and Williams, 1988). The larvae of reef fishes being passive drifters, its distribution is governed by oceanographic features of coral reefs. Physical hydrographic features such as currents (Leis 1982a,b; Williams *et al*., 1984) eddies (Lobel and Robinson, 1988), tidal fronts (Kingsford *et al*., 1991) and circulation (Black *et al*., 1990) have an influence on the distribution and survival of these larvae. However in recent times, the traditional view that larvae are essentially passive plankters whose distribution was determined entirely by the currents has largely been discarded (Leis and Goldman, 1984, 1987; Leis, 1986a). Some types of larvae apparently remain within a few hundred meters of their natal reef,while others travel far and have distributions more like larvae of oceanic fishes than reef fishes (Leis, 1991b). Some species of the families Apogonidae, Pomacentridae and Clupeidae (*Spratelloides*) use atoll lagoons throughout the larval stage (Leis, 1986b). Young larvae of Apogonidae and Clupeidae (*Spratelloides*) also use small reef lagoons on the continental shelf. But larger or older larvae are rare and this indicates that although spawning takes place, the pelagic stage is not usually completed within the lagoon (Leis, 1981, 1986a). The larvae of caesionids are found to occur in the open ocean < 25 km from reefs (Leis, 1986b). Leis (1986c) also observed larvae of a reef associated Clupeid (*S. gracilis*) very close to the coral substrate of the reef. Vertical migrations in certain species of apogonids and pomacentrids have also been recorded (Leis, 1991a).

Virtually all coral reef fishes undergo a profound transition from life as a larva adrift in the oceanic plankton to a settled existence closely associated with the coral reef structure (Victor, 1991). Coral reef fish larvae settle over a very broad range of sizes (Wellington and Victor, 1989; Thresher and Brothers, 1989; Leis, 1989) with a majority settling between 7 and 12 mm SL. Except for a few observations on damselfishes (Thresher *et al*., 1989; Robertson *et al*., 1988) much is not known about settling strategies of families that comprise the tuna livebaits. Investigations on recruitment and other reproductive aspects of reef fishes from India are rare, an exception is the observations of Pillai et al. (1983) on the recruitment of Ctenochaetus strigosus at Minicoy.

Apart from the pomacentrids and apogonids, there are also a few observations on the reproductive biology of other tuna livebaits. Hida and Uchiyama (1977) reports the sexratio, maturity and fecundity of Herklotsichthys punctatus and Pranesus pinguis from Majuro atoll, Marshall Islands and Bell and Colin (1986) observed the mass spawning of Caesio teres at Enewetak atoll also in Marshall Islands. The biology of the major bait species of Papua New Guinea, namely, Stolephorus heterolobus, S. devisi, Spratelloides gracilis and S. lewisi has been studied (Dalzell and Wankowski, 1980; Anon. 1982; Dalzell, 1985, 1987a,b). Lewis et al. (1983) describes the biology of Herklotsichthys quadrimaculatus and Spratelloides delicatulus from Fiji. The population structure and reproductive biology of S. gracilis from Koshiki Islands in Japan is described by Ozawa et al. (1989). An extensive work on life history of 8 species of clupeids in North-Eastern Australis is reported (Williams and Cappo, 1990). Hallier (1990) investigated the biology of Decapterus maruadi and D. macrosoma two potential species of baitfish from Seychelles. The reproductive biology of three major tuna baitfish species : Spratelloides delicatulus, S. gracilis and Stolephorus heterolobus were compared between Solomon Islands and Maldives (Milton et al. 1990b). Milton and Blaber (1991) studied the maturation, spawning seasonality and proximate spawning stimuli of 6 species of tuna baitfish in the

Solomon Islands. The maturity and spawning, spawning season and frequency, sex ratio and fecundity of *S. delicatulus* and *S. gracilis* is reported by Mohan and Kunhikoya (1985). Biology of the blue-puller *Chromis caeruleus* also from Minicoy has been studied (Mohan *et al*. 1986). Luther (1990) described the biology of whitebait anchovies of Indian waters. Reproductive biology of 10 species of tuna livebait from Lakshadweep is reported by Gopakumar *et al*. (1991).

In the present study, reproductive biology of 11 species of livebait from Minicoy and *S. delicatulus* from Agatti, Bangaram and Perumal Par are described. Some species contributed to the fishery in low percentages at Minicoy and their occurrence was erratic. Therefore a complete picture of reproduction does not emerge for many of them. Number of samples analysed is small due to the non-availability of specimens for study. However, as observations on the fishery biology of tuna livebaits from Lakshadweep is virtually lacking, it is hoped that these preliminary observations would form a basis for future research.

## MATERIALS AND METHODS

Samples were collected from the commercial pole-and-line fishing boats at Minicoy and Agatti. Individual fish were measured (total and standard length in mm), weighed (to the nearest 0.001 g), sexed and gonad weight recorded. Gonads were lassified into 5 developmental stages on the basis of orphological observations (Qasim, 1957, 1973).

Stage I : Immature virgins - Ovary pinkish occupying 1/4 to 1/2 of body cavity. Oocytes irregular, spherical or oval in shape and transparent. Testis whitish ribbon shaped occupying 1/4 to 1/2 body cavity.

Stage II : Maturing virgins or recovered spents - Ovary light yellowish, occupying 1/2 to 2/3 of body cavity. Ova round and some are partially yolk laden. Testis whitish occupying 2/3 body cavity.

Stage III : Ripening - Ovary yellowish, occupying 2/3 to 3/4 body cavity. Majority of oocytes round and fully yolk laden, much increase in the oocyte diameter. Oocytes become translucent. Testis creamy white occupying 3/4 body cavity.

tage IV : Ripe - Ovary deep yellow/golden, occupying almost entire body cavity with some ova visible to exterior. Eggs increased in diameter and easily separable. Blood vessels are prominent on the ovary surface. Testis creamy white occupying entire body cavity.

tage V : Spent - Ovaries blood shot and pinkish, collapsed, shrunken, translucent with prominent blood vessels, almost 1/2 of body cavity. Few unspawned yolky oocytes are also visible. Testis flaccid occupying almost 1/2 body cavity.

Sex ratio in the different months and size groups were calculated and tested for significant variation from 1:1 by Chi-square test. Gonosomatic indices (GSI) were calculated as the ratio of wet gonad weight to somatic weight expressed as a percentage. For ova diameter studies, ovary as a whole was teased and 30 ova of each fish in all samples at various stages of maturity were measured. A calibrated ocular micrometer mounted on a light microscope set at 150 times magnification was used. Ova were separated into micrometer division groups, converted to millimeters and frequency polygons drawn for the different maturity stages. These were employed to observe changes in ova size frequency with increasing gonadal maturation. Size at first maturity was determined by linear regression of size on percentage maturity. Absolute fecundity was estimated by counting the total number of ova in both the lobes of ovaries in stages III and IV. Relative fecundity was defined as the number of eggs per gram of body weight. Linear regression of total length and weight on absolute fecundity was also calculated.

## RESULTS

*S. delicatulus* at Minicoy had mature stages in all the months of its occurrence except in October. Spent fishes in low percentage was observed only in April (Table 1). The mature

Table 1 : Percentage occurrence of different maturity stages of sprats at Minicoy.

| th & ear | Sex | Stages of Maturity | | | | |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | V |
| delicatulus | | | | | | |
| v 88 | M | - | 28.57 | 28.57 | 42.86 | - |
| | F | - | 33.33 | 66.67 | - | - |
| c 88 | M | 8.33 | 83.34 | 8.33 | - | - |
| | F | 42.86 | 28.57 | 28.57 | - | - |
| r 89 | M | - | 83.33 | 16.67 | - | - |
| | F | - | 84.62 | - | 7.69 | 7.69 |
| p 89 | M | 33.33 | 16.67 | - | 50.00 | - |
| | F | 91.67 | - | 8.33 | - | - |
| t 89 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| gracilis | | | | | | |
| v 88 | M | - | - | 60.00 | 40.00 | - |
| | F | - | 50.00 | 16.67 | 33.33 | - |
| c 88 | M | 55.56 | 22.22 | 11.11 | 11.11 | - |
| | F | 70.00 | 10.00 | 20.00 | - | - |
| n 89 | M | 25.00 | 75.00 | - | - | - |
| | F | 87.50 | - | 12.50 | - | - |
| c 89 | M | 88.46 | 11.54 | - | - | - |
| | F | 86.11 | 5.56 | 8.33 | - | - |
| n 90 | M | - | 25.81 | 74.19 | - | - |
| | F | - | 100.00 | - | - | - |
| b 90 | M | 100.00 | - | - | - | - |
| | F | 66.67 | 33.33 | - | - | - |
| r 90 | M | - | 8.33 | - | 91.67 | - |
| | F | - | 43.33 | 56.67 | - | - |
| r 90 | M | 14.29 | - | - | 85.71 | - |
| | F | - | 56.25 | - | 43.75 | - |

stages of S. gracilis was also recorded in all the months except in February (Table 1) with predominance of ripe fishes during November, March and April. Immature (Stage I) gonads of caesionids could be observed only under a light microscope. Only in certain months larger gonads were observed which were visible to the naked eye. Depending on their weight and space occupied in the body cavity, these gonads have been designated stage II and III. G. argenteus was in immature condition during most of the months except in January and March 90, when comparatively bigger gonads were observed (Table 2). A similar condition was observed for C. striatus with relatively advanced stages of maturity in November 89 and March 90, but only stage I gonads were noticed in P. chrysozona during the months it contributed to the fishery (Table 2). C. caeruleus had mature gonads during November and December while in L. tapeinosoma mature males were present during February (Table 3). Among apogonids, A. fucata and R. gracilis revealed mature condition in March and in A. thermalis mature stages were observed in January (Table 3). S. delicatulus at Agatti, Bangaram and Perumal Par indicated maturity in almost all the months of the fishery except in October when they were either totally lacking or available in small percentages (Table 4). However, the mature stages were prevalent only during November and December.

Maturity stages advanced with increase in length in all species of baitfishes. Mature males and females of S.

Table 2 : Gonads of fusiliers in various stages of maturity at Minicoy.

| nth & ear | Sex | Stages of Maturity | | | | |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | V |
| *argenteus* | | | | | | |
| an 89 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| eb 89 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| ar 89 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| ov 89 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| ec 89 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| an 90 | M | 45.45 | 18.18 | 36.67 | - | - |
| | F | 68.42 | 10.53 | 21.05 | - | - |
| ar 90 | M | 20.00 | 60.00 | 20.00 | - | - |
| | F | 66.67 | 33.33 | - | - | - |
| *striatus* | | | | | | |
| ov 88 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| ec 88 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| ov 89 | M | 85.00 | 10.00 | 5.00 | - | - |
| | F | 72.22 | 22.22 | 5.56 | - | - |
| ec 89 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| an 90 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| eb 90 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| ar 90 | M | - | - | 100.00 | - | - |
| | F | - | - | 100.00 | - | - |
| *chrysozona* | | | | | | |
| ov 88 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| eb 90 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| ar 90 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |

Table 3 : Maturity stages of damsel and cardinal fishes at Minicoy

| Month & Year | Sex | Stages of maturity | | | | |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | V |
| ***C. caeruleus*** | | | | | | |
| Nov 88 | M | 100.00 | - | - | - | - |
| | F | 66.67 | - | - | 33.33 | - |
| Dec 88 | M | - | 100.00 | - | - | - |
| | F | - | 42.86 | 57.14 | - | - |
| Feb 89 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| Feb 90 | M | 100.00 | - | - | - | - |
| | F | 88.24 | 11.76 | - | - | - |
| ***tapeinosoma*** | | | | | | |
| Nov 89 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| Dec 89 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| Jan 90 | M | 100.00 | - | - | - | - |
| | F | 83.33 | 16.67 | - | - | - |
| Feb 90 | M | 53.85 | 30.77 | 15.38 | - | - |
| | F | 100.00 | - | - | - | - |
| ***fucata*** | | | | | | |
| Mar 89 | M | 100.00 | - | - | - | - |
| | F | 18.18 | 45.46 | 18.18 | 18.18 | - |
| Feb 90 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| Apr 90 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| ***thermalis*** | | | | | | |
| Jan 90 | M | 75.00 | 25.00 | - | - | - |
| | F | 50.00 | 10.00 | 30.00 | 10.00 | - |
| Feb 90 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| Mar 90 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| Apr 90 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |
| ***gracilis*** | | | | | | |
| Mar 89 | M | 100.00 | - | - | - | - |
| | F | - | 60.00 | 40.00 | - | - |
| Feb 90 | M | 100.00 | - | - | - | - |
| | F | 100.00 | - | - | - | - |

Table 4 : Maturity stages of *S. delicatulus* at Agatti.

| Month & Year | Sex | Stages of maturity | | | | |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | V |
| Dec 88 | M | 33.33 | 13.33 | 6.66 | 46.78 | - |
| | F | 21.43 | 71.43 | - | 7.14 | - |
| Feb 89 | M | 71.43 | 14.29 | 14.28 | - | - |
| | F | 89.47 | - | 10.53 | - | - |
| Mar 89 | M | 21.05 | 78.95 | - | - | - |
| | F | 56.25 | 43.75 | - | - | - |
| Nov 89 | M | - | 54.55 | 18.18 | 27.27 | - |
| | F | - | 100.00 | - | - | - |
| **Bangaram** | | | | | | |
| Nov 88 | M | 9.09 | 9.09 | 72.73 | 9.09 | - |
| | F | 37.50 | 31.25 | 25.00 | 6.25 | - |
| Jan 89 | M | 10.00 | 33.33 | 43.33 | 13.34 | - |
| | F | 31.58 | 68.42 | - | - | - |
| Feb 89 | M | 40.74 | 29.63 | 25.93 | 3.70 | - |
| | F | 33.33 | 30.00 | 36.67 | - | - |
| Mar 89 | M | 40.91 | 45.45 | - | 13.64 | - |
| | F | 73.68 | 21.05 | 5.26 | - | - |
| Oct 89 | M | 88.89 | 11.11 | - | - | - |
| | F | 96.55 | 3.45 | - | - | - |
| Nov 89 | M | - | 60.00 | 30.00 | 10.00 | - |
| | F | - | 96.30 | - | 3.70 | - |
| Dec 89 | M | - | 23.33 | 33.33 | 43.34 | - |
| | F | - | 100.00 | - | - | - |
| Jan 90 | M | 93.33 | 6.67 | - | - | - |
| | F | 70.83 | 25.00 | - | 4.17 | - |
| Feb 90 | M | 52.94 | 14.71 | 20.59 | 11.76 | - |
| | F | 69.57 | 30.43 | - | - | - |
| **Perumal Par** | | | | | | |
| Nov 88 | M | 10.71 | 21.43 | 42.86 | 10.00 | - |
| | F | 43.48 | 52.17 | 4.35 | - | - |
| Dec 88 | M | 15.00 | 35.00 | 45.00 | 5.00 | - |
| | F | 8.70 | 39.13 | 21.74 | 17.39 | 13.04 |
| Jan 89 | M | 3.33 | 53.33 | 36.67 | 6.67 | - |
| | F | - | 93.33 | - | 6.67 | - |
| Feb 89 | M | 48.28 | 48.28 | 3.44 | - | - |
| | F | 57.89 | 15.79 | 5.26 | 21.06 | - |
| Mar 89 | M | 40.00 | 45.00 | 10.00 | 5.00 | - |
| | F | 44.00 | 52.00 | - | - | 4.00 |
| Oct 89 | M | 53.85 | 46.15 | - | - | - |
| | F | 56.25 | 12.50 | - | 31.75 | - |
| Nov 89 | M | 46.67 | 33.33 | 13.33 | 6.67 | - |
| | F | 22.73 | 54.55 | 9.09 | 13.63 | - |
| Dec 89 | M | - | 29.63 | 22.22 | 48.15 | - |
| | F | - | 80.00 | - | 8.00 | 12.00 |
| Jan 90 | M | 91.30 | 4.35 | - | 4.35 | - |
| | F | 100.00 | - | - | - | - |
| Feb 90 | M | 48.28 | 10.34 | 24.14 | 17.24 | - |
| | F | 52.17 | 30.43 | 8.70 | - | - |

delicatulus at Minicoy first occurred in the size group 31-35 mm TL and all fishes were mature in the size group of 51-55 (Fig. 1A,B). S. gracilis also indicated maturity at 31-35 mm with fishes in the size group 56-60 mm attaining 100% maturity (Fig. 2A,B). The stage III males of G. argenteus first appeared in the size group 71-80 mm (Fig. 3A) while females were noticed at 81-90 mm (Fig. 3B). In C. striatus, males and female fishes with stage III first became visible in the size group of 91-100 mm (Fig. 4A,B). Mature fishes of the Pomacentrid C. caeruleus were observed in the size group 27-33 mm TL with all the fishes being mature at 62-68 mm (Fig. 5A,B). Archamia fucata consisted of immature fishes in all the size groups except in 51-55 mm when females were observed in stage II and III also. Apogon thermalis, however had stage III females at 41-45 mm and stage IV females at 46-50 mm and R. gracilis were immature in all the size groups barring 46-50 when females in stage II and III were also noticed. S. delicatulus at Agatti had mature females at 26-30 mm size group (Fig. 6B) and males at 31-35 mm (Fig. 6A). At Bangaram, mature males and females were first observed at 31-35 mm TL (Fig 7A,B). At both Agatti and Bangaram, stage IV females were absent or only in small percentages. Perumal Par had mature fishes at 31-35 mm and spent females from 41-45 mm (Fig. 8A,B). Unlike at Agatti and Bangaram, stage IV females were available in all size groups albeit in lesser percentages.

Females dominated over males in most of the months for

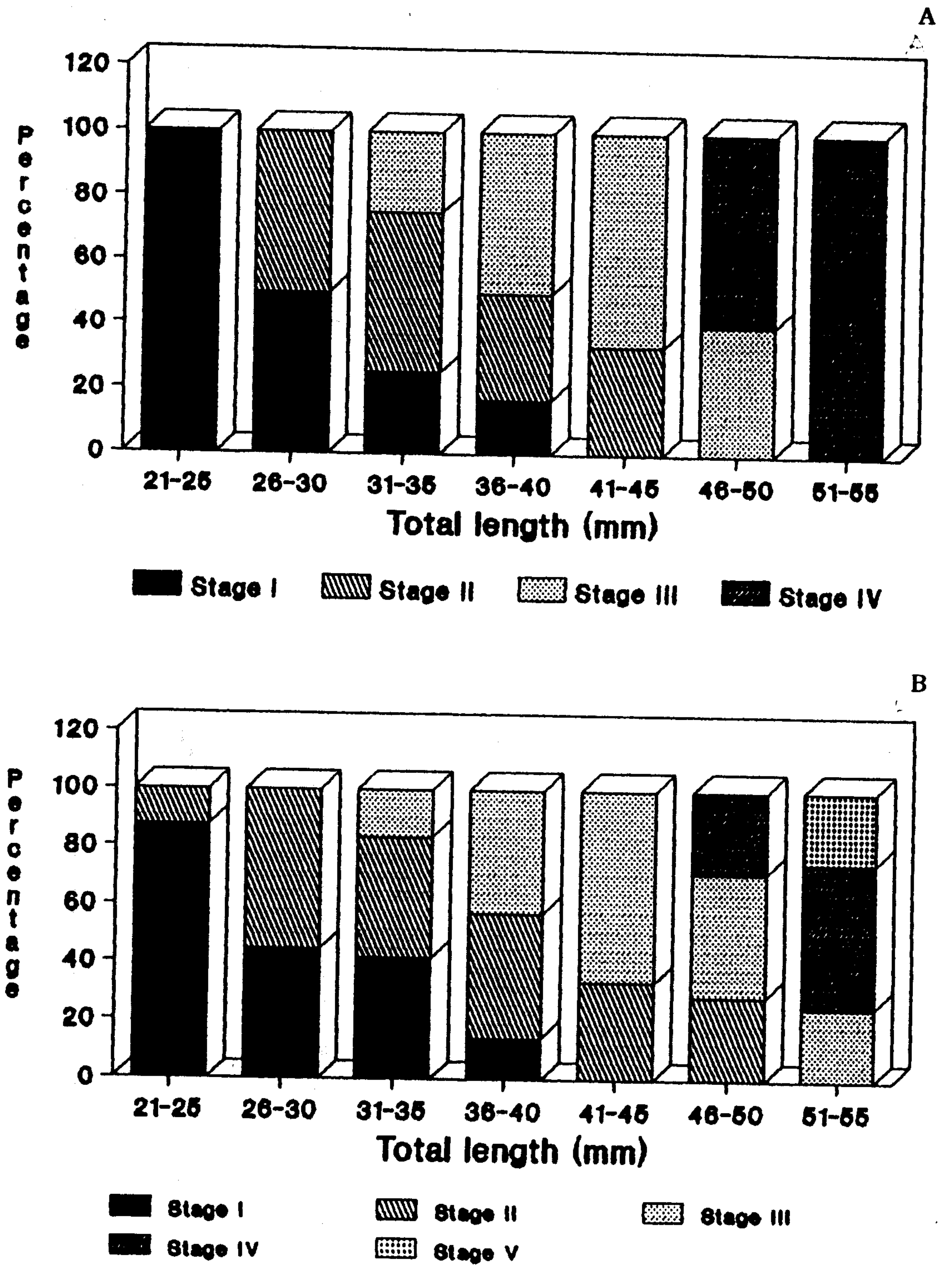


Fig. 1. Maturity stages in relation to size of S. delicatulus at Minicoy. A. Male B. Female.

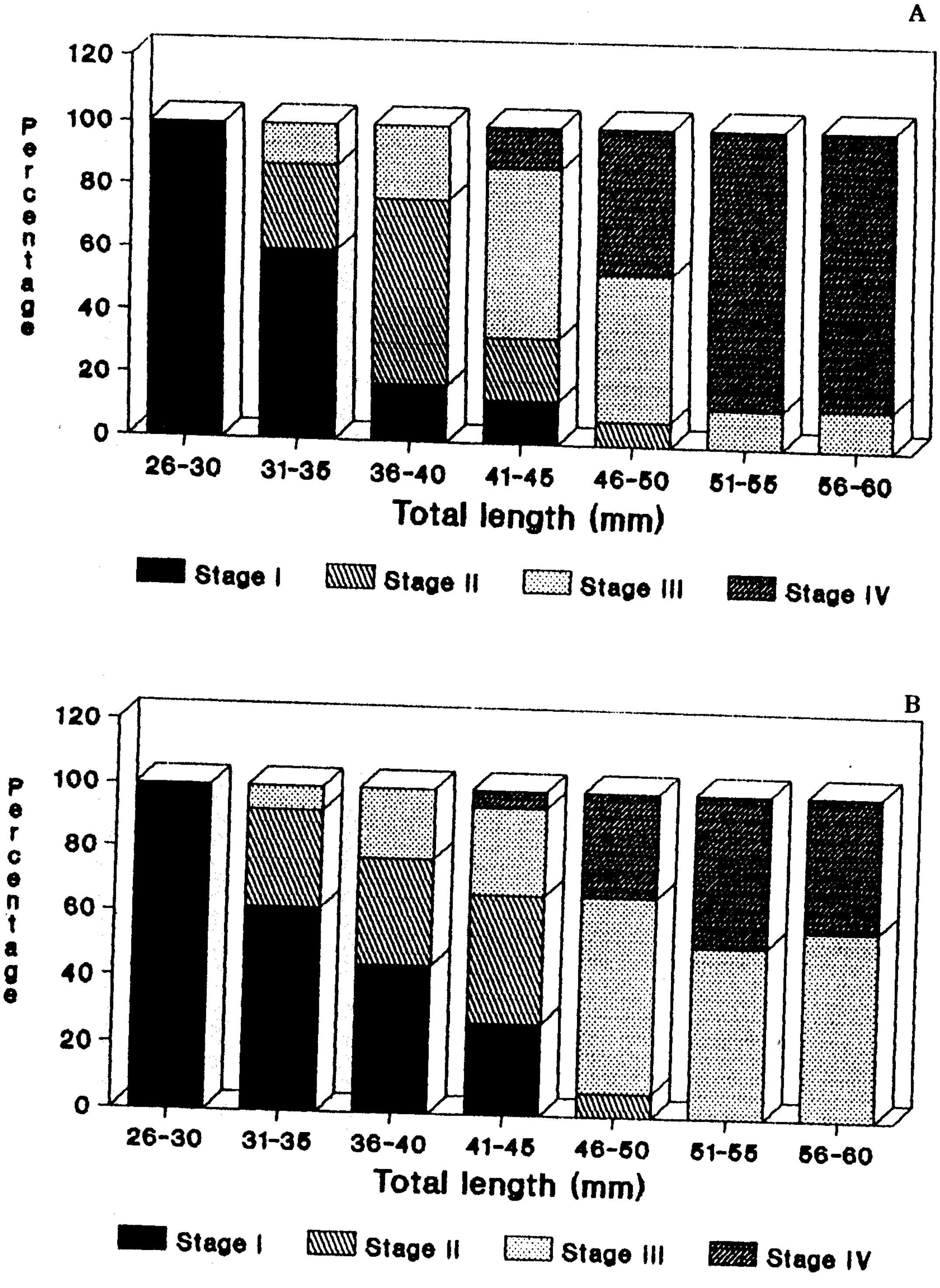


Fig. 2. Maturity stages in relation to size of *S. gracilis* at Minicoy. A. Male B. Female.

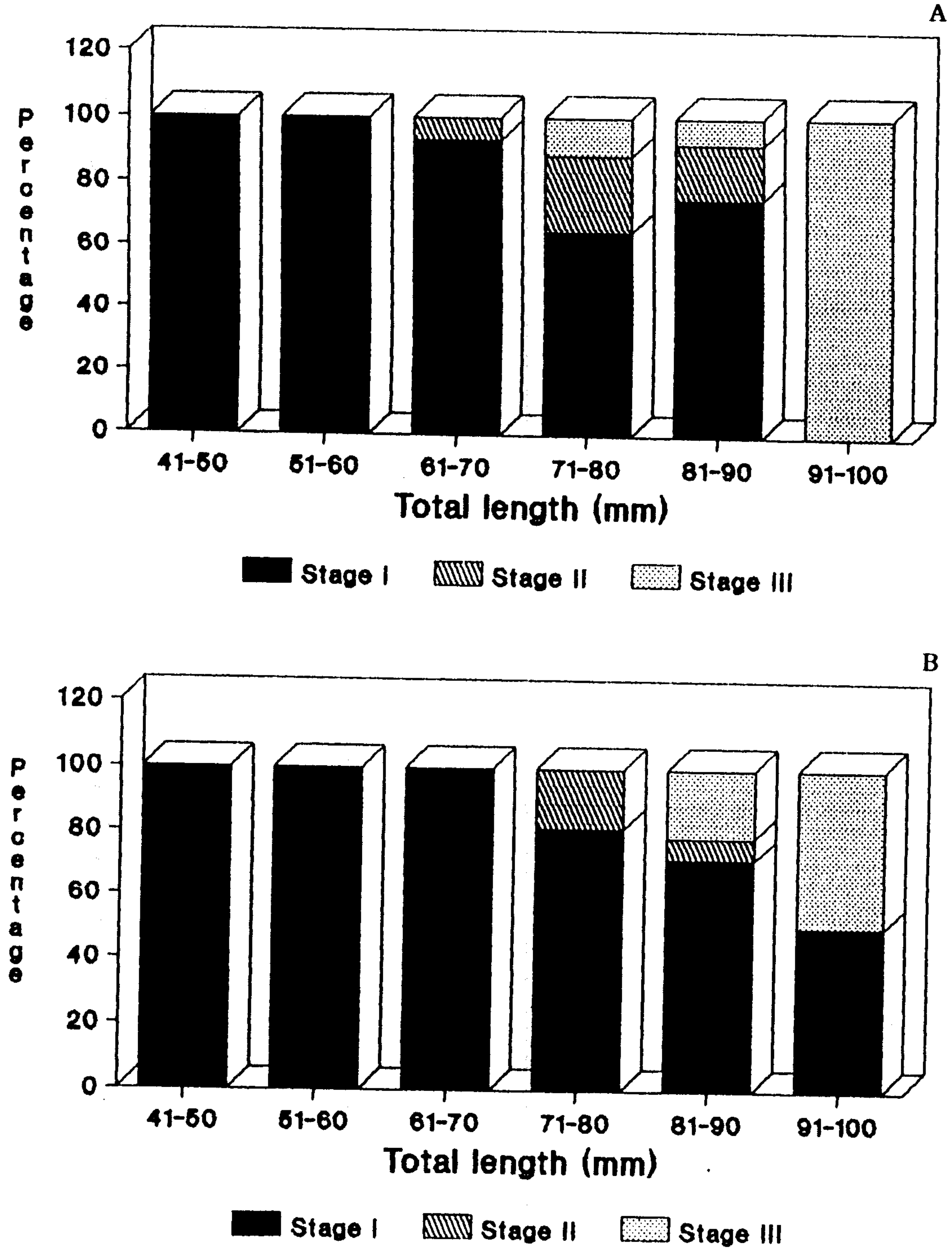


Fig. 3. Maturity stages in relation to size of *G. argenteus* at Minicoy. A. Male B. Female

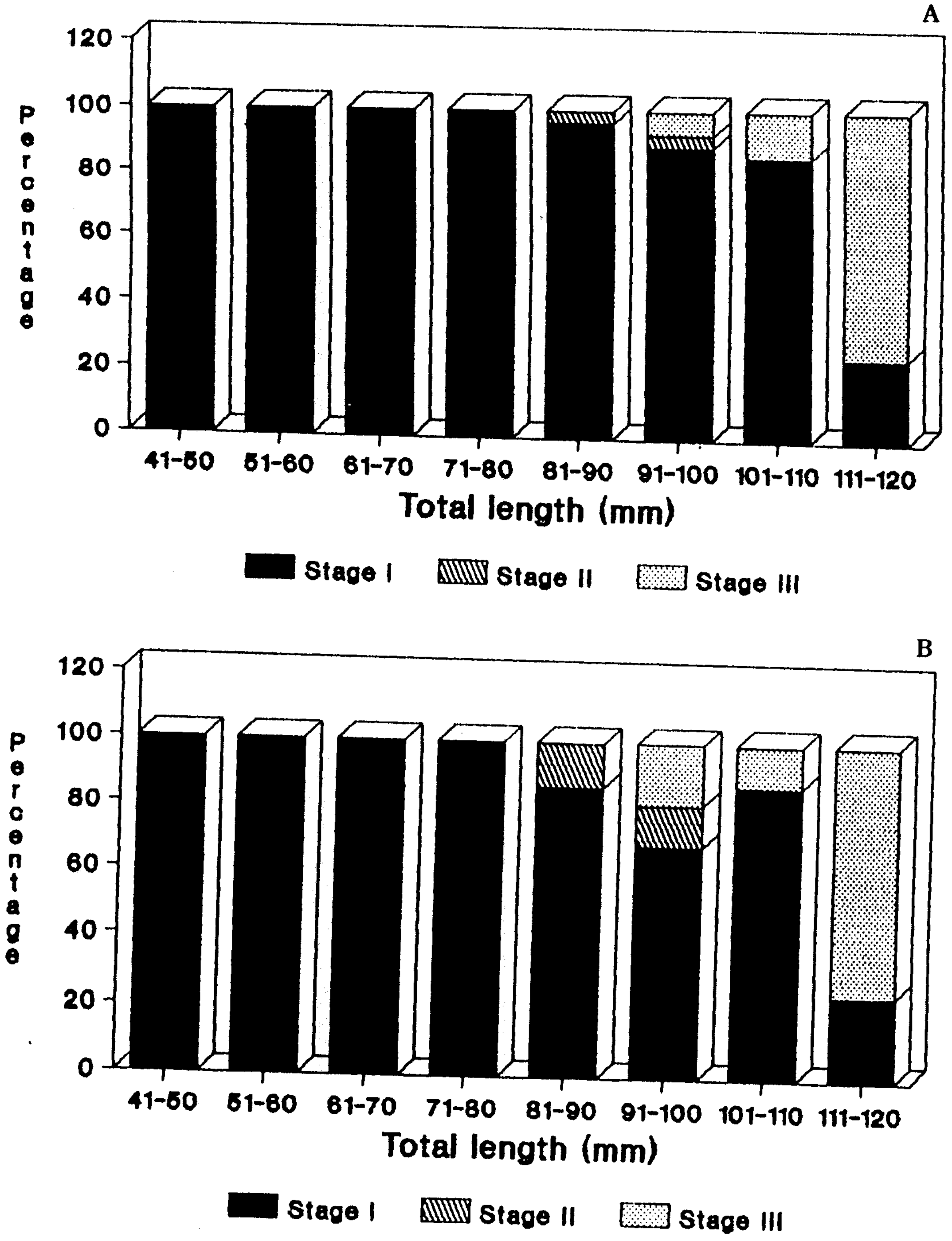


Fig. 4. Maturity stages in relation to size of C. straitus at Minicoy. A. Male B. Female.

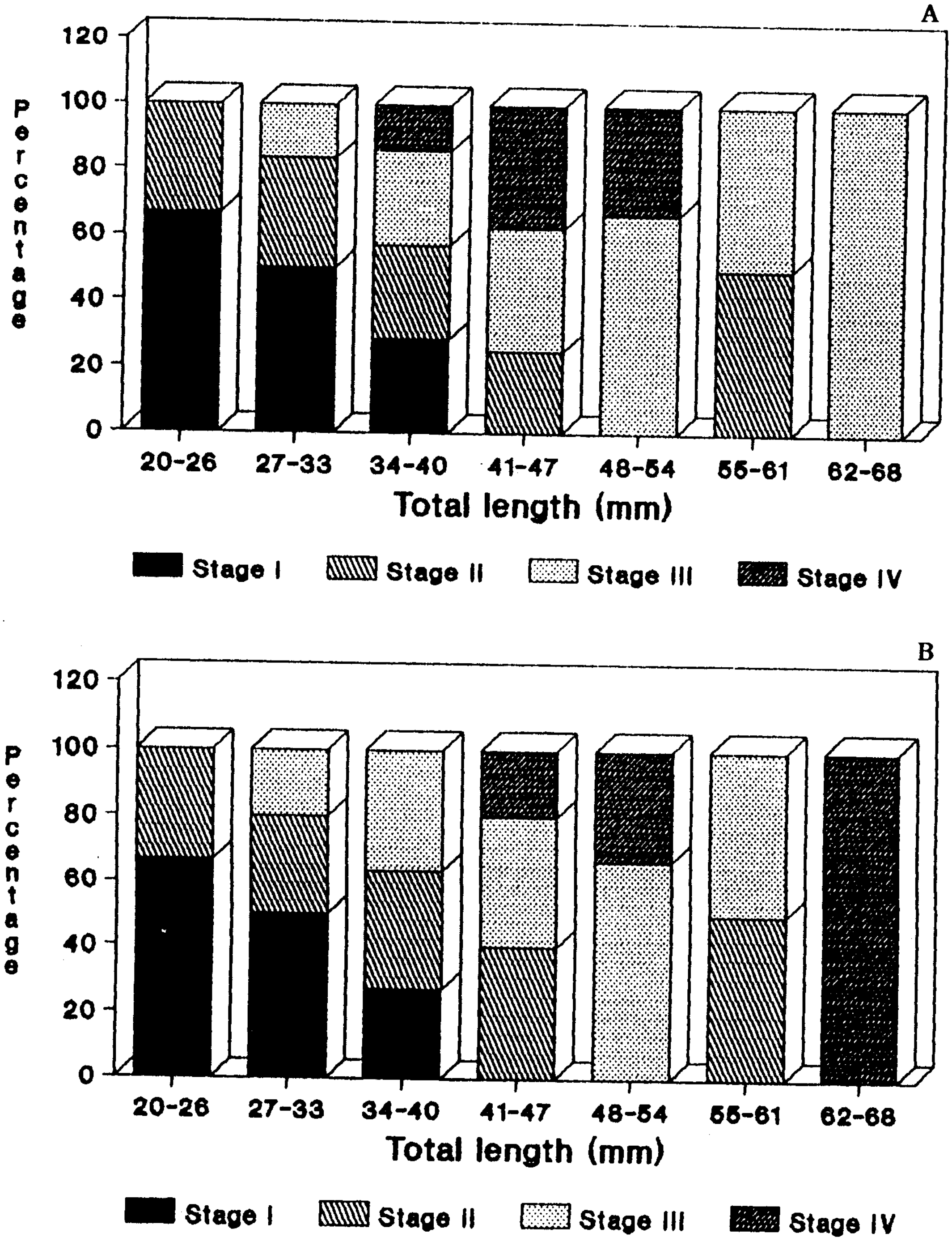


Fig. 5. Maturity stages in relation to size of C. caeruleus at Minicoy. A. Male B. Female.

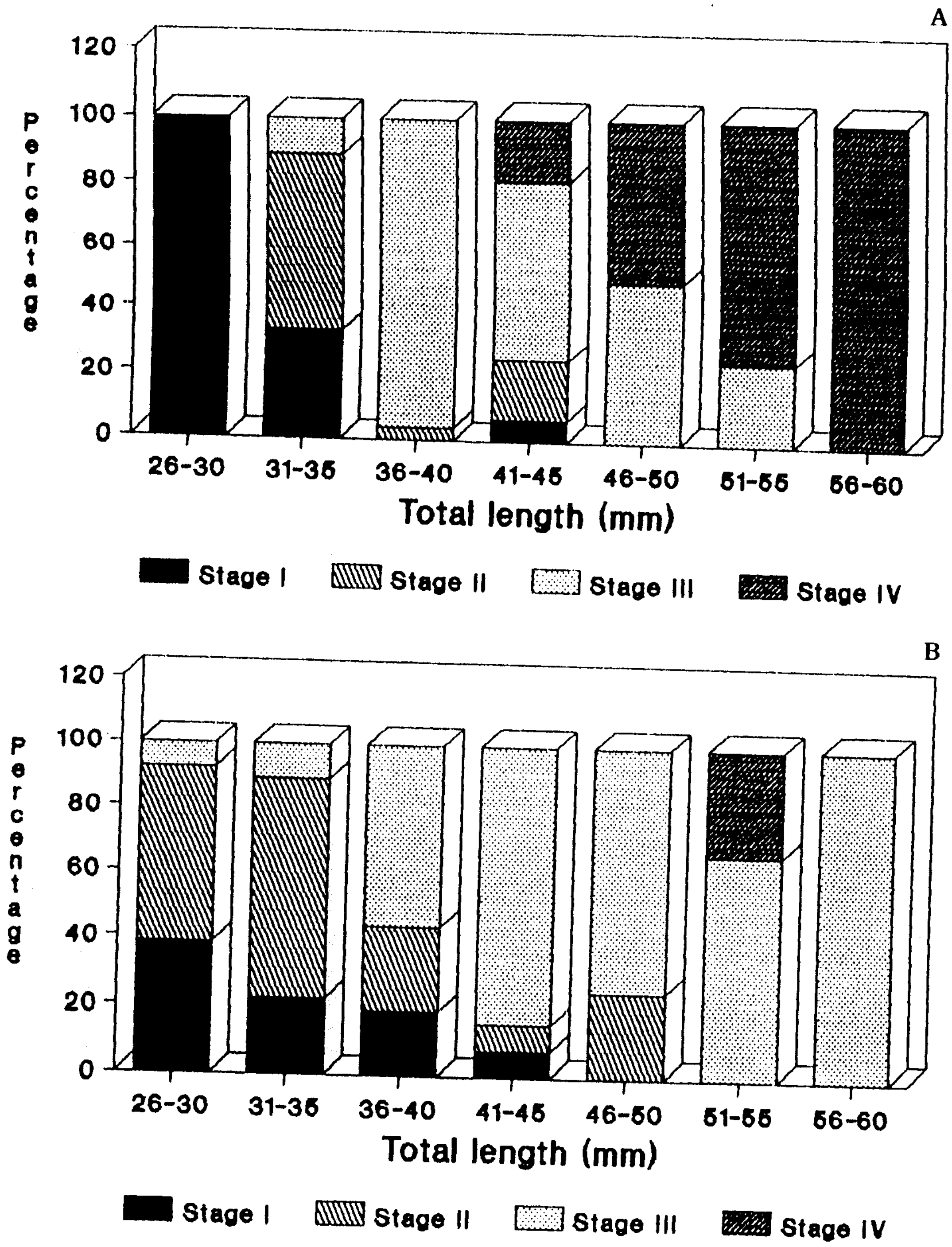


Fig. 6. Maturity stages in relation to size of S. delicatulus at Agatti. A. Male B. Female.

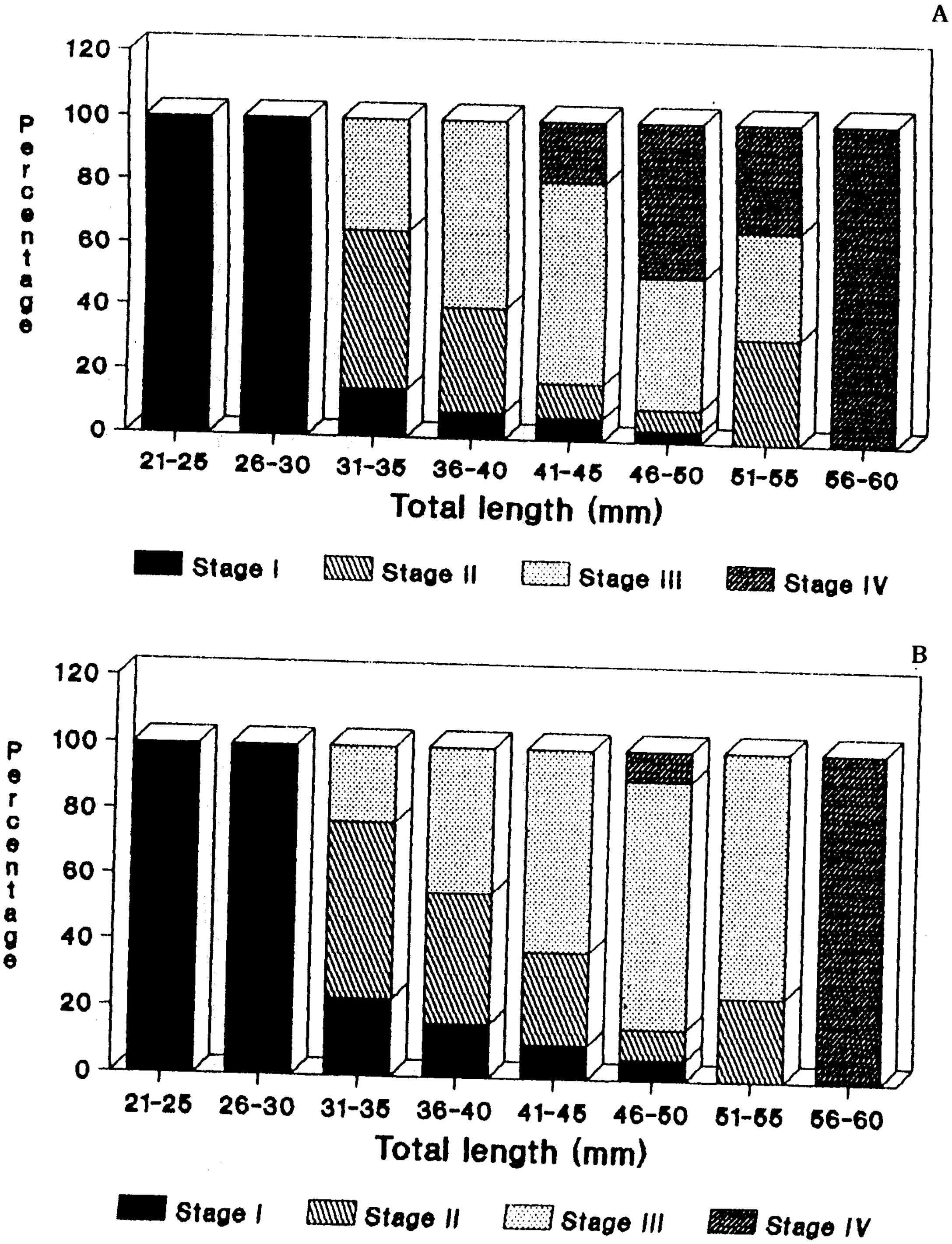


Fig. 7. Maturity stages in relation to size of S. delicatulus at Bangaram. A. Male B. Female.

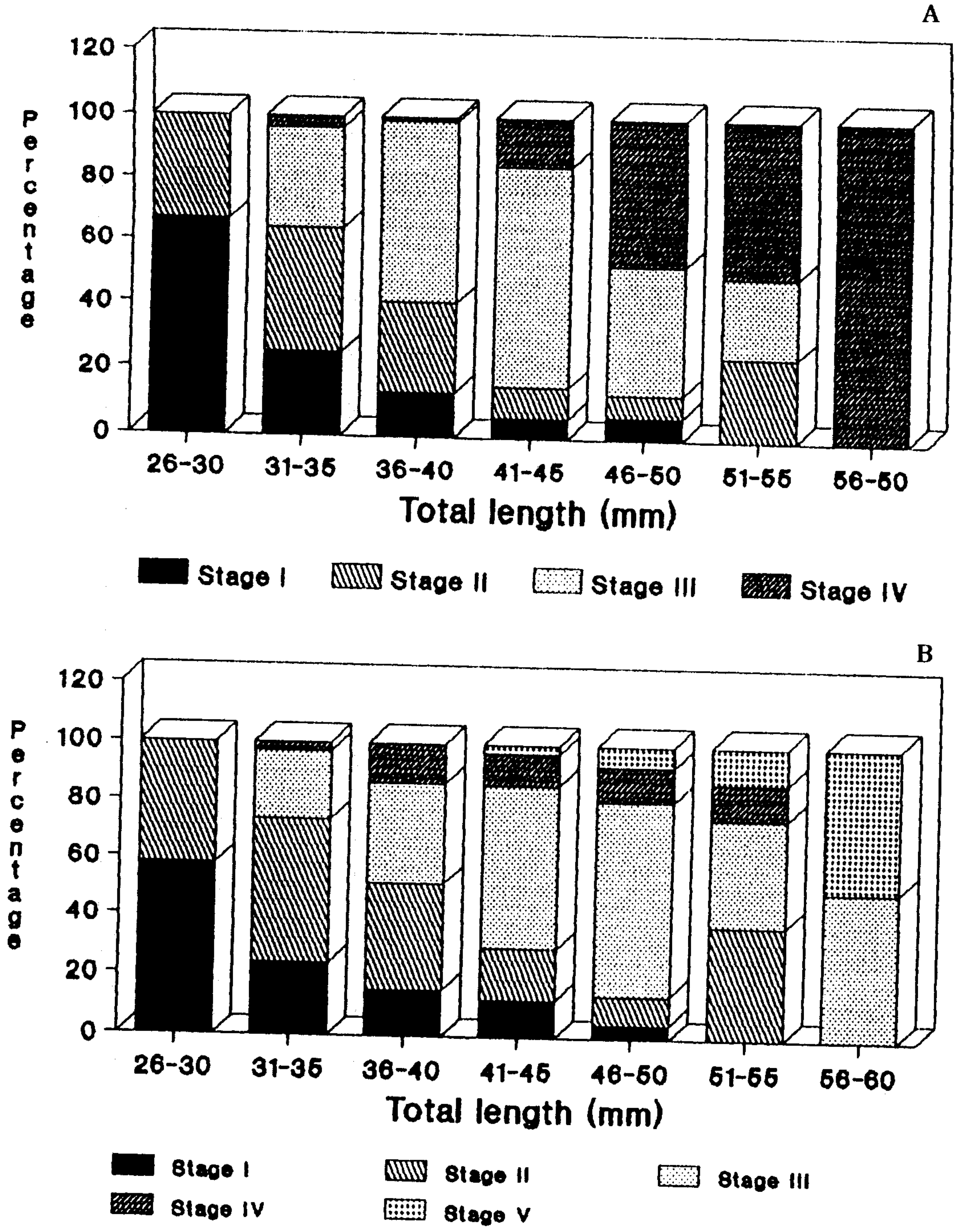


Fig. 8. Maturity stages in relation to size of S. delicatulus at Perumal Par. A. Male B. Female.

*S. delicatulus* and *S. gracilis* at Minicoy (Table 5). The sex ratio of *G. argenteus* and *P. chrysozona* also showed a similar trend while *C. striatus* exhibited more of males in the population (Table 5). There was a predominance of females in *C. caeruleus* while the sex ratio of *L. tapeinosoma* showed a marginal inclination for males. The ratio was significant (P<0.05) during December when females were more than the males (Table 5). *A. fucata* had a female predominant occurrence, *A. thermalis* has male dominating in some months and females in others and in *R. gracilis* the males were predominant (Table 5). *S. delicatulus* at Agatti indicated a dominance of males while at Bangaram females were in relative abundance with the ratio being significant (P<0.01) during October (Table 6). The bluesprat at Perumal Par had males dominating for 5 months, and similar to the observation at Bangaram, the sex ratio was significant (P<0.05) in October (Table 6).

*S. delicatulus* at Minicoy showed a higher percentage of females in all size groups except 41-45 mm TL where the ratio was 1:1. The female occurrence was highest in the 51-55 mm category with 4 females for every male (Table 7). This ratio was significant (P<0.01). In the small fish groups of *S. gracilis* females dominated barring 31-35 mm, and the higher size groups have a male domination. Females dominated in a majority of size groups of *G. argenteus* and *P. chrysozona* while males dominated in most size groups of *C. striatus* (Table 7). In the early sizes of

Table 5 : Sex ratio of live-baits at Minicoy.

| es | Month & Year | N | Percentage |  | Sex Ratio (M:F) |
|---|---|---|---|---|---|
|  |  |  | Male | Female |  |
| *icatulus* | Nov 88 | 19 | 36.84 | 63.16 | 1:1.7 |
|  | Dec 88 | 19 | 63.16 | 36.84 | 1:0.5 |
|  | Apr 89 | 19 | 31.58 | 68.42 | 1:2.1 |
|  | Sep 89 | 19 | 31.53 | 68.42 | 1:2.1 |
|  | Oct 89 | 18 | 61.11 | 38.89 | 1:0.6 |
| *racilis* | Nov 88 | 11 | 45.45 | 54.55 | 1:1.2 |
|  | Dec 88 | 19 | 47.37 | 52.63 | 1:1.1 |
|  | Jan 89 | 20 | 60.00 | 40.00 | 1:0.7 |
|  | Dec 89 | 62 | 41.94 | 58.06 | 1:1.4 |
|  | Jan 90 | 36 | 86.11 | 13.89 | 1:0.2 |
|  | Feb 90 | 7 | 57.14 | 42.86 | 1:0.8 |
|  | Mar 90 | 54 | 44.44 | 55.56 | 1:1.3 |
|  | Apr 90 | 30 | 46.67 | 53.33 | 1:1.1 |
| *rgenteus* | Jan 89 | 10 | 50.00 | 50.00 | 1:1.0 |
|  | Feb 89 | 20 | 45.00 | 55.00 | 1:1.2 |
|  | Mar 89 | 12 | 41.67 | 58.33 | 1:1.4 |
|  | Nov 89 | 56 | 50.00 | 50.00 | 1:1.0 |
|  | Dec 89 | 31 | 54.84 | 45.16 | 1:0.8 |
|  | Jan 90 | 30 | 36.67 | 63.33 | 1:1.7 |
|  | Mar 90 | 16 | 62.50 | 37.50 | 1:0.6 |
| *riatus* | Nov 88 | 13 | 69.23 | 30.77 | 1:0.4 |
|  | Dec 88 | 16 | 68.75 | 31.25 | 1:0.5 |
|  | Nov 89 | 38 | 52.63 | 47.37 | 1:0.9 |
|  | Dec 89 | 43 | 72.09 | 27.91 | 1:0.4 |
|  | Jan 90 | 37 | 45.95 | 54.05 | 1:1.2 |
|  | Feb 90 | 17 | 70.59 | 29.41 | 1:0.4 |
|  | Mar 90 | 16 | 31.25 | 68.75 | 1:2.2 |
| *rysozona* | Nov 88 | 14 | 50.00 | 50.00 | 1:1.0 |
|  | Feb 90 | 12 | 41.67 | 58.33 | 1:1.4 |
|  | Mar 90 | 12 | 66.67 | 33.33 | 1:0.5 |
| *eruleus* | Nov 88 | 15 | 40.00 | 60.00 | 1:1.5 |
|  | Dec 88 | 14 | 50.00 | 50.00 | 1:1.0 |
|  | Feb 89 | 11 | 36.36 | 63.34 | 1:1.8 |
|  | Feb 90 | 27 | 37.04 | 62.96 | 1:1.7 |
| *peinosoma* | Nov 89 | 12 | 50.00 | 50.00 | 1:1.0 |
|  | Dec 89 | 24 | 29.17 | 70.83 | 1:2.4 |
|  | Jan 90 | 16 | 62.50 | 37.50 | 1:0.6 |
|  | Feb 90 | 19 | 68.42 | 31.58 | 1:0.5 |
| *cata* | Mar 89 | 18 | 38.89 | 61.11 | 1:1.6 |
|  | Feb 90 | 10 | 40.00 | 60.00 | 1:1.5 |
|  | Apr 90 | 24 | 41.67 | 58.33 | 1:1.4 |
| *ermalis* | Jan 90 | 22 | 54.55 | 45.45 | 1:0.8 |
|  | Feb 90 | 17 | 70.59 | 29.41 | 1:0.4 |
|  | Mar 90 | 18 | 38.89 | 61.11 | 1:1.6 |
|  | Apr 90 | 32 | 43.75 | 56.25 | 1:1.3 |
| *acilis* | Mar 89 | 17 | 70.59 | 29.41 | 1:0.4 |
|  | Feb 90 | 28 | 60.71 | 39.29 | 1:0.6 |

Table 6 : Monthly sex ratio of *S. delicatulus* at Agatti.

| tion | Month & Year | N | Percentage | | Sex Ratio (M:F) |
|---|---|---|---|---|---|
| | | | Male | Female | |
| ti | Dec 88 | 30 | 53.33 | 46.67 | 1:0.9 |
| | Feb 89 | 34 | 41.18 | 58.82 | 1:1.4 |
| | Mar 89 | 37 | 54.05 | 45.95 | 1:0.9 |
| | Nov 89 | 38 | 57.29 | 42.22 | 1:0.7 |
| aram | Nov 88 | 30 | 40.00 | 60.00 | 1:1.5 |
| | Jan 89 | 57 | 59.65 | 40.35 | 1:0.7 |
| | Feb 89 | 57 | 47.37 | 52.63 | 1:1.1 |
| | Mar 89 | 42 | 54.76 | 45.24 | 1:0.8 |
| | Oct 89 | 38 | 23.68 | 76.32 | 1:3.2** |
| | Nov 89 | 57 | 52.63 | 47.37 | 1:0.9 |
| | Dec 89 | 40 | 75.00 | 25.00 | 1:0.3 |
| | Jan 90 | 39 | 38.46 | 61.54 | 1:1.6 |
| | Feb 90 | 57 | 59.65 | 40.35 | 1:0.6 |
| mal Par | Nov 88 | 52 | 55.77 | 44.23 | 1:0.8 |
| | Dec 88 | 44 | 45.45 | 54.55 | 1:1.2 |
| | Jan 89 | 45 | 66.67 | 33.37 | 1:0.5 |
| | Feb 89 | 48 | 60.42 | 39.58 | 1:0.7 |
| | Mar 89 | 46 | 43.48 | 56.52 | 1:1.3 |
| | Oct 89 | 45 | 28.89 | 71.11 | 1:2.5* |
| | Nov 89 | 37 | 40.54 | 59.46 | 1:1.5 |
| | Dec 89 | 52 | 51.92 | 48.08 | 1:0.9 |
| | Jan 90 | 54 | 42.59 | 57.41 | 1:1.4 |
| | Feb 90 | 52 | 55.77 | 44.23 | 1:0.8 |

* $P < 0.01$     ** $P < 0.01$

able 7 : Size-wise sex ratio of clupeids and caesionids and pomacentrids at Minicoy.

| cies | Total Length (mm) | N | Percentage |  | Sex Ratio (M:F) |
|---|---|---|---|---|---|
|  |  |  | Male | Female |  |
| *delicatulus* | 21-25 | 15 | 46.67 | 53.33 | 1:1.1 |
|  | 26-30 | 17 | 47.06 | 52.94 | 1:1.1 |
|  | 31-35 | 23 | 40.00 | 60.00 | 1:1.5 |
|  | 36-40 | 13 | 46.15 | 53.85 | 1:1.2 |
|  | 41-45 | 6 | 50.00 | 50.00 | 1:1.0 |
|  | 46-50 | 12 | 41.67 | 58.33 | 1:1.4 |
|  | 51-55 | 5 | 20.00 | 80.00 | 1:4.0 |
|  | 56-60 | 2 | 100.00 | - | - |
|  | 61-65 | 1 | 100.00 | - | - |
| *gracilis* | 26-30 | 3 | 33.33 | 66.67 | 1:2.0 |
|  | 31-35 | 28 | 53.57 | 46.43 | 1:0.9 |
|  | 36-40 | 35 | 48.57 | 51.43 | 1:1.1 |
|  | 41-45 | 33 | 45.45 | 54.55 | 1:1.2 |
|  | 46-50 | 53 | 49.06 | 50.94 | 1:1.0 |
|  | 51-55 | 57 | 55.74 | 44.26 | 1:0.8 |
|  | 56-60 | 30 | 53.33 | 46.67 | 1:0.9 |
| *argenteus* | 41-50 | 6 | 33.33 | 66.67 | 1:2.0 |
|  | 51-60 | 47 | 46.81 | 53.19 | 1:1.1 |
|  | 61-70 | 58 | 49.12 | 50.88 | 1:1.0 |
|  | 71-80 | 33 | 51.52 | 48.48 | 1:0.9 |
|  | 81-90 | 26 | 46.15 | 53.85 | 1:1.2 |
|  | 91-100 | 5 | 60.00 | 40.00 | 1:0.7 |
| *striatus* | 41-50 | 3 | 66.67 | 33.33 | 1:0.5 |
|  | 51-60 | 4 | 75.00 | 25.00 | 1:0.3 |
|  | 61-70 | 24 | 50.00 | 50.00 | 1:1.0 |
|  | 71-80 | 16 | 56.25 | 43.75 | 1:0.8 |
|  | 81-90 | 47 | 64.29 | 35.71 | 1:0.6 |
|  | 91-100 | 63 | 62.79 | 37.21 | 1:0.6 |
|  | 101-110 | 15 | 46.67 | 53.33 | 1:1.1 |
|  | 111-120 | 8 | 50.00 | 50.00 | 1:1.0 |
| *chrysozona* | 41-50 | 2 | 50.00 | 50.00 | 1:1.0 |
|  | 51-60 | 3 | 66.67 | 33.33 | 1:0.5 |
|  | 61-70 | 5 | 60.00 | 40.00 | 1:0.7 |
|  | 71-80 | 21 | 33.33 | 66.67 | 1:2.0 |
|  | 81-90 | 5 | 60.00 | 40.00 | 1:0.7 |
|  | 91-100 | 2 | 50.00 | 50.00 | 1:1.0 |
| *caeruleus* | 20-26 | 9 | 33.33 | 66.67 | 1:2.0 |
|  | 27-33 | 16 | 37.50 | 62.50 | 1:1.7 |
|  | 34-40 | 19 | 38.89 | 61.11 | 1:1.6 |
|  | 41-47 | 13 | 61.54 | 38.46 | 1:0.6 |
|  | 48-54 | 6 | 50.00 | 50.00 | 1:1.0 |
|  | 55-61 | 4 | 50.00 | 50.00 | 1:1.0 |
| *tapeinosoma* | 41-45 | 24 | 50.00 | 50.00 | 1:1.0 |
|  | 46-50 | 34 | 46.88 | 53.12 | 1:1.1 |
|  | 51-55 | 11 | 45.45 | 54.55 | 1:1.2 |
|  | 61-65 | 2 | 50.00 | 50.00 | 1:1.0 |

C. caeruleus, females were dominant and in later stages the ratio was equal. The sex ratio of L. tapeinosoma tended to be near 1:1 with occasional dominance of females. A. fucata comprised more of females in early stages and males in later while the condition is reversed in the case of A. thermalis and R. gracilis (Table 8). A distinct predominance of females in the starting size groups and then by males in bigger stages was noticed for S. delicatulus at Agatti. Similar conditions was observed both at Bangaram and Perumal Par with females reasserting at the 46-50 mm TL group (Table 9).

The minimum gonosomatic index (GSI) values for ripening (Stage III) females of S. delicatulus was 2.08 at Minicoy and the maximum of 3.50 at Agatti (Table 10). The percent weight of ovaries that were ripe (Stage IV) was considerably low at Perumal Par when compared to the other sites. S. gracilis had a similar GSI values for stage III as that of S. delicatulus but the values for stage IV was considerably lower. The comparatively advanced ovaries of G. argenteus and C. striatus occupied only less than 1% of the total body weight. C. caeruleus with values of above 4.0 were mature and at 6.0 were in ripe condition. The mature gonads of apogonids showed GSI values ranging from 2.01 for A. fucata to 3.58 for A. thermalis, while the ripe condition values ranged from 4 to 6% (Table 10).

The progression of egg size with maturity stages indicated a range with distinct peaks for the various livebaits

Table 8 : Size-wise sex ratio of apogonids at Minicoy

| | Total Length (mm) | N | Percentage Male | Percentage Female | Sex Ratio (M:F) |
|---|---|---|---|---|---|
| ta | 41-45 | 2 | 50.00 | 50.00 | 1:1.0 |
| | 46-50 | 5 | 40.00 | 60.00 | 1:1.5 |
| | 51-55 | 33 | 42.42 | 57.58 | 1:1.4 |
| | 56-60 | 11 | 54.55 | 45.45 | 1:0.8 |
| | 61-65 | 1 | - | 100.00 | - |
| malis | 31-35 | 13 | 69.23 | 30.77 | 1:0.4 |
| | 36-40 | 44 | 45.45 | 54.55 | 1:1.2 |
| | 41-45 | 23 | 43.48 | 56.52 | 1:1.3 |
| | 46-50 | 6 | 33.33 | 66.67 | 1:2.0 |
| | 51-55 | 1 | 100.00 | - | - |
| | 56-60 | 2 | 100.00 | - | - |
| ilis | 21-25 | 6 | 66.67 | 33.33 | 1:0.5 |
| | 26-30 | 8 | 50.00 | 50.00 | 1:1.0 |
| | 31-35 | 17 | 52.94 | 47.06 | 1:0.9 |
| | 36-40 | 6 | 100.00 | - | |
| | 41-45 | 2 | 100.00 | - | |
| | 46-50 | 6 | 33.33 | 66.67 | 1:2.0 |

able 9 : Size-wise sex ratio of *S. delicatulus* at Agatti.

| n | Total Length (mm) | N | Percentage Male | Percentage Female | Sex Ratio (M:F) |
|---|---|---|---|---|---|
| | 26-30 | 19 | 31.58 | 68.42 | 1:2.2 |
| | 31-35 | 21 | 42.86 | 57.14 | 1:1.3 |
| | 36-40 | 42 | 59.52 | 40.48 | 1:0.7 |
| | 41-45 | 28 | 57.14 | 42.86 | 1:0.8 |
| | 46-50 | 13 | 61.54 | 38.46 | 1:0.6 |
| | 51-55 | 9 | 55.55 | 44.45 | 1:0.8 |
| | 56-60 | 7 | 42.86 | 57.14 | 1:1.3 |
| m | 21-25 | 4 | 50.00 | 50.00 | 1:1.0 |
| | 26-30 | 22 | 31.82 | 68.18 | 1:2.1 |
| | 31-35 | 39 | 53.85 | 46.15 | 1:0.9 |
| | 36-40 | 119 | 52.10 | 47.90 | 1:0.9 |
| | 41-45 | 154 | 56.49 | 43.51 | 1:0.8 |
| | 46-50 | 70 | 44.29 | 55.71 | 1:1.3 |
| | 51-55 | 7 | 42.86 | 57.14 | 1:1.3 |
| | 56-60 | 2 | 50.00 | 50.00 | 1:1.0 |
| Par | 26-30 | 26 | 30.77 | 69.23 | 1:2.3 |
| | 31-35 | 64 | 48.44 | 51.56 | 1:1.1 |
| | 36-40 | 142 | 53.52 | 46.48 | 1:0.9 |
| | 41-45 | 151 | 53.64 | 46.36 | 1:0.9 |
| | 46-50 | 71 | 43.66 | 56.34 | 1:1.3 |
| | 51-55 | 17 | 47.06 | 52.94 | 1:1.1 |
| | 56-60 | 4 | - | 100.00 | - |

studied. S. delicatulus at Minicoy showed two peaks for stages I and IV with only a single mode at stages II and III (Fig. 9A). The ova diameter of S. gracilis ranged from 0.07 mm for stage I to 0.62 mm for stage IV (Fig.9B). Distinct modes were not observed in stages II and III and the mode at stage IV was distinct at 0.57 mm. C. caeruleus indicated short ranges for each stage with mode at 0.05, 0.11, 0.22 and 0.33 mm for stages I to IV respectively (Fig.10A). More than one mode was seen for each stage of maturity in the case of A. fucata, with the first mode at 0.11 in stage I to a last mode at 0.45 mm for stage IV (Fig.10B). S. delicatulus at Agatti showed a decreasing trend for stage I with increase in ova diameter with peaks at 0.03 and 0.07 mm. The other stages had distinct modes over a wide range of egg size (Fig.11A). Multiple modes were observed in all stages except stage I in S. delicatulus at Bangaram (Fig.11B) with minimum ova diameter group at 0.03 and maximum at 0.53 mm. Definite modes were apparent in the earlier stages of maturity of S. delicatulus at Perumal Par but at stage IV the egg diameter ranged widely from 0.36 to 0.74 mm and sharp modes were absent (Fig.12).

The size at first maturity for pooled data of S. delicatulus from Minicoy was 35 mm SL, whilst that of S. gracilis was 37 mm. Males attained maturity faster than females in both the cases (Table 11). At Agatti, Bangaram and Perumal Par the size at maturity of S. delicatulus were 32, 33 and 31 mm

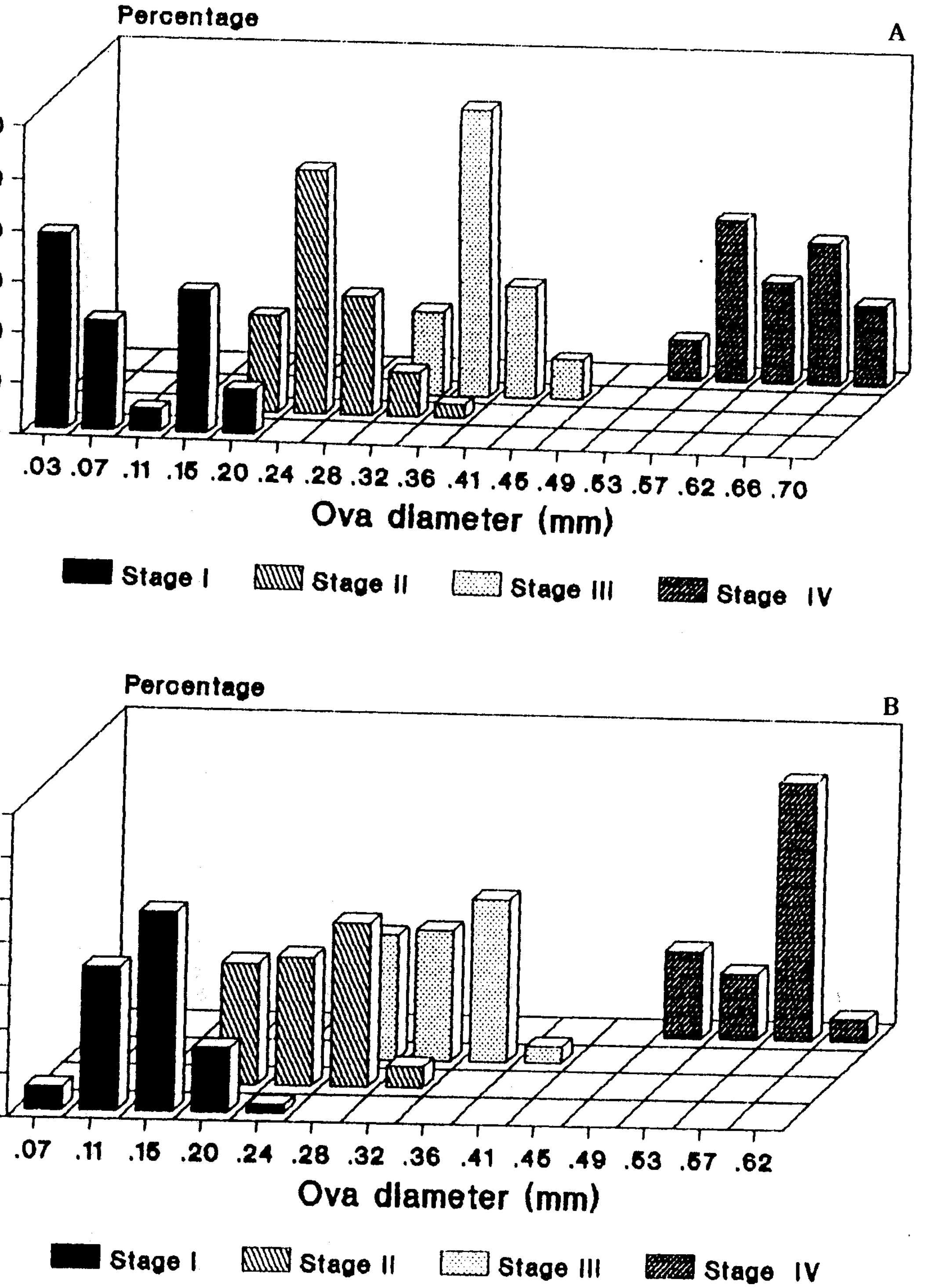


Fig. 9. Progressive development of maturing eggs of Clupeids at Minicoy.
A. *S. delicatulus* B. *S. gracilis.*

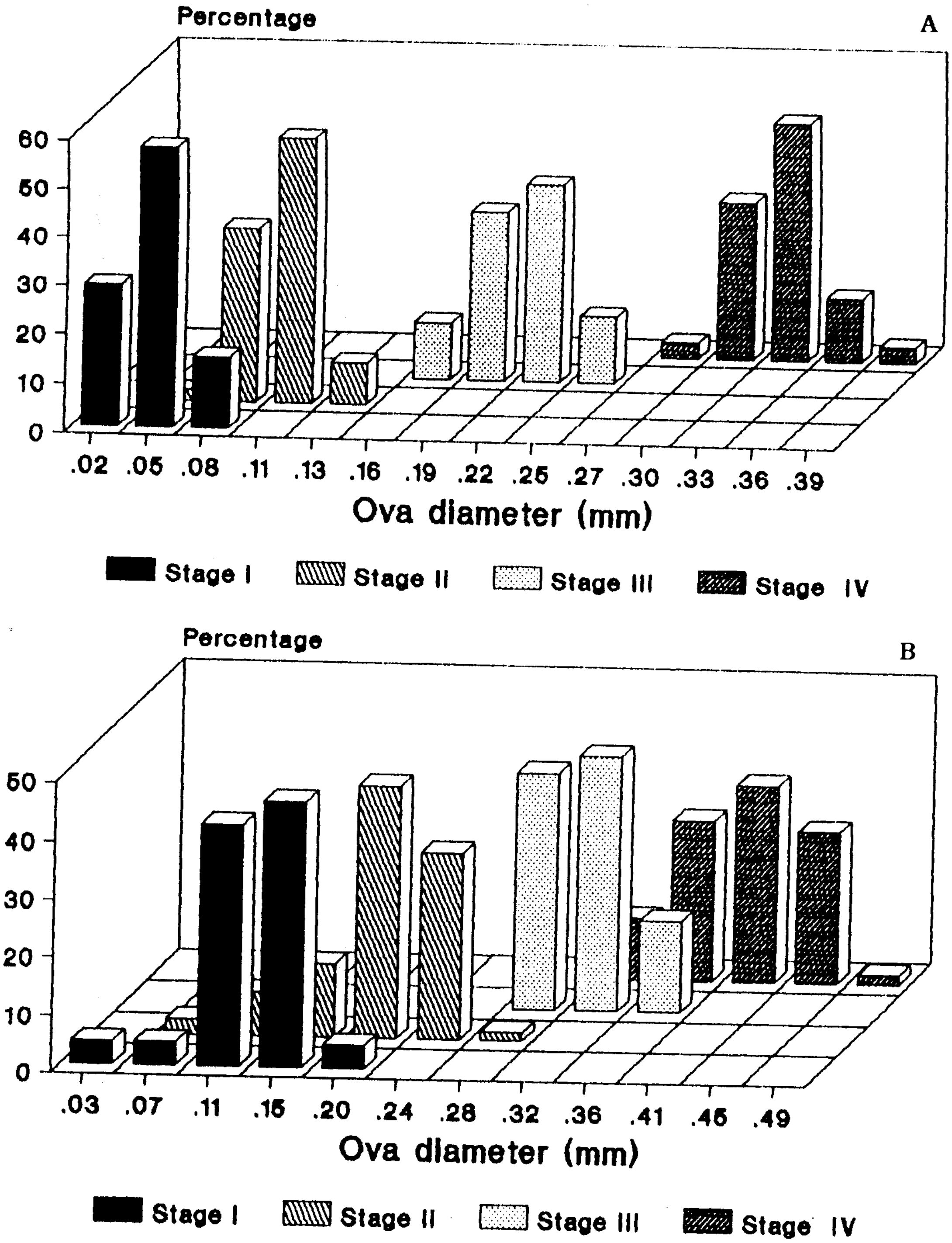


Fig. 10. Progressive development of maturing eggs of C. caeruleus (A) and A. fucata (B) at Minicoy.

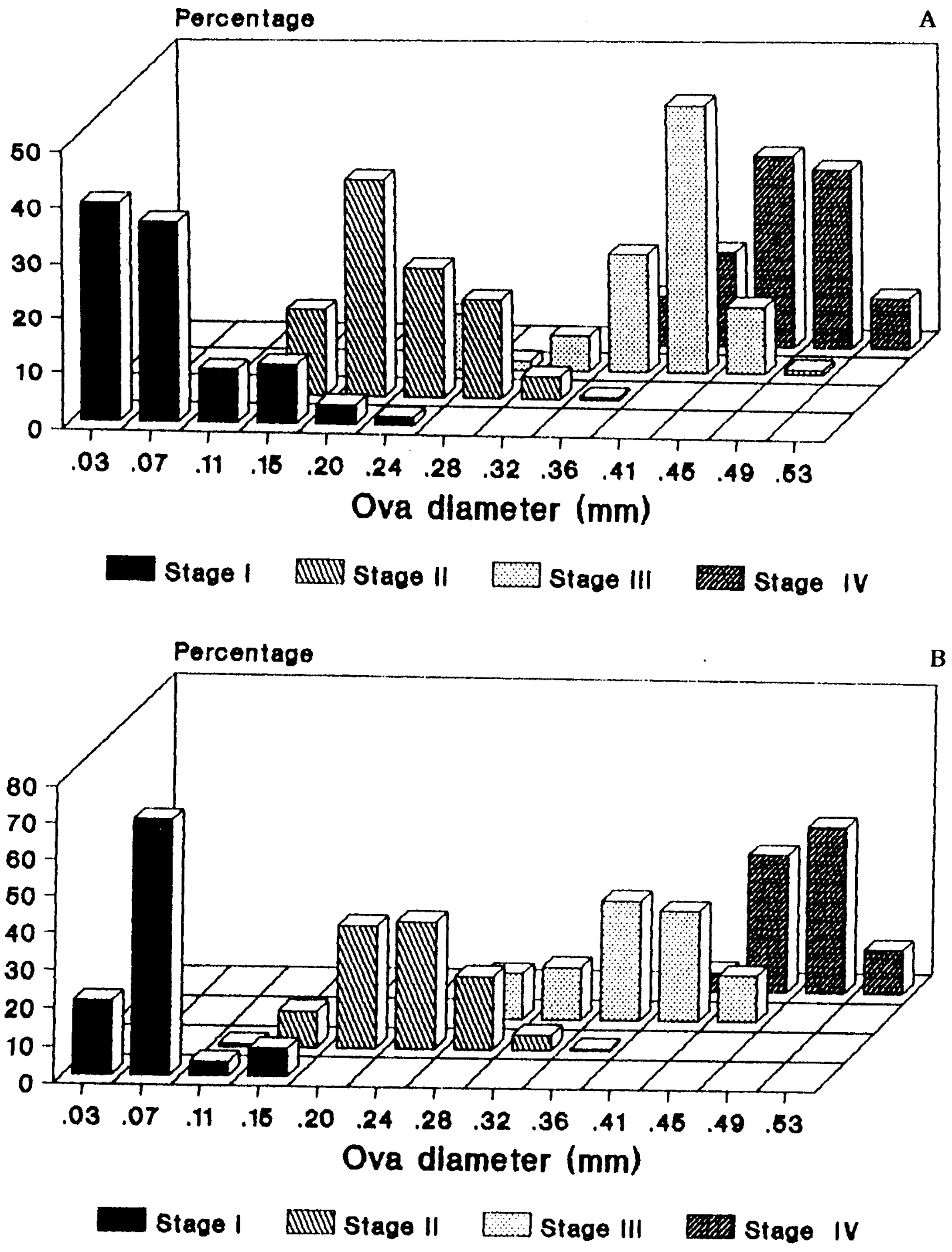


Fig. 11. Progressive development of maturing eggs of S. delicatulus at Agatti (A) and Bangaram (B).

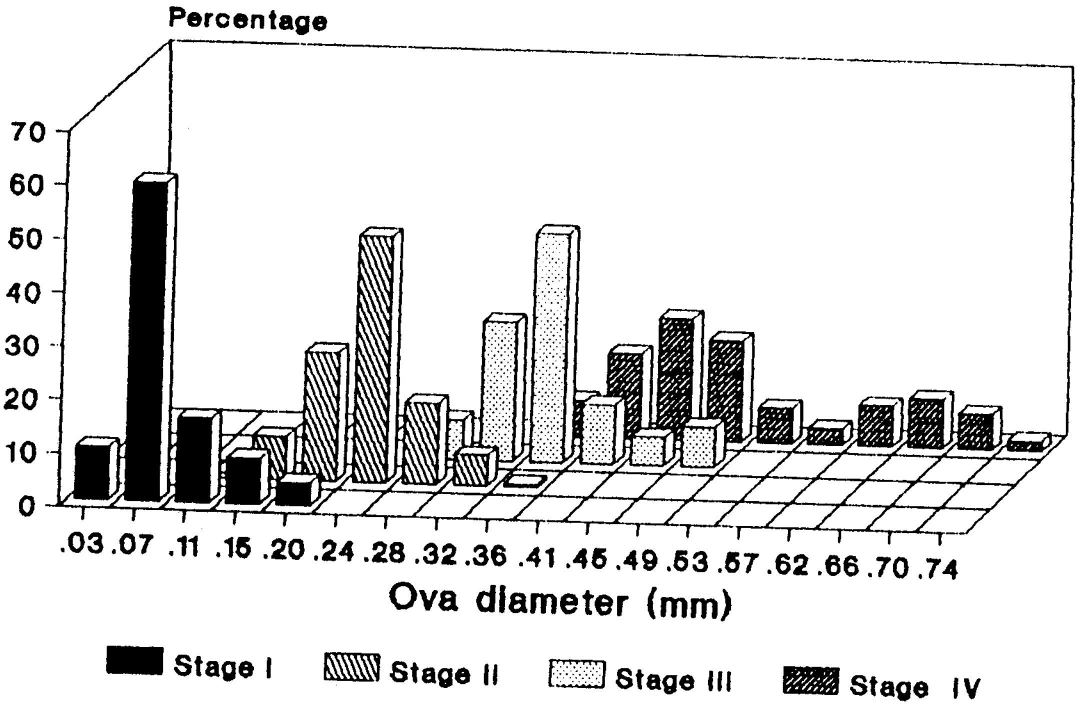


Fig. 12. Progressive development of maturing eggs of *S. delicatulus* at Perumal Par.

respectively. For the other baitfishes, length at sexual maturity could not be calculated by linear regression. The minimum size at which stage III was recorded in these fishes are given in Table 12.

The relation between fecundity and total length and total weight was calculated by regression analysis. Barring the relationship for S. delicatulus at Agatti, there was a significant correlation ($P<0.01$) at the other sites (Table 13). A similar relationship was also observed with S. gracilis and A. fucata (Table 13). The mean absolute fecundity of S. delicatulus at Minicoy, Agatti, Bangaram and Perumal Par in sequence were 545, 369, 261 and 387 (Tables 14,15). Average absolute fecundity for S. gracilis was higher at 884 eggs. The mean total number of eggs in the ovaries of C. caeruleus was 3507 while that of A. fucata was 1650. Average relative fecundity for S. delicatulus was minimum at Perumal Par and maximum at Minicoy. The difference in fecundity between the sites was not significant ($P>0.05$) while the relation between absolute and relative fecundities were significant ($P<0.05$, Table 16).

## DISCUSSION

S. delicatulus at the four sites showed protracted spawning from September to April with peaks in November and December. Spent fishes which are an indication that spawning has occurred were present only on four occasions. At Minicoy it

Table 10 : Minimum and mean GSI values for ripening and ripe ovaries.

| pecies | Location | GSI (%) |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
|  |  | Stage III |  |  | Stage IV |  |  |
|  |  | Min. | Mean | N | Min. | Mean | N |
| L. *delicatulus* | Minicoy | 2.08 | 5.09 | 19 | 8.00 | 8.89 | 2 |
|  | Agatti | 3.50 | 4.17 | 3 | 8.00 | 8.13 | 2 |
|  | Bangaram | 3.22 | 4.96 | 5 | 7.02 | 7.65 | 2 |
|  | Perumal Par | 2.66 | 3.85 | 9 | 5.05 | 7.93 | 10 |
| L. *gracilis* |  | 3.03 | 4.98 | 6 | 4.62 | 6.79 | 17 |
| L. *argenteus* |  | 0.55 | 0.75 | 4 | - | - | - |
| L. *striatus* |  | 0.72 | 1.02 | 5 | - | - | - |
| L. *caeruleus* |  | 3.96 | 4.03 | 2 | 6.01 | 6.10 | 2 |
| L. *fucata* |  | 2.01 | 2.44 | 2 | 3.98 | 4.04 | 2 |
| L. *thermalis* |  | 3.58 | 4.41 | 3 | 5.98 | 6.12 | 2 |
| L. *gracilis* |  | 2.12 | 2.37 | 2 | - | - | - |

able 11: Relation between mature sizes (M) and standard length (SL) and estimated length at first maturity (ELM) of sprats.

| pecies | Location | Sex | Regression equation | $r^2$ | N | ELM |
|---|---|---|---|---|---|---|
| L. *delicatulus* | Minicoy | Male | M = 4.0 SL - 83.67 | 0.95 | 5 | 33 |
|  |  | Female | M = 2.9 SL - 55.87 | 0.87 | 5 | 36 |
|  |  | Pooled | M = 3.5 SL - 67.77 | 0.94 | 5 | 35 |
|  | Agatti | Male | M = 3.6 SL - 61.59 | 0.57 | 5 | 31 |
|  |  | Female | M = 3.9 SL - 83.97 | 0.82 | 5 | 34 |
|  |  | Pooled | M = 3.8 SL - 72.78 | 0.74 | 5 | 32 |
|  | Bangaram | Male | M = 1.9 SL - 4.92 | 0.48 | 5 | 29 |
|  |  | Female | M = 2.9 SL - 51.75 | 0.86 | 5 | 35 |
|  |  | Pooled | M = 2.4 SL - 28.33 | 0.71 | 5 | 33 |
|  | Perumal Par | Male | M = 2.1 SL - 12.29 | 0.62 | 5 | 29 |
|  |  | Female | M = 1.5 SL - 4.38 | 0.37 | 5 | 35 |
|  |  | Pooled | M = 1.8 SL - 8.34 | 0.51 | 5 | 31 |
| L. *gracilis* | Minicoy | Male | M = 5.6 SL - 149.90 | 0.95 | 4 | 36 |
|  |  | Female | M = 4.3 SL - 114.96 | 0.89 | 6 | 38 |
|  |  | Pooled | M = 4.1 SL - 104.15 | 0.91 | 6 | 37 |

Table 12 : Minimum size at which Stage III was recorded in some live-baits.

| pecies | SL (mm) |  | Species | SL (mm) |  |
|---|---|---|---|---|---|
|  | Male | Female |  | Male | Female |
| L. *argenteus* | 64 | 67 | *A. fucata* | -- | 42 |
| L. *striatus* | 78 | 78 | *A. thermalis* | -- | 35 |
| L. *caeruleus* | -- | 38 | *R. gracilis* | -- | 40 |
| L. *tapeinosoma* | 61 | -- |  |  |  |

Table 13 : Relation between fecundity (F) and total length (TL, mm) and total weight (TW, g) of selected tuna livebaits.

| Species | Location | Regression equation | r | N |
|---|---|---|---|---|
| *S. delicatulus* | Minicoy | F = 38.99 TL - 1347 | 0.83* | 6 |
| | | F = 961.56 TW - 196 | 0.85** | 6 |
| | Agatti | F = 26.28 TL - 804 | 0.85 | 3 |
| | | F = 8.00 TW + 78 | 0.77 | 3 |
| | Bangaram | F = 30.63 TL - 1031 | 0.78* | 4 |
| | | F = 689.83 TW - 66 | 0.73* | 4 |
| | Perumal Par | F = 9.19 TL + 4 | 0.93** | 4 |
| | | F = 236.48 TW + 280 | 0.91** | 4 |
| *S. gracilis* | Minicoy | F = 51.03 TL - 1790 | 0.84** | 10 |
| | | F = 973.65 TW + 47 | 0.80** | 10 |
| *C. caeruleus* | Minicoy | F = 66.94 TL + 378 | 0.37 | 4 |
| | | F = 642.66 TW + 2448 | 0.33 | 4 |
| *A. fucata* | Minicoy | F = 122.22 TL - 5378 | 1.00** | 2 |
| | | F = 1341.5 TW - 1248 | 1.00** | 2 |

* P<0.05 ** P<0.01

Table 14 : Absolute and relative fecundity of livebaits at Minicoy.

| Species | Total Length (mm) | Total Weight (g) | Gonad Weight (g) | Stage of Maturity | Fecundity | |
|---|---|---|---|---|---|---|
| | | | | | Abso. | Rela. |
| *S. delicatulus* | 41 | 0.450 | 0.040 | IV | 170 | 378 |
| | 52 | 0.905 | 0.055 | III | 556 | 614 |
| | 48 | 0.765 | 0.035 | III | 606 | 792 |
| | 52 | 0.890 | 0.050 | III | 614 | 690 |
| | 49 | 0.840 | 0.045 | III | 618 | 736 |
| | 49 | 0.770 | 0.050 | III | 704 | 914 |
| *s. gracilis* | 44 | 0.520 | 0.045 | III | 400 | 769 |
| | 52 | 0.833 | 0.059 | IV | 782 | 939 |
| | 52 | 0.823 | 0.058 | IV | 802 | 974 |
| | 52 | 0.781 | 0.058 | IV | 822 | 1052 |
| | 55 | 0.933 | 0.060 | IV | 834 | 894 |
| | 51 | 0.780 | 0.055 | IV | 930 | 1192 |
| | 55 | 1.050 | 0.080 | IV | 998 | 950 |
| | 52 | 0.778 | 0.050 | IV | 1050 | 1350 |
| | 54 | 0.947 | 0.073 | IV | 1102 | 1164 |
| | 57 | 1.151 | 0.071 | IV | 1120 | 973 |
| *C. caeruleus* | 53 | 2.100 | 0.130 | IV | 3600 | 1714 |
| | 48 | 1.950 | 0.120 | III | 3112 | 1596 |
| | 46 | 1.567 | 0.120 | III | 4800 | 3063 |
| | 40 | 0.973 | 0.118 | III | 2516 | 2586 |
| *A. fucata* | 62 | 2.570 | 0.105 | IV | 2200 | 856 |
| | 53 | 1.750 | 0.050 | III | 1100 | 629 |

ble 15 : Absolute and relative fecundity of <u>S. delicatulus</u> at Agatti.

| ation | Total Length (mm) | Total Weight (g) | Gonad Weight (g) | Stage of Maturity | Fecundity | |
|---|---|---|---|---|---|---|
| | | | | | Abso. | Rela. |
| tti | 40 | 0.425 | 0.038 | III | 170 | 400 |
| | 43 | 0.504 | 0.040 | III | 431 | 855 |
| | 51 | 0.970 | 0.080 | IV | 507 | 523 |
| garam | 42 | 0.505 | 0.025 | III | 158 | 313 |
| | 40 | 0.350 | 0.035 | III | 202 | 577 |
| | 41 | 0.420 | 0.038 | III | 221 | 526 |
| | 42 | 0.450 | 0.035 | III | 238 | 529 |
| | 41 | 0.459 | 0.030 | III | 315 | 686 |
| | 47 | 0.655 | 0.046 | IV | 429 | 655 |
| umal Par | 45 | 0.560 | 0.030 | IV | 264 | 471 |
| | 52 | 0.990 | 0.050 | IV | 305 | 308 |
| | 43 | 0.545 | 0.048 | IV | 317 | 582 |
| | 40 | 0.398 | 0.030 | IV | 356 | 894 |
| | 47 | 0.725 | 0.040 | IV | 363 | 501 |
| | 45 | 0.612 | 0.032 | IV | 367 | 600 |
| | 48 | 0.755 | 0.030 | III | 383 | 507 |
| | 45 | 0.550 | 0.035 | IV | 415 | 755 |
| | 43 | 0.473 | 0.041 | IV | 416 | 879 |
| | 46 | 0.655 | 0.030 | III | 435 | 664 |
| | 50 | 0.750 | 0.040 | IV | 453 | 604 |
| | 42 | 0.441 | 0.043 | IV | 574 | 1302 |

Table 16 : Comparison of fecundity between locations.

| rce | df | SS | MSS | F | P |
|---|---|---|---|---|---|
| atment | 3 | 31564.380 | 10521.460 | 1.40 | $P > 0.05$ |
| licate | 1 | 109746.100 | 109746.100 | 14.55 | $P < 0.05$ |
| or | 3 | 22621.380 | 7540.459 | | |

TREATMENT MEAN

| | |
|---|---|
| T1 | 616 |
| T2 | 480.5 |
| T3 | 466.5 |
| T4 | 467.5 |

REPLICATE MEAN

| | |
|---|---|
| R1 | 390.5 |
| R2 | 624.75 |

appeared in April and once in March and twice in December at Perumal Par. The conclusion therefore from the available data could be that the bluesprat spawn during most of the months of the year at Lakshadweep with a mode just before the south-west monsoon (April) and another in the post-monsoon (November-December). Mohan and Kunhikoya (1985) concluded that spawning in this species at Minicoy takes place during the south-west monsoon period and extends upto December. The pattern of spawning by *S. delicatulus* at Solomon Islands revealed almost continuous spawning with minor peak in April (Milton *et al*., 1990b), and at one site a single major protracted spawning season from December to March (Milton and Blaber, 1991). It is seen that spawning occurs in all the fishing months at one site or the other when the data from Agatti, Bangaram and Perumal Par are pooled. As pointed out be Milton *et al*.(1990b) this has important implications for the management of the fishery. Local heavy fishing, even during peak spawning, should not seriously affect the overall fishery, as there will be some recruitment to the fishery from fish spawning at other sites. The percentage of ripe *S. gracilis* was also higher during the months of November-December and March-April. Mohan and Kunhikoya (1985) opined that it is difficult to state anything about its spawning season as it is usually available only for few months every year at Minicoy. They stated that *S. gracilis* has an extended spawning season starting from March. Similar observations were made by Milton *et al*. (1990b) at Maldives where spawning was greatest during the south-east monsoon from March to September and from March to December at Papaua New Guinea (Dalzell and Wankowski, 1980). A lack of distinct seasonality of spawning in banded bluesprat of the equatorial waters is to be expected since the physical characteristics of the aquatic environment remains relatively stable throughout the year (Dalzell, 1985). The role of environmental factors on spawning of baitfishes are poorly understood. Although ecological data were collected at Minicoy, the biological data was insufficient due to the irregular occurrence of different species of livebaits to correlate with the spawning and reproductive behaviour of livebaits. Milton and Blaber (1991) did not find clear proximal stimuli for spawning of _Spratelloides_ at Solomon Islands and concluded that the extended spawning and the adaptation of livebait population to local conditions should make them elastic to increased fishing mortality. The other species of livebaits were available only for a short duration in the fishery and therefore the spawning months could not be identified. Bell and Colin (1986) reports mass spawning of _Caesio teres_ at Marshall Islands between March and August. It is interesting that the relatively advanced gonads of caesionids (_G. argenteus_ and _Caesio striatus_) are observed at about the same time at Minicoy.

The change in sex ratio with month and length did not show a distinct pattern. _S. delicatulus_ from the northern regions showed male dominance in the middle size groups sandwiched between females in the starting and later size groups. At Minicoy, a clear female bias was noticed. Milton _et al_. (1990b) pointed out the possibility of environmental influence (such as temperature) apart from genetic determination of sex in livebaits. The dominance of females in _S. gracilis_ is attributed to their higher survival and early death of males due to a greater reproductive effort (Milton _et al_., 1990b). Significant predominance of any one sex was also not observed in the resident, colony forming pomacentrids and apogonids. Garnaud (1977) observed a higher percentage of females in a population of _A. imberbis_ with a ratio of 1:4. The GSI values for _S. delicatulus_ and _S. gracilis_ is much higher than those previously reported (Dalzell, 1985; Milton and Blaber, 1991). This means, in comparison, the gonads will have to weigh more at Lakshadweep in relation to body weight at the time of maturity and spawning. However, GSI values of _Archamia zosterophora_ reported from Solomon Islands (Milton and Blaber, 1991) compares with that of _A. fucata_ but is much lower than that of _Apogon thermalis_. GSI values of _C. caeruleus_ is similar to those computed from Mohan _et al_., (1986).

Egg size of _S. delicatulus_ from Minicoy were comparable to those of Solomon Islands (Milton _et al_.,1990b) but the eggs of the other sites were comparatively smaller. Milton _et al_. (1990b) observed that bait populations with higher fecundity had smaller eggs. But a reverse of this was observed for _S. delicatulus_ from

Lakshadweep. Fishes from Minicoy had the larger egg size and also the highest mean relative fecundity. Ova diameter of *S. gracilis* were analogous to those of Solomon Islands and Maldives (Milton *et al*., 1990b) but were smaller than those reported from Papua New Guinea (Dalzell, 1985). Similarly the egg size of *C. caeruleus* in ripe condition were much smaller than those reported by Mohan *et al*., (1986).

The size at maturity of *S. delicatulus* was much smaller than those reported previously (Lewis *et al*., 1983; McCarthy, 1985; Mohan and Kunhikoya, 1986; Milton and Blaber, 1991). Significant differences in length at maturity between sexes and between locations was also noticed. Likewise the size at maturity of *S. gracilis* is smaller than those from many locations except Solomon Islands (Dalzell, 1985; Milton *et al*., 1990b). Such differences in the size at maturity may be partly an artifact of the different sexual maturity criteria used (Milton and Blaber, 1991). Another reason cited is that unfavourable conditions may delay gonadal development to help offset reproductive uncertainty. In *C. caeruleus*, the minimum size at which mature fish was recorded is identical to the size at first maturity reported from Minicoy (Mohan *et al*., 1986) but lower than the value of Gopakumar *et al*. (1991). *A. fucata* matured at a size of about 68% of maximum size which agrees with the observation of Milton and Blaber (1991) for related species. There was however a wide difference from the values given by Gopakumar *et al*. (1991) for apogonids from Lakshadweep.

Fecundity of *S. delicatulus* did not vary significantly between the different locations of Lakshadweep. In studying the fecundity the advanced state (stage IV) was also taken into consideration although there is a possibility that some eggs may have been shed prior to capture (Leary *et al*., 1975; Dalzell, 1985). The mean relative fecundity was, however, nearly the same as reported for the various sites of Solomon Islands (Milton *et al*.,1990b) but less than that of New Caledonia (Conand, 1988) and Lakshadweep (Gopakumar *et al*., 1991). Similarly, the relative fecundity of *S. gracilis* was also comparable with those reported (Dalzell, 1985; Mohan and Kunhikoya, 1985; Milton *et al*., 1990b; Gopakumar *et al*., 1991). Milton *et al*. (1990b) attributed minor variations in fecundity to egg size differences between countries, or to the different length ranges examined in each study. According to them, the total egg production in a particular area may also depend on spawning frequency and ability to develop a new batch of eggs after each spawning. Absolute fecundity was positively related to length and weight except for *S. delicatulus* at Agatti and *C. caeruleus* at Minicoy which may be due to insufficient number of observations. Mean relative fecundity of *C. caeruleus* and *A. fucata* were higher than previously reported (Mohan *et al*., 1986; Gopakumar *et al*., 1991). Studies on reproductive biology of livebaits especially *Spratelloides* spp. showed that they are continuous spawners with several spawning peaks that vary according to time and place. Spawning appears to be driven by food availability, an array of environmental factors and favourable conditions for the larvae (Blaber, 1990).

Lewis (1990) recognised two basic life cycle strategies in the baitfish. Type 1 are those with a short life cycle, small size, grow rapidly, attains sexual maturity in 3-4 months, spawn over an extended period, and have batch fecundities of 500-1500 oocytes per gram of fish. S. delicatulus and S. gracilis belong to this category. Type 2 are species with an annual life cycle, larger in size, attain sexual maturity towards the end of the first year, spawn on a restricted seasonal basis and have batch fecundities of the order of 300-500 oocytes per gram of fish. The various species of caesionids and pomacentrids recorded may belong to this group. In a separate class are the mouth-breeding cardinal fish (apogonids) with an annual life cycle, unknown length of spawning season and probable low fecundity.

# CHAPTER 5

# HYDROGRAPHY

## INTRODUCTION

Coral reefs are complex ecosystems with numerous plants and animal interactions and a rapid but efficient cycling of nutrients. They are oases in the nutrient poor deserts of the tropical seas. Coral reef ecologists are often confronted with questions regarding the role of hydrological parameters especially nutrients in organic production. Is production of organic matter limited by nutrients and at higher levels in the ecosystem, is production limited by the flow of nutrients up the chain ? (Grigg *et al*., 1984). Lewis (1977) reviewed the processes of organic production on coral reefs. Productivity on reefs is considerably higher than in surrounding waters in spite of nutrient limitation. A fundamental reason for this high productivity is the abundant light energy. This is coupled by the ability to fix nitrogen by a host of reef organisms and the continuous recycling of phosphorus.

Nutrient supply and loss from coral reefs are difficult to estimate. This has resulted in very limited knowledge about the nutrient budget for reefs. The importance of nitrogen as a primary growth-limiting element in the sea, the aspects of marine nitrogen cycling and its availability has been well documented (Thomas, 1970; Ryther and Dunstan, 1971; Corner and Davies, 1971; Dugdale, 1976; Carpenter and Capone, 1983). 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). But the abundance and function of nitrogen in coral reefs have been addressed only in limited studies. D'Elia and Wiebe (1990) reviewed the biogeochemical nutrient cycles of coral reefs.

Nitrogen concentrations in tropical coral reef areas generally tend to be low except in locations of upwelling or terrestrial run-off. Marsh (1977) observed that groundwater seepage into the reef system at Guam had a major influence on nutrient levels. Groundwater discharge was also significant in other reef areas (D'Elia et al., 1981; Lewis, 1985). Concentrations of nitrogen in atolls and enclosed reef areas are observed to be higher than that of the oceanic waters. Hatcher and Hatcher (1981) showed that epilithic algal communities on reefs absorb nutrients from ebbing lagoonal waters. Seasonal and tidal variations in nutrient concentrations of lagoons have also been reported (Hatcher and Frith, 1985). Elevated nitrogen present in coral skeletons and sediment pore waters also results in a flux of dissolved nitrogen to the water column (Andrews and Muller, 1983; Risk and Muller, 1983). Net fluxes of nitrogen between coral reef and the water column has also been observed. Johannes _et al_. (1972) and Webb _et al_. (1975) found export of nitrate, ammonia and dissolved and particulate organic nitrogen from a reef community. This high rate of nitrogen production was attributed to fixation by reef flat communities (Wiebe, 1976; Wiebe _et al_., 1975). The uptake of nutrients by the benthic community may be either concentration-dependent or time-dependent (Johannes _et al_., 1983a). Nitrogen fixation is now recognised as an important component of the nitrogen cycle of coral reefs. Fixation by a variety of reef organisms in different types of reef ecosystems have been reported in the literature (Dugdale _et al_., 1961; Mague and Holm-Hansen, 1975; Burris, 1976; Hanson and Gundersen, 1977; Capone, 1977; Capone _et al_., 1977; Wilkinson and Fay, 1979; Penhale and Capone, 1981; Wilkinson _et al_., 1983; Paerl, 1984). However, there is a paucity of information on the breakdown of this nitrogen and its transfer to the rest of the reef trophic system. The processes of ammonification, nitrification and assimilation in coral reefs is also not fully understood (D'Elia and Wiebe, 1990)

The phosphorus dynamics of coral reefs have received less attention than nitrogen. Phosphorus concentrations in tropical waters overlying most coral reefs are considerably lower than in deep-ocean, temperate or upwelling areas (D'Elia and Wiebe, 1990). Studies on phosphorus in coral reefs have indicated that reef communities are not limited by the supply of phosphorus and have evolved either internal (biochemical) or external (food chain) recycling loops to satisfy their need for phosphorus (Pomeroy and Kuenzler, 1969; Pilson and Betzer, 1973; Pomeroy et al., 1974). The available evidence points to an ecosystem that is well adjusted to life in a very dilute solution of essential elements. Observations on nutrient flux over coral reefs also suggest that there is active recycling of phosphorus with minimum leakage to the overlying water (Johannes et al., 1972, 1983a). DiSalvo (1974) found direct relation between bacterial count of sediment and amounts of soluble nutrients. He concluded that interaction between bacteria and dissolved organics may effect the retention of phosphorus in reefs.

Phosphorus concentrations in reefs are elevated by terrestrial run-off (Marsh, 1977), by ancient or modern seabird guano deposits (Allaway and Ashford, 1984) or by groundwater inputs (Lewis, 1987). Kinsey and Davies (1979) noticed a suppression of reef calcification with increased enrichment by phosphorus. Phosphorus is exchanged freely between the benthos and the water column. High input of phosphorus provides a continual source to maintain high biomass, but the low concentration in reef waters limits the specific growth rate of the community (Atkinson, 1981 and 1983). Reef sediments contain a higher concentration of phosphorus and can provide soluble phosphorus to the algal community in a concentration well above that of the water (Entsch et al., 1983). Geesey et al. (1984)

traced the high phosphorus levels in fish faeces to the gut microbial population. Similar biological regeneration of phosphorus from corals have also been reported (Risk and Muller, 1983; Andrews and Muller, 1983).

Like dissolved nitrogen and phosphorus, silicic acid concentrations in reef waters are also low. Smith and Jokiel (1978) observed higher silica in areas of upwelling and Webb (1981) concluded that silicon cycle in reefs is affected by chemical and biological processes. Seasonal differences in the uptake and release of silicic acid has been observed (Johannes _et al_., 1983a). Studies on silicate in reefs have shown that there is a low utilization of silicon in most reef environments (Smith and Jokiel, 1978; Smith _et al_., 1984).

The early reports on the hydrography of Lakshadweep waters is that of Jayaraman _et al_. (1959 and 1960) and Jones (1959). Jayaraman _et al_. (1960) observed that the circulatory water movements helps to maintain the highly productive waters in the vicinity of the islands for a considerable length of time. Patil and Ramamirtham (1963) also observed circulatory patterns in winter although on a considerably reduced scale than those observed during summer. Rao and Jayaraman (1966) recorded upwelling in the Minicoy region during November and attributed it to diverging current systems. A bloom of _Trichodesmium_ in the Lakshadweep sea caused depletion of nitrate nitrogen and a sparse population of other phytoplankton and zooplankton (Qasim, 1970).

Sankaranarayanan (1973) studied the chemical characteristics of the waters in the lagoon and in the surrounding sea at Kavaratti. He noticed that many of the parameters showed high degree of variability with location in the lagoon. Physical characteristics of the Laccadive sea has received some attention (Kesava Das *et al*., 1979; Varkey *et al*., 1979). The chemical characteristics of water, sediment and plants of seagrass beds at Minicoy are reported (Ansari, 1984; Jagtap and Untawale, 1984). Wafar *et al*., (1986) measured concentrations of nitrogenous nutrients and primary production in oceanic Lakshadweep waters. They concluded that excluding urea, the rest of the dissolved organic nitrogen, though abundant, does not appear to be directly available for phytoplankton production. Nitrification studies on coral reefs indicated that ammonia oxidation is an important step in nitrogen recycling (Wafar *et al*., 1990). Suresh (1991) described the hydrobiology of the Kavaratti lagoon.

The present study aims at understanding the variations in hydrographical parameters between different locations of the Minicoy lagoon and between the different seasons.

## MATERIALS AND METHODS

Surface and bottom water samples were collected from six locations of the Minicoy lagoon for a period of 16 months from December 1988 to March 1990. Surface samples were collected by a bucket and bottom water by a Cassela bottle and stored in

250 ml polythene bottles. Samples for dissolved oxygen estimation was carefully siphoned into 125 ml glass 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.

The locations of stations 1 to 6 are shown in Figure 1. The lagoon floor of station 1 is composed mainly of colonies of live branching corals with a depth of about 6-8 m. The inner reef flat (station 2) is sandy with reef building corals and a depth range of 2-3 m. Station 3 is the reef flat of about 8 m in width with profuse growth of reef corals and algae and a depth of 1.5-3 m. Open sea samples (station 4) were collected in the oceanic region about 0.5 km away from the reef with a total depth of 100 m. Bottom samples at this station were collected at a depth of 10 m. The sand flat area in the southern part of the lagoon was fixed as station 5. The lagoon floor of this area comprise of coralline sand with intermittent live and dead coral beds and seaweed beds having a depth of 3-4 m. Station 6 is located midway between the Fisheries and Main jetty on a seagrass bed of Thalassia and Syringodium with a depth of 0.5-2 m. The stations were selected in such a way as to cover different bottom biotopes and also major areas of baitfishery.

Salinity was determined by Mohr's titration method and dissolved oxygen by Winkler's method (Strickland and Parsons,

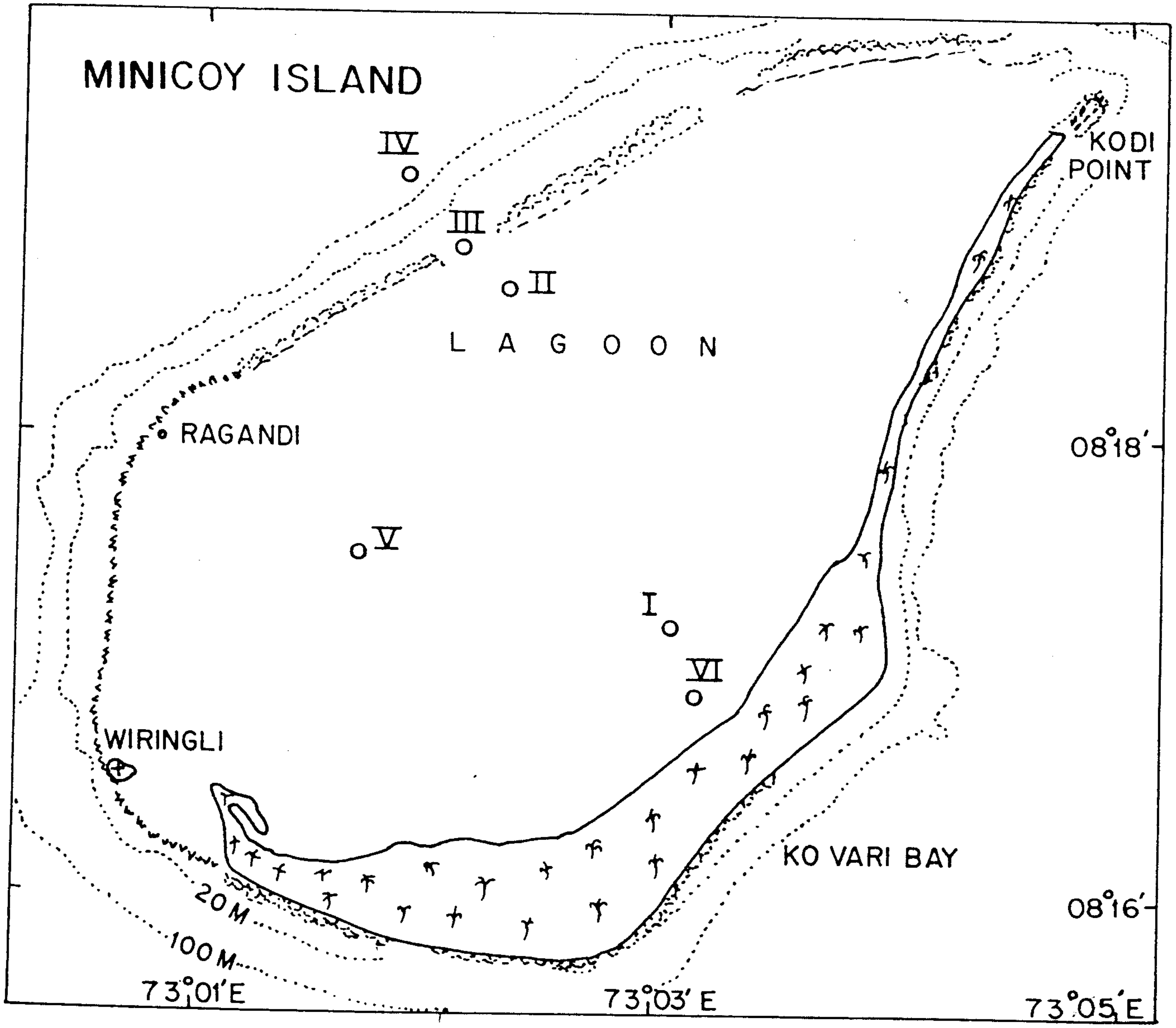


**Fig. 1** Stations fixed for hydrographical studies at Minicoy.

1968). All nutrients except nitrate was analysed using the methods outlined by FAO (Anon. 1975) and measured on a spectrophotometer (ECIL GS866D). Nitrate was determined by a modified method of Mullin and Riley (1955).

**Phosphate** : The phosphate in seawater is allowed to react with ammonium molybdate, forming a complex heteropoly acid. This acid is reduced by ascorbic acid, to a blue-coloured complex, the light absorption of which is then measured at 882 nm.

**Nitrite** : Nitrite ion is diazotized with sulphanilamide, resulting in a diazo compound, which in turn is coupled with N-(1-naphthyl)-ethylenediamine to form a highly coloured azo dye with an absorption maxima at 545 nm.

**Nitrate** : The nitrate in seawater is 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 a reducing agent (copper sulphate + hydrazine sulphate) was added and kept in dark for 20 hrs. This reduced solution is treated with sulphanilamide and NNED and the intensity of colour developed is measured at 545 nm.

**Silicate** : The determination of dissolved silicon compound is based on the formation of a yellow silicomolybdic acid, when a more or less acidic sample is treated with a molybdate reagent. Since this acid is rather weak in colour, they are reduced (by ascorbic acid) to intensely coloured blue complexes. The absorbance of the sample is measured against distilled water at a wavelength of 810 nm.

The data were grouped arbitarily into three seasons for statistical analysis : premonsoon (January to April), monsoon (May to August) and postmonsoon (September to December).

## RESULTS

Mean and standard deviation of various parameters for surface waters are given in Table 1. Water temperature was higher during monsoon and postmonsoon. Station 1 and 6 consistently showed higher values than the other stations. A similar trend was observed in the case of salinity which was 1 ppt less during premonsoon. Dissolved oxygen averaged higher values of more than 5 ml/l during monsoon. A reducing trend is observed in the case of nutrients with high values in premonsoon and low in postmonsoon. The only exception was nitrite which peaked in monsoon. The estimated mean and standard deviation for bottom samples are shown in Table 2. Water temperature was near stable in the different seasons with only minor variation. An increasing trend is noticed for salinity from premonsoon to postmonsoon. Similar to the surface waters an increase in concentration is observed for phosphate and silicate from premonsoon to postmonsoon. This is however disrupted in the case of nitrite and nitrate by the high values (> 1.5 mug.at/l)

Table 1 : Mean and standard deviation of the different parameters for surface waters at the six stations.

| Parameter | Season | Stations |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
|  |  | 1 | 2 | 3 | 4 | 5 | 6 |
| Water temperature (deg.C) | Premonsoon | 29.2 | 28.5 | 28.6 | 28.5 | 28.5 | 29.3 |
|  |  | 0.78 | 0.70 | 0.50 | 0.26 | 0.63 | 0.68 |
|  | Monsoon | 29.1 | 28.7 | 28.9 | 28.9 | 28.9 | 29.1 |
|  |  | 0.63 | 0.48 | 0.97 | 0.30 | 0.81 | 0.79 |
|  | Postmonsoon | 29.3 | 28.9 | 28.9 | 28.6 | 28.9 | 29.3 |
|  |  | 0.42 | 0.63 | 0.26 | 0.52 | 0.49 | 1.01 |
| Salinity (ppt) | Premonsoon | 34.2 | 33.5 | 34.1 | 33.9 | 34.0 | 34.0 |
|  |  | 0.90 | 0.54 | 0.54 | 0.72 | 1.27 | 0.95 |
|  | Monsoon | 34.6 | 35.0 | 34.9 | 34.9 | 35.2 | 35.0 |
|  |  | 0.09 | 0.52 | 0.54 | 0.61 | 0.55 | 0.50 |
|  | Postmonsoon | 35.0 | 34.8 | 34.9 | 34.9 | 34.5 | 34.6 |
|  |  | 1.47 | 1.13 | 1.69 | 1.61 | 1.22 | 1.03 |
| Dissolved oxygen (ml/l) | Premonsoon | 4.83 | 4.26 | 4.21 | 5.06 | 3.97 | 4.14 |
|  |  | 0.28 | 0.37 | 0.52 | 0.33 | 1.12 | 1.33 |
|  | Monsoon | 4.99 | 5.05 | 4.81 | 4.83 | 5.01 | 5.53 |
|  |  | 0.37 | 0.20 | 0.20 | 0.03 | 0.57 | 0.27 |
|  | Postmonsoon | 4.73 | 4.48 | 4.38 | 4.59 | 4.82 | 4.18 |
|  |  | 0.27 | 0.47 | 0.40 | 0.28 | 0.26 | 0.74 |
| Phosphate (mug.at/l) | Premonsoon | 0.35 | 0.44 | 0.65 | 0.68 | 0.68 | 0.74 |
|  |  | 0.29 | 0.30 | 0.57 | 0.43 | 0.42 | 0.33 |
|  | Monsoon | 0.30 | 0.35 | 0.38 | 0.61 | 0.29 | 0.53 |
|  |  | 0.07 | 0.12 | 0.10 | 0.05 | 0.22 | 0.15 |
|  | Postmonsoon | 0.23 | 0.16 | 0.19 | 0.22 | 0.21 | 0.38 |
|  |  | 0.18 | 0.14 | 0.12 | 0.16 | 0.15 | 0.24 |
| Nitrite (mug.at/l) | Premonsoon | 0.37 | 0.28 | 0.32 | 0.37 | 0.34 | 0.36 |
|  |  | 0.21 | 0.09 | 0.11 | 0.11 | 0.14 | 0.09 |
|  | Monsoon | 0.36 | 0.39 | 0.49 | 0.46 | 0.22 | 0.31 |
|  |  | 0.07 | 0.17 | 0.32 | 0.10 | 0.14 | 0.07 |
|  | Postmonsoon | 0.24 | 0.26 | 0.28 | 0.25 | 0.33 | 0.25 |
|  |  | 0.16 | 0.17 | 0.16 | 0.19 | 0.28 | 0.15 |
| Nitrate (mug.at/l) | Premonsoon | 0.61 | 0.36 | 0.39 | 0.48 | 0.44 | 0.61 |
|  |  | 0.49 | 0.30 | 0.34 | 0.29 | 0.30 | 0.44 |
|  | Monsoon | 0.39 | 0.44 | 0.45 | 0.39 | 0.13 | 0.49 |
|  |  | 0.15 | 0.42 | 0.37 | 0.33 | 0.07 | 0.40 |
|  | Postmonsoon | 0.23 | 0.26 | 0.31 | 0.27 | 0.30 | 0.28 |
|  |  | 0.23 | 0.38 | 0.39 | 0.29 | 0.20 | 0.24 |
| Silicate (mug.at/l) | Premonsoon | 4.43 | 4.32 | 3.62 | 3.71 | 4.25 | 4.19 |
|  |  | 0.90 | 1.03 | 0.95 | 0.46 | 1.14 | 0.82 |
|  | Monsoon | 2.60 | 4.24 | 3.65 | 3.56 | 3.81 | 3.58 |
|  |  | 0.53 | 0.96 | 0.37 | 0.19 | 0.85 | 0.43 |
|  | Postmonsoon | 3.65 | 3.13 | 2.76 | 2.87 | 3.08 | 3.90 |
|  |  | 0.88 | 1.03 | 0.62 | 0.53 | 0.48 | 1.43 |

Table 2 : Mean and standard deviation of various hydrological parameters for bottom waters at the six stations.

| Parameter | Season | Stations 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Water temperature | Premonsoon | 29.0 | 28.3 | 28.5 | 28.5 | 28.3 | 29.2 |
| | | 0.08 | 0.46 | 0.58 | 0.46 | 0.68 | 0.69 |
| | Monsoon | 29.0 | 28.7 | 28.5 | 29.0 | 28.8 | 28.9 |
| | | 0.75 | 0.48 | 1.08 | 0.71 | 0.59 | 0.63 |
| | Postmonsoon | 29.1 | 28.9 | 28.7 | 28.7 | 28.7 | 29.1 |
| | | 0.39 | 0.53 | 0.41 | 0.64 | 0.75 | 0.92 |
| Salinity | Premonsoon | 33.9 | 33.7 | 33.6 | 34.1 | 34.1 | 34.1 |
| | | 0.78 | 0.51 | 0.68 | 0.81 | 1.28 | 0.86 |
| | Monsoon | 34.4 | 34.6 | 34.6 | 34.9 | 34.6 | 34.9 |
| | | 0.19 | 0.44 | 0.55 | 0.46 | 0.57 | 0.47 |
| | Postmonsoon | 35.0 | 35.6 | 34.9 | 35.2 | 34.9 | 35.1 |
| | | 0.70 | 1.89 | 1.49 | 1.70 | 1.75 | 1.22 |
| Dissolved oxygen | Premonsoon | 4.93 | 4.50 | 4.33 | 5.17 | 4.06 | 4.49 |
| | | 0.27 | 0.35 | 0.39 | 0.31 | 1.11 | 0.74 |
| | Monsoon | 4.94 | 5.34 | 4.93 | 5.04 | 5.18 | 5.64 |
| | | 0.31 | 0.22 | 0.17 | 0.26 | 0.67 | 0.44 |
| | Postmonsoon | 4.68 | 4.59 | 4.55 | 4.86 | 4.82 | 4.02 |
| | | 0.35 | 0.46 | 0.33 | 0.30 | 0.33 | 0.61 |
| Phosphate | Premonsoon | 0.43 | 0.49 | 0.67 | 0.87 | 0.59 | 0.65 |
| | | 0.24 | 0.36 | 0.53 | 0.54 | 0.31 | 0.29 |
| | Monsoon | 0.42 | 0.33 | 0.34 | 0.52 | 0.36 | 0.66 |
| | | 0.10 | 0.10 | 0.13 | 0.02 | 0.21 | 0.31 |
| | Postmonsoon | 0.18 | 0.21 | 0.19 | 0.21 | 0.20 | 0.32 |
| | | 0.14 | 0.13 | 0.12 | 0.15 | 0.15 | 0.26 |
| Nitrite | Premonsoon | 0.65 | 0.33 | 0.34 | 0.31 | 0.32 | 0.35 |
| | | 0.73 | 0.13 | 0.12 | 0.12 | 0.12 | 0.11 |
| | Monsoon | 0.34 | 0.35 | 0.35 | 1.55 | 0.21 | 0.30 |
| | | 0.05 | 0.30 | 0.23 | 2.04 | 0.15 | 0.14 |
| | Postmonsoon | 0.27 | 0.28 | 0.35 | 0.26 | 0.33 | 0.24 |
| | | 0.20 | 0.18 | 0.31 | 0.29 | 0.23 | 0.15 |
| Nitrate | Premonsoon | 0.40 | 0.49 | 0.39 | 0.44 | 0.48 | 0.51 |
| | | 0.37 | 0.33 | 0.32 | 0.35 | 0.37 | 0.37 |
| | Monsoon | 0.40 | 0.50 | 0.54 | 1.88 | 0.16 | 0.49 |
| | | 0.17 | 0.39 | 0.36 | 2.89 | 0.10 | 0.52 |
| | Postmonsoon | 0.21 | 0.27 | 0.34 | 0.24 | 0.26 | 0.39 |
| | | 0.25 | 0.35 | 0.34 | 0.19 | 0.26 | 0.33 |
| Silicate | Premonsoon | 4.14 | 3.43 | 3.42 | 3.79 | 3.94 | 3.98 |
| | | 0.70 | 0.86 | 0.92 | 0.85 | 0.85 | 0.82 |
| | Monsoon | 2.62 | 3.80 | 3.62 | 4.69 | 4.21 | 3.49 |
| | | 0.45 | 0.95 | 0.28 | 1.62 | 1.01 | 0.17 |
| | Postmonsoon | 2.92 | 2.85 | 2.79 | 3.13 | 2.90 | 3.61 |
| | | 0.62 | 0.43 | 0.87 | 1.03 | 0.49 | 1.24 |

observed during monsoon.

Results of two-way ANOVA to test variations between stations and seasons for surface and bottom waters are presented in Table 3. Water temperature showed significant variation between stations, and salinity and dissolved oxygen between seasons. Surface phosphate changed significantly both between stations and seasons while bottom water phosphate was significant only between seasons. Nitrogenous nutrients did not exhibit variations except for surface nitrate which was significant over seasons. Silicate varied significantly only between seasons for both surface and bottom samples. Individual comparisons between stations and seasons for significant parameters are indicated in Table 4. Water temperature of stations 1 and 6 showed significant variation when compared to that of other stations. Concentrations of surface phosphate in stations 1, 2, 4 and 6 were significantly different. Salinity values for surface samples did not show significant change between monsoon and postmonsoon. Surface and bottom dissolved oxygen was not significant among pre and postmonsoon while surface nitrate was significant only between these seasons. Surface silicate was significant amid pre and postmonsoon whilst non significance was recorded among premonsoon and monsoon for bottom waters.

Interactions among the different parameters in each station for surface and bottom samples was tested by correlation matrices (Tables 5 and 6). Nitrite showed positive relation with

Table 3 : A two-way ANOVA between stations (treatment) and between seasons (replicate) for the various hydrological parameters.

| Parameter | Source | df | SS | MSS | F | P |
|---|---|---|---|---|---|---|
| Surface water temp. | Treatment | 5 | 0.859 | 0.179 | 6.09 | P < 0.01 |
| | Replicate | 2 | 0.203 | 0.102 | 3.60 | P > 0.05 |
| | Error | 10 | 0.282 | 0.028 | | |
| Bottom water temp. | Treatment | 5 | 0.744 | 0.149 | 4.23 | P < 0.05 |
| | Replicate | 2 | 0.183 | 0.091 | 2.60 | P > 0.05 |
| | Error | 10 | 0.352 | 0.035 | | |
| Surface salinity | Treatment | 5 | 0.086 | 0.017 | 0.27 | P > 0.05 |
| | Replicate | 2 | 3.367 | 1.684 | 26.36 | P < 0.01 |
| | Error | 10 | 0.639 | 0.064 | | |
| Bottom salinity | Treatment | 5 | 0.357 | 0.071 | 1.61 | P > 0.05 |
| | Replicate | 2 | 4.363 | 2.182 | 48.99 | P < 0.01 |
| | Error | 10 | 0.445 | 0.045 | | |
| Surface dis. oxygen | Treatment | 5 | 0.329 | 0.066 | 0.55 | P > 0.05 |
| | Replicate | 2 | 1.328 | 0.664 | 5.52 | P < 0.05 |
| | Error | 10 | 1.202 | 0.120 | | |
| Bottom dis. oxygen | Treatment | 5 | 0.327 | 0.065 | 0.49 | P > 0.05 |
| | Replicate | 2 | 1.416 | 0.708 | 5.33 | P < 0.05 |
| | Error | 10 | 1.328 | 0.133 | | |
| Surface phosphate | Treatment | 5 | 0.153 | 0.031 | 3.61 | P < 0.05 |
| | Replicate | 2 | 0.385 | 0.193 | 22.79 | P < 0.01 |
| | Error | 10 | 0.085 | 0.008 | | |
| Bottom phosphate | Treatment | 5 | 0.124 | 0.025 | 2.70 | P > 0.05 |
| | Replicate | 2 | 0.478 | 0.239 | 25.91 | P < 0.01 |
| | Error | 10 | 0.092 | 0.009 | | |
| Surface nitrite | Treatment | 5 | 0.012 | 0.002 | 0.50 | P > 0.05 |
| | Replicate | 2 | 0.034 | 0.017 | 3.46 | P > 0.05 |
| | Error | 10 | 0.049 | 0.005 | | |
| Bottom nitrite | Treatment | 5 | 0.381 | 0.076 | 0.76 | P > 0.05 |
| | Replicate | 2 | 0.158 | 0.079 | 0.78 | P > 0.05 |
| | Error | 10 | 1.010 | 0.101 | | |
| Surface nitrate | Treatment | 5 | 0.045 | 0.009 | 1.10 | P > 0.05 |
| | Replicate | 2 | 0.111 | 0.056 | 6.79 | P < 0.05 |
| | Error | 10 | 0.082 | 0.008 | | |
| Bottom nitrate | Treatment | 5 | 0.595 | 0.119 | 0.91 | P > 0.05 |
| | Replicate | 2 | 0.429 | 0.214 | 1.62 | P > 0.05 |
| | Error | 10 | 1.314 | 0.131 | | |
| Surface silicate | Treatment | 5 | 0.886 | 0.177 | 0.83 | P > 0.05 |
| | Replicate | 2 | 2.223 | 1.111 | 5.18 | P < 0.05 |
| | Error | 10 | 2.146 | 0.125 | | |
| Bottom silicate | Treatment | 5 | 1.050 | 0.210 | 0.90 | P > 0.05 |
| | Replicate | 2 | 2.123 | 1.062 | 4.57 | P < 0.05 |
| | Error | 10 | 2.321 | 0.232 | | |

Table 4 : Station and season comparison based on ANOVA tables.

STATION COMPARISONS

| Parameter | Station | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Surface water temp. | 1 | sig | sig | sig | sig | n.s |
| | 2 | --- | n.s | n.s | n.s | sig |
| | 3 | --- | --- | n.s | n.s | sig |
| | 4 | --- | --- | --- | n.s | sig |
| | 5 | --- | --- | --- | --- | sig |
| Bottom water temp. | 1 | sig | sig | n.s | sig | n.s |
| | 2 | --- | n.s | n.s | n.s | sig |
| | 3 | --- | --- | n.s | n.s | sig |
| | 4 | --- | --- | --- | n.s | n.s |
| | 5 | --- | --- | --- | --- | sig |
| Surface phosphate | 1 | n.s | n.s | sig | n.s | sig |
| | 2 | --- | n.s | sig | n.s | sig |
| | 3 | --- | --- | n.s | n.s | n.s |
| | 4 | --- | --- | --- | n.s | n.s |
| | 5 | --- | --- | --- | --- | n.s |

SEASON COMPARISONS

| Parameter | Season | Monsoon | Postmonsoon |
|---|---|---|---|
| Surface salinity | Premonsoon | sig | sig |
| | Monsoon | --- | n.s |
| Bottom salinity | Premonsoon | sig | sig |
| | Monsoon | --- | sig |
| Surface dissolved oxygen | Premonsoon | sig | n.s |
| | Monsoon | --- | sig |
| Bottom dissolved oxygen | Premonsoon | sig | n.s |
| | Monsoon | --- | sig |
| Surface phosphate | Premonsoon | sig | sig |
| | Monsoon | --- | sig |
| Bottom phosphate | Premonsoon | sig | sig |
| | Monsoon | --- | sig |
| Surface nitrate | Premonsoon | n.s | sig |
| | Monsoon | --- | n.s |
| Surface silicate | Premonsoon | n.s | sig |
| | Monsoon | --- | n.s |
| Bottom silicate | Premonsoon | n.s | sig |
| | Monsoon | --- | sig |

n.s - not significant sig - significant

Table 5 : Correlation matrices for various hydrological parameters for surface and bottom waters at stations 1, 2 and 3.

| Station | Parameters | W.T. | Sal. | Oxy. | Pho. | Nit. | Nit. | Sil. |
|---|---|---|---|---|---|---|---|---|
| 1. Surface | Water temp. | 1.00 | | | | | | |
| | Salinity | 0.01 | 1.00 | | | | | |
| | Oxygen | 0.11 | 0.17 | 1.00 | | | | |
| | Phosphate | -0.02 | 0.09 | 0.06 | 1.00 | | | |
| | Nitrite | -0.22 | -0.07 | 0.06 | 0.78* | 1.00 | | |
| | Nitrate | -0.32* | -0.35* | 0.15 | -0.12 | 0.12 | 1.00 | |
| | Silicate | 0.09 | -0.11 | -0.07 | 0.16 | 0.01 | 0.05 | 1.00 |
| 1. Bottom | Water temp. | 1.00 | | | | | | |
| | Salinity | 0.13 | 1.00 | | | | | |
| | Oxygen | -0.30* | -0.01 | 1.00 | | | | |
| | Phosphate | -0.22 | -0.15 | 0.46* | 1.00 | | | |
| | Nitrite | -0.17 | -0.33* | 0.27 | 0.42* | 1.00 | | |
| | Nitrate | -0.20 | -0.07 | 0.17 | -0.04 | 0.45* | 1.00 | |
| | Silicate | 0.15 | -0.19 | -0.15 | 0.04 | 0.19 | -0.02 | 1.00 |
| . Surface | Water temp. | 1.00 | | | | | | |
| | Salinity | 0.42* | 1.00 | | | | | |
| | Oxygen | 0.21 | 0.41* | 1.00 | | | | |
| | Phosphate | 0.10 | -0.31* | 0.11 | 1.00 | | | |
| | Nitrite | 0.11 | -0.29* | 0.19 | 0.46* | 1.00 | | |
| | Nitrate | -0.27 | 0.16 | 0.58* | -0.08 | 0.03 | 1.00 | |
| | Silicate | -0.38* | -0.32* | 0.09 | 0.33* | -0.01 | 0.15 | 1.00 |
| . Bottom | Water temp. | 1.00 | | | | | | |
| | Salinity | 0.39* | 1.00 | | | | | |
| | Oxygen | -0.02 | 0.03 | 1.00 | | | | |
| | Phosphate | -0.37* | -0.36* | 0.01 | 1.00 | | | |
| | Nitrite | -0.04 | -0.36* | -0.03 | 0.42* | 1.00 | | |
| | Nitrate | -0.56* | -0.25 | 0.56* | 0.22 | -0.06 | 1.00 | |
| | Silicate | -0.33* | -0.13 | 0.16 | -0.08 | -0.03 | 0.32* | 1.00 |
| . Surface | Water temp. | 1.00 | | | | | | |
| | Salinity | -0.03 | 1.00 | | | | | |
| | Oxygen | -0.19 | 0.09 | 1.00 | | | | |
| | Phosphate | -0.28* | -0.27* | 0.34* | 1.00 | | | |
| | Nitrite | -0.08 | -0.13 | 0.22 | 0.27 | 1.00 | | |
| | Nitrate | -0.33* | 0.16 | 0.52* | 0.28* | -0.05 | 1.00 | |
| | Silicate | -0.04 | -0.40* | 0.03 | 0.13 | -0.13 | -0.11 | 1.00 |
| Bottom | Water temp. | 1.00 | | | | | | |
| | Salinity | 0.10 | 1.00 | | | | | |
| | Oxygen | -0.13 | 0.27 | 1.00 | | | | |
| | Phosphate | -0.32* | -0.55* | 0.01 | 1.00 | | | |
| | Nitrite | -0.30* | -0.55* | -0.07 | 0.37* | 1.00 | | |
| | Nitrate | -0.35* | -0.06 | 0.25 | -0.09 | -0.08 | 1.00 | |
| | Silicate | -0.16 | -0.34* | 0.06 | 0.04 | 0.07 | -0.16 | 1.00 |

* indicates significant relation between parameters

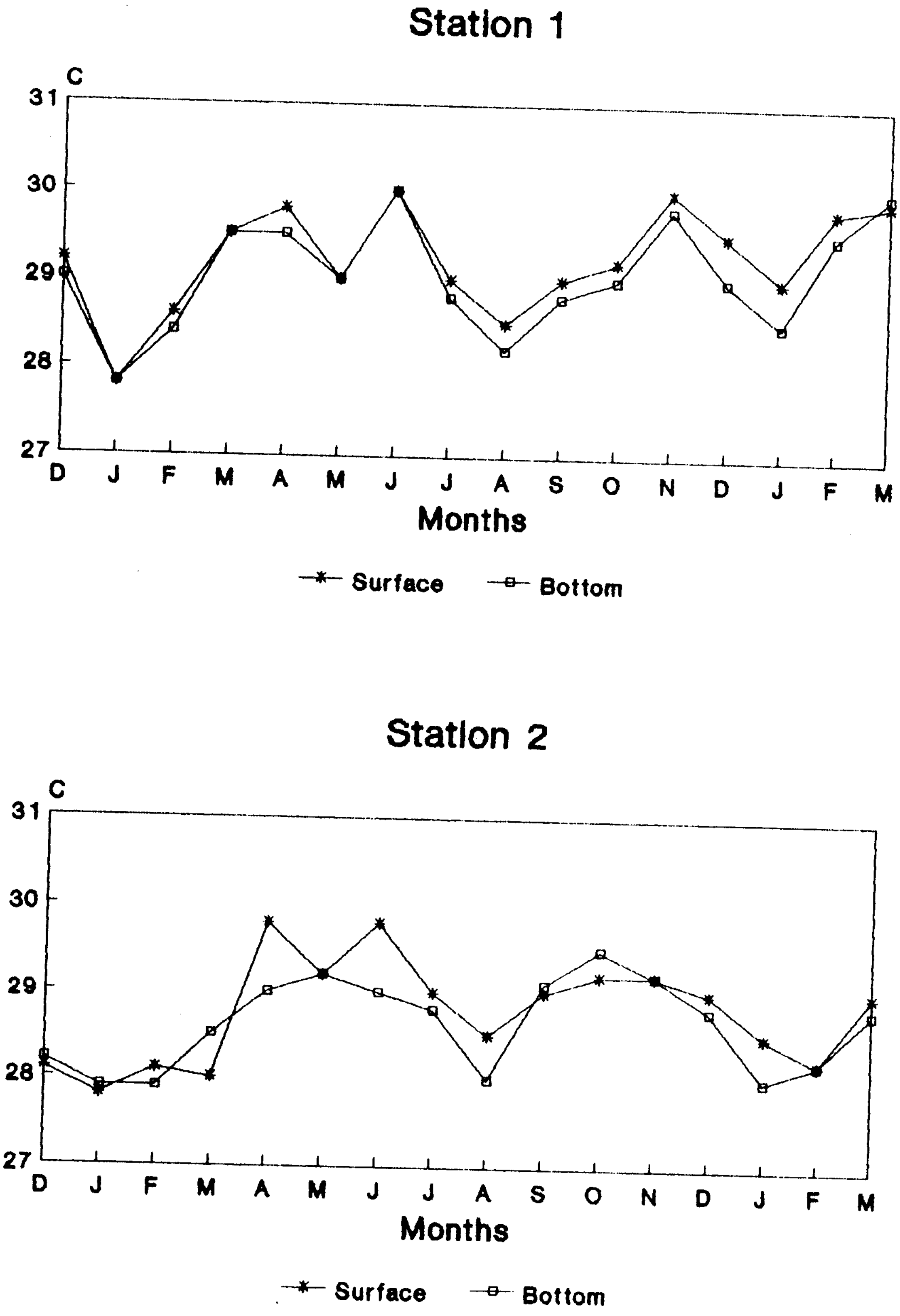
Table 6 : Correlation matrices for various hydrological parameters of surface and bottom waters at stations 4, 5 and 6.

| tation | Parameters | W.T. | Sal. | Oxy. | Pho. | Nit. | Nit. | Sil. |
|---|---|---|---|---|---|---|---|---|
| Surface | Water temp. | 1.00 | | | | | | |
| | Salinity | 0.49* | 1.00 | | | | | |
| | Oxygen | -0.33* | -0.53 | 1.00 | | | | |
| | Phosphate | -0.29* | -0.47* | 0.42* | 1.00 | | | |
| | Nitrite | -0.15 | -0.60* | 0.37* | 0.69* | 1.00 | | |
| | Nitrate | -0.21 | -0.15 | 0.16 | 0.16 | 0.18 | 1.00 | |
| | Silicate | -0.19 | -0.70* | 0.67* | 0.45* | 0.53* | 0.09 | 1.00 |
| Bottom | Water temp. | 1.00 | | | | | | |
| | Salinity | 0.22 | 1.00 | | | | | |
| | Oxygen | -0.51* | -0.17 | 1.00 | | | | |
| | Phosphate | -0.36* | -0.49* | 0.65* | 1.00 | | | |
| | Nitrite | -0.13 | 0.01 | 0.21 | 0.02 | 1.00 | | |
| | Nitrate | -0.27 | 0.01 | 0.42* | 0.10 | 0.69* | 1.00 | |
| | Silicate | 0.03 | -0.47* | 0.07 | 0.39* | 0.12 | -0.01 | 1.00 |
| Surface | Water temp. | 1.00 | | | | | | |
| | Salinity | 0.15 | 1.00 | | | | | |
| | Oxygen | 0.11 | 0.16 | 1.00 | | | | |
| | Phosphate | -0.27 | -0.39* | -0.18 | 1.00 | | | |
| | Nitrite | -0.33* | -0.34* | -0.10 | 0.47* | 1.00 | | |
| | Nitrate | -0.26 | -0.39* | -0.12 | 0.12 | 0.43* | 1.00 | |
| | Silicate | -0.17 | -0.42* | -0.35* | 0.14 | 0.07 | 0.04 | 1.00 |
| Bottom | Water temp. | 1.00 | | | | | | |
| | Salinity | 0.28* | 1.00 | | | | | |
| | Oxygen | 0.27 | 0.26 | 1.00 | | | | |
| | Phosphate | -0.22 | -0.35* | -0.38* | 1.00 | | | |
| | Nitrite | -0.02 | -0.22 | -0.07 | 0.09 | 1.00 | | |
| | Nitrate | -0.07 | -0.09 | -0.16 | 0.06 | 0.45* | 1.00 | |
| | Silicate | -0.27 | -0.58* | -0.29* | 0.41* | -0.35* | 0.06 | 1.00 |
| Surface | Water temp. | 1.00 | | | | | | |
| | Salinity | -0.07 | 1.00 | | | | | |
| | Oxygen | -0.15 | 0.00 | 1.00 | | | | |
| | Phosphate | -0.28* | -0.33* | 0.50* | 1.00 | | | |
| | Nitrite | -0.15 | -0.71* | -0.19 | 0.28* | 1.00 | | |
| | Nitrate | -0.50* | -0.01 | 0.04 | 0.27 | 0.22 | 1.00 | |
| | Silicate | -0.46* | -0.36* | -0.29* | 0.07 | 0.37* | 0.20 | 1.00 |
| Bottom | Water temp. | 1.00 | | | | | | |
| | Salinity | -0.07 | 1.00 | | | | | |
| | Oxygen | -0.19 | -0.01 | 1.00 | | | | |
| | Phosphate | -0.28* | -0.33* | 0.49* | 1.00 | | | |
| | Nitrite | -0.15 | -0.71* | 0.19 | 0.28* | 1.00 | | |
| | Nitrate | -0.50* | -0.01 | 0.04 | 0.27 | 0.22 | 1.00 | |
| | Silicate | -0.46* | -0.36* | 0.29* | 0.05 | 0.36* | 0.18 | 1.00 |

* indicates significant relation between parameters

phosphate and nitrate indicated negative relationship with water temperature and salinity in surface samples of station 1. Nitrite was positively related to phosphate and nitrate in bottom waters. This positive relation between phosphate and nitrite was observed in station 2 also and nitrite exhibited a similar relation with silicate. In station 3, the significant relationship was among phosphate and nitrate. Surface water of station 4, 5 and 6 also had significant positive relation among phosphate and nitrite. Silicate showed positive coupling with phosphate and nitrite at stations 4, 5 and 6.

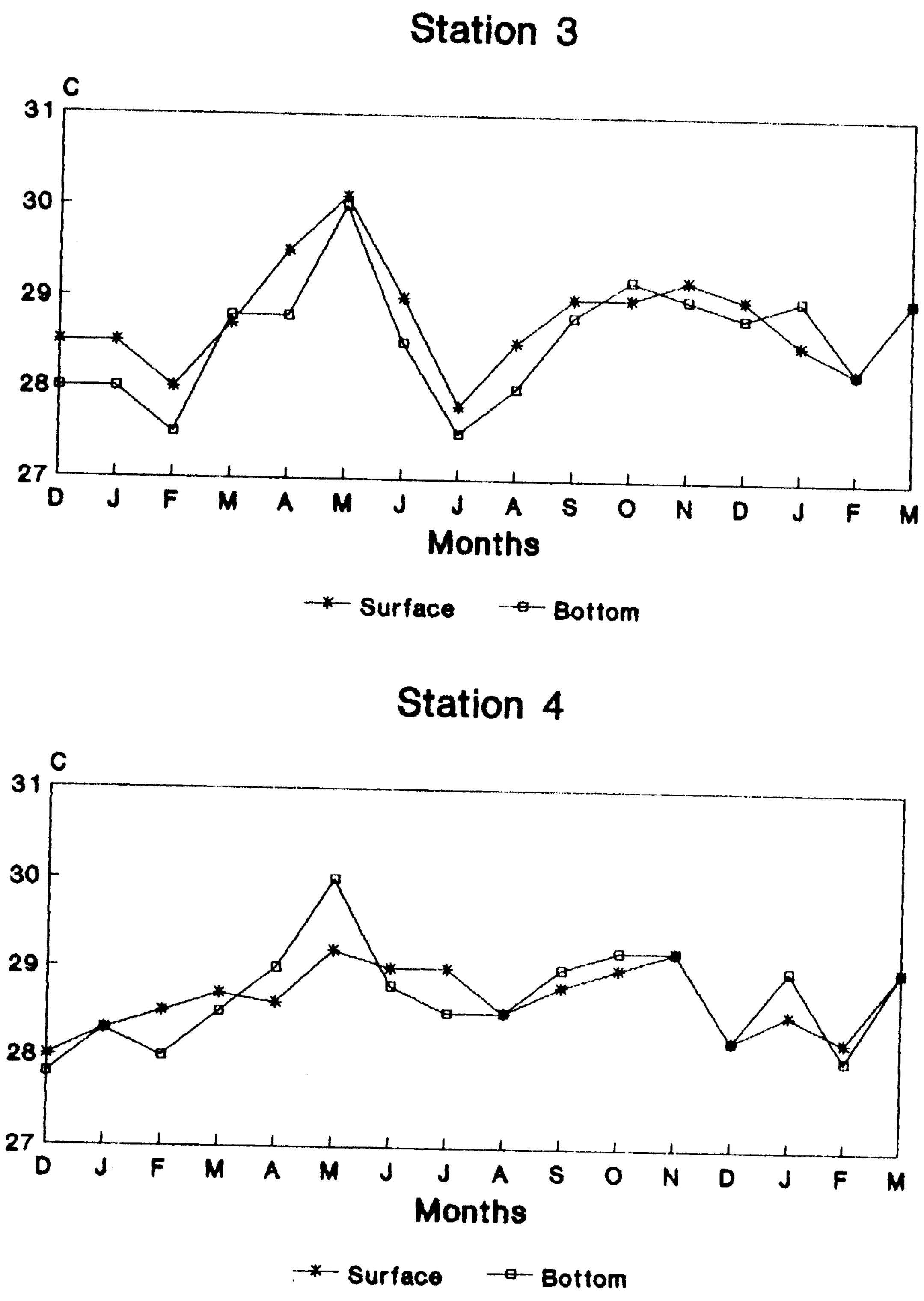
The monthly values for the various hydrological parameters are depicted in Figures 2 to 22. Water temperatures (Fig. 2,3 and 4) indicated relatively low values in January and in the monsoon and postmonsoon months of July to September. Bottom water temperatures closely followed that of surface and was lower during most of the months. Salinity (Fig. 5,6 and 7) remained comparatively stable with marginally increasing trend during the months January to September. A peak of about 37 ppt was observed in October at all the stations followed by a sharp decline before improving to normal conditions. Dissolved oxygen values of bottom water in most cases were a close shadow of that of the surface with the former dominating. Except for an increasing trend from March to August at station 2 and a sudden dip in March at station 5, no distinct pattern was evident (Fig. 8,9 and 10). Phosphate values (Fig. 11,12 and 13) indicated



Station 1

Station 2

Fig. 2 Monthly variations in water temperature at stations 1 and 2.


Station 3

Station 4

**Fig. 3** Monthly variations in water temperature at stations 3 and 4.

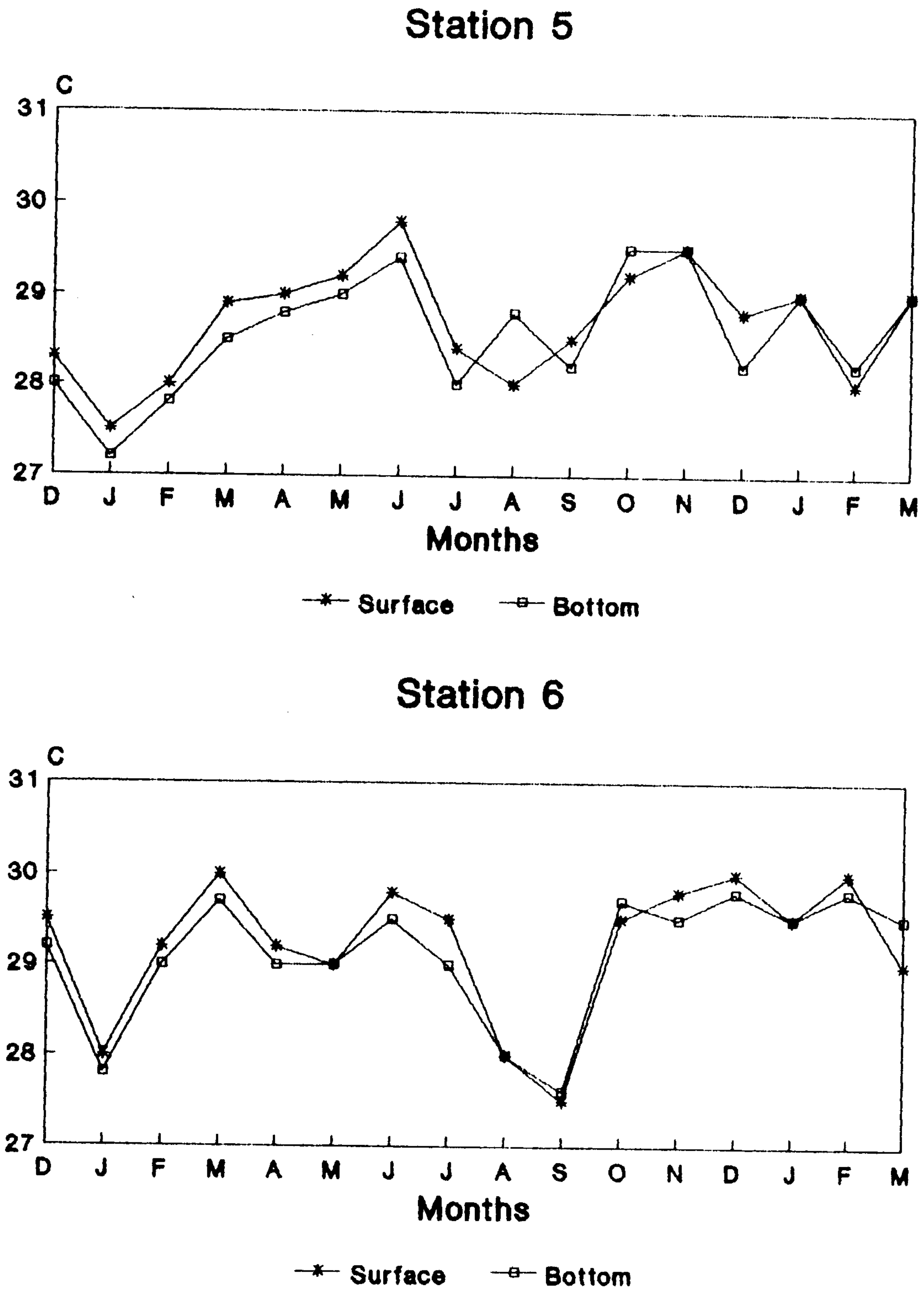


**Fig. 4** Monthly variations in water temperature at stations 5 and 6

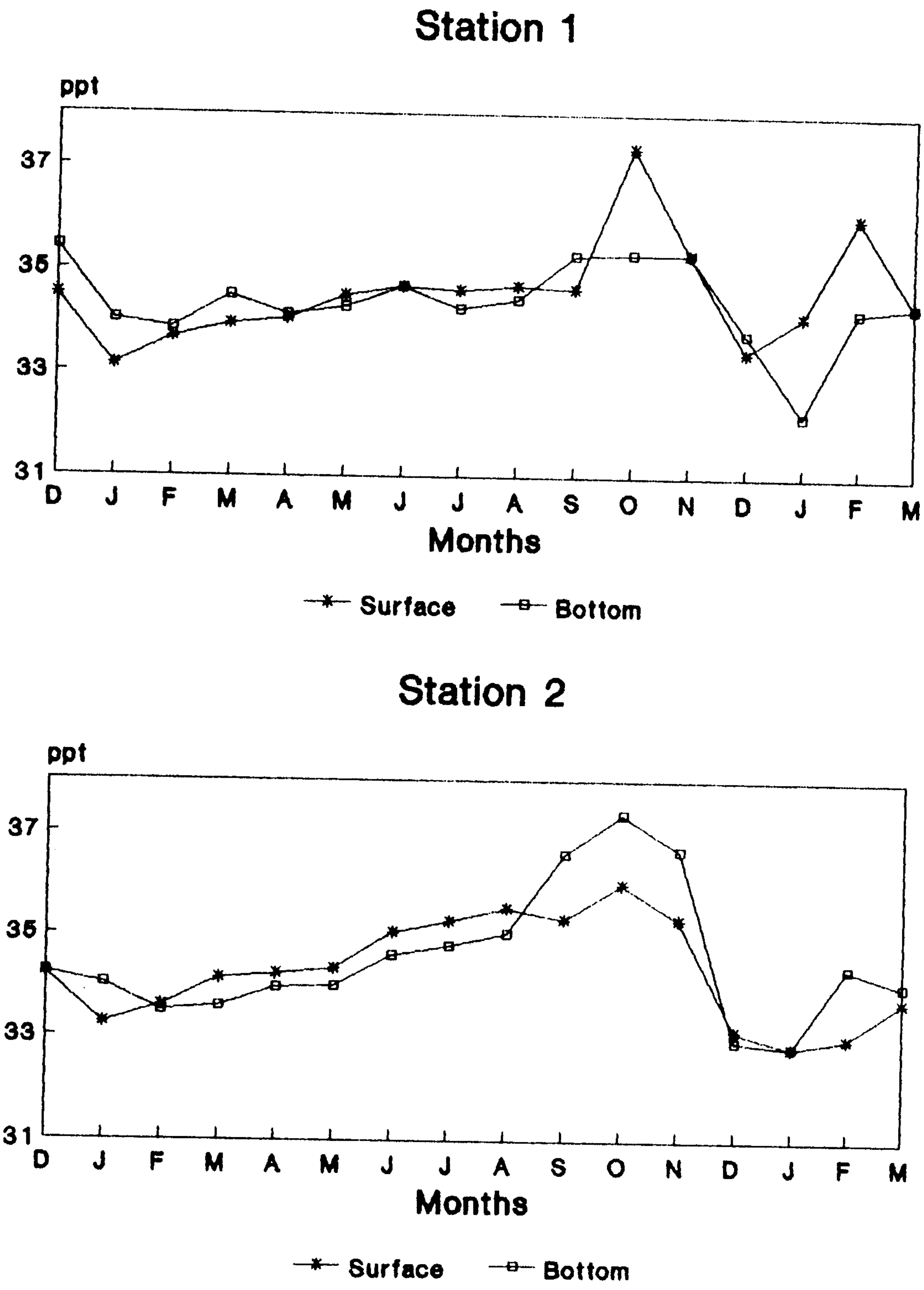


**Fig. 5** Changes in salinity at stations 1 and 2

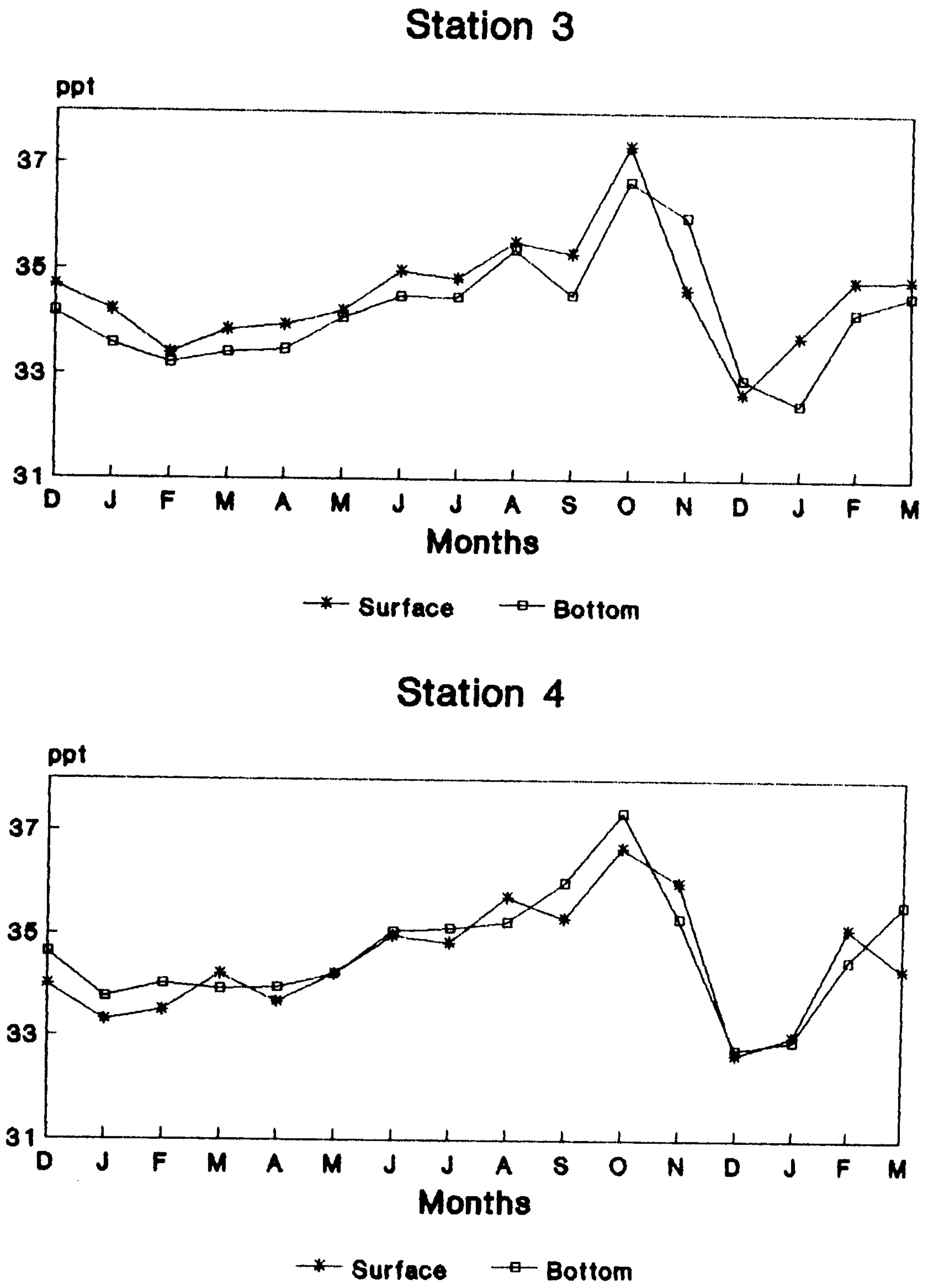
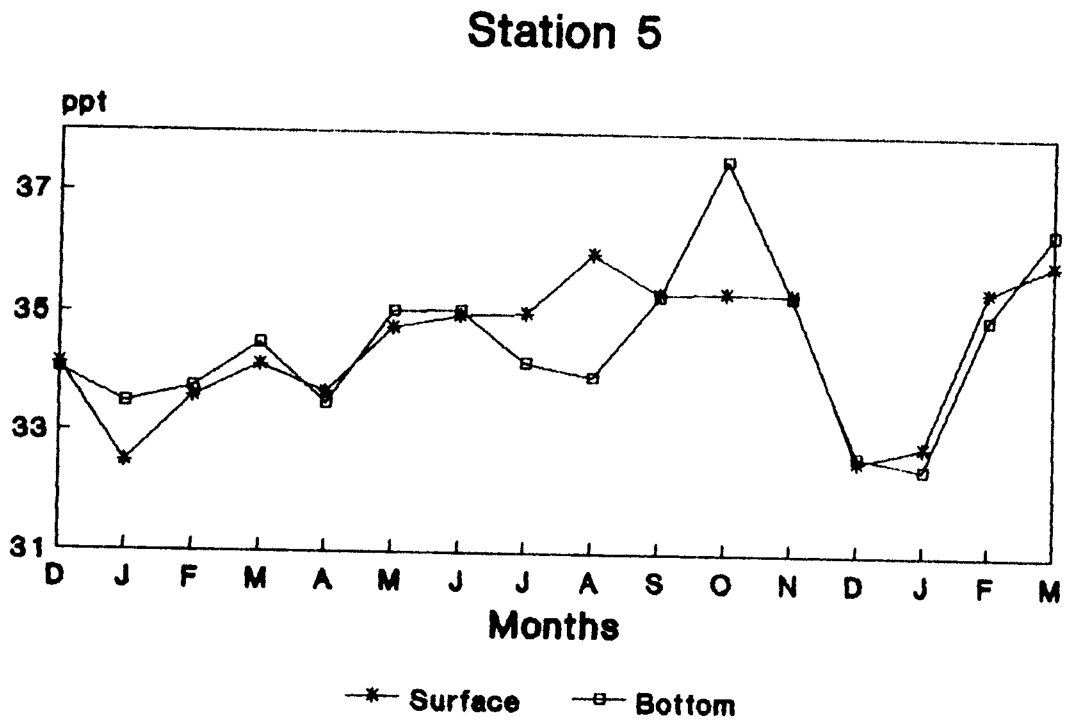


**Fig. 6** Changes in salinity at stations 3 and 4



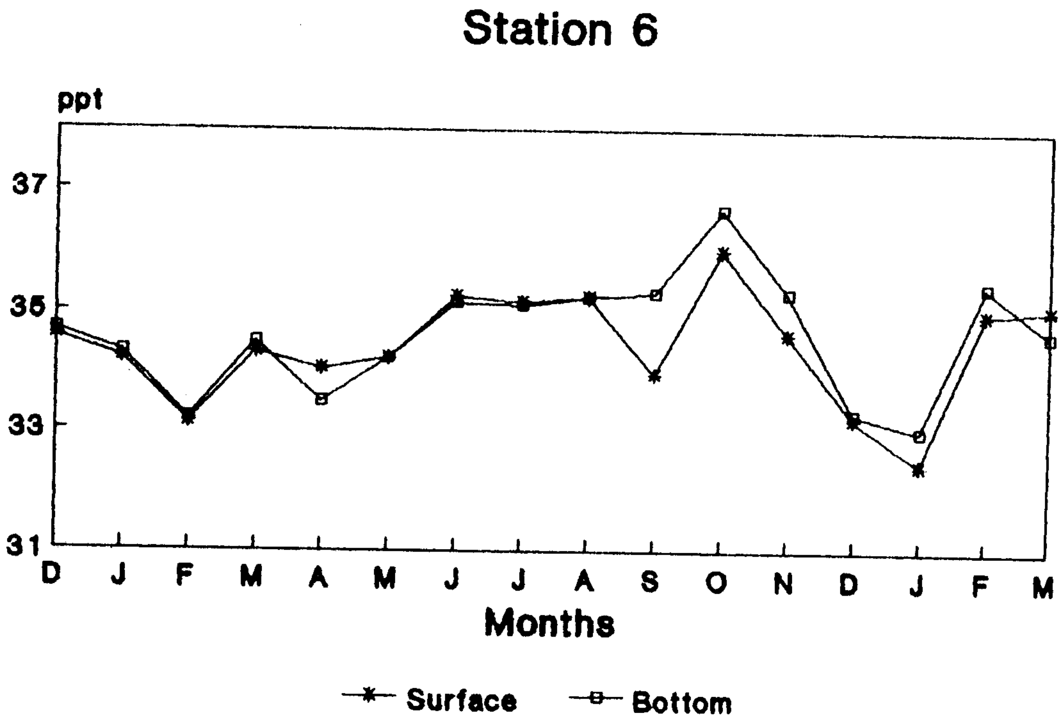


**Fig. 7** Changes in salinity at stations 5 and 6

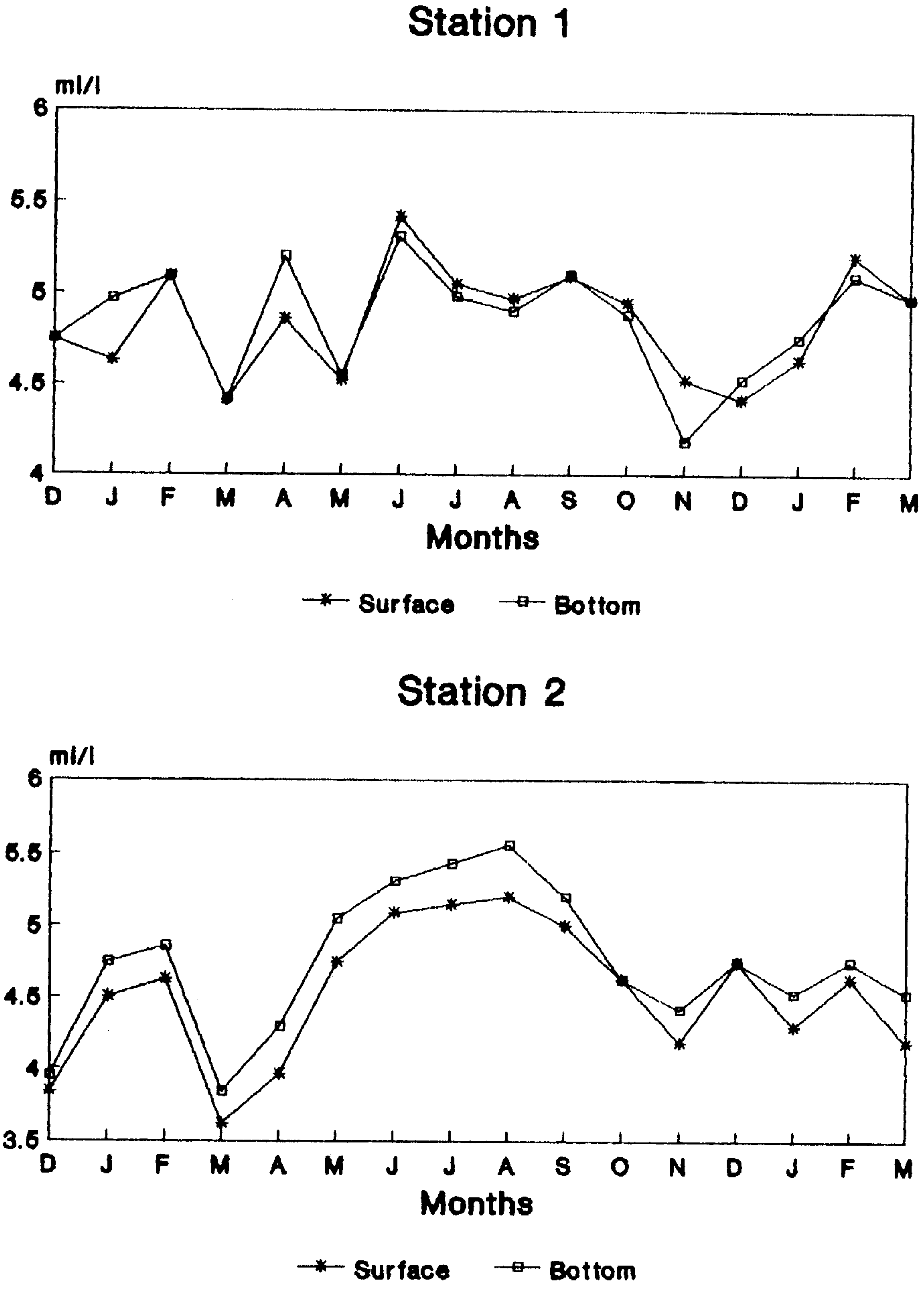
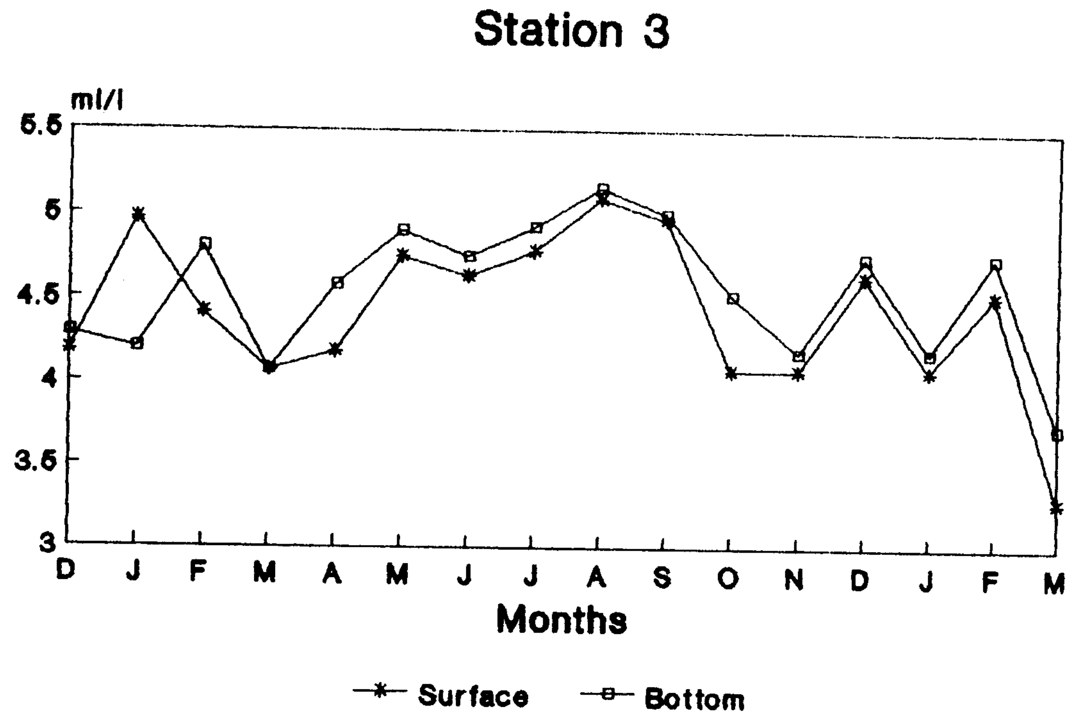


**Fig. 8** Fluctuations in dissolved oxygen at stations 1 and 2.



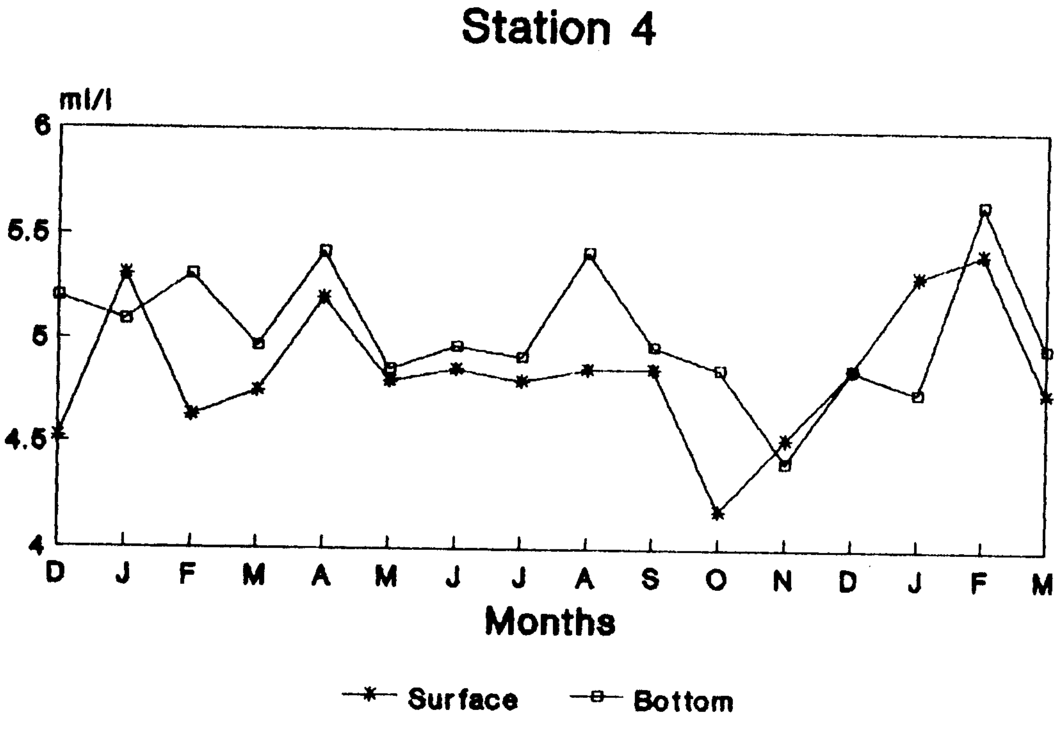


**Fig. 9** Fluctuations in dissolved oxygen at stations 3 and 4.

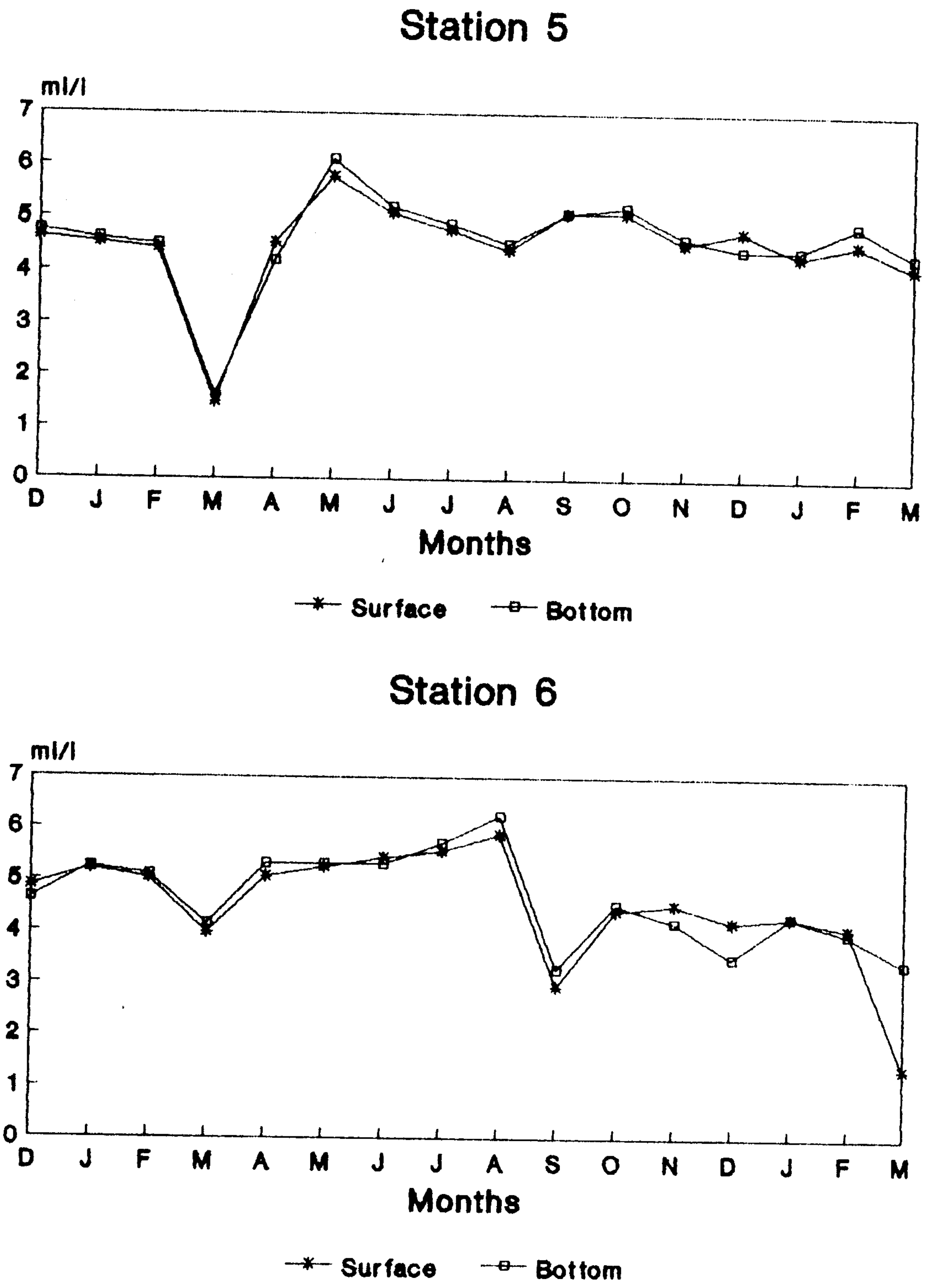


**Fig. 10** Fluctuations in dissolved oxygen at stations 5 and 6.

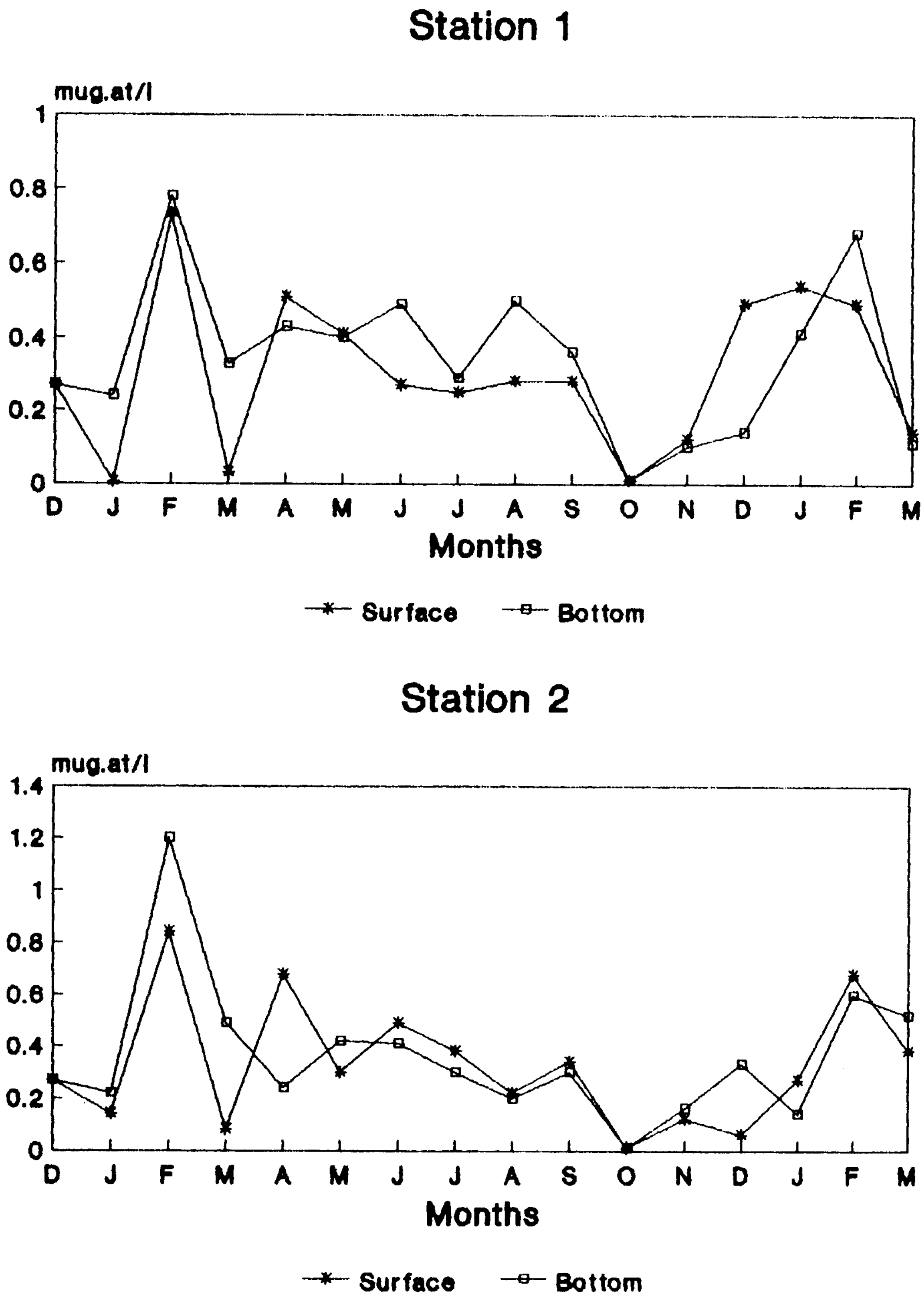
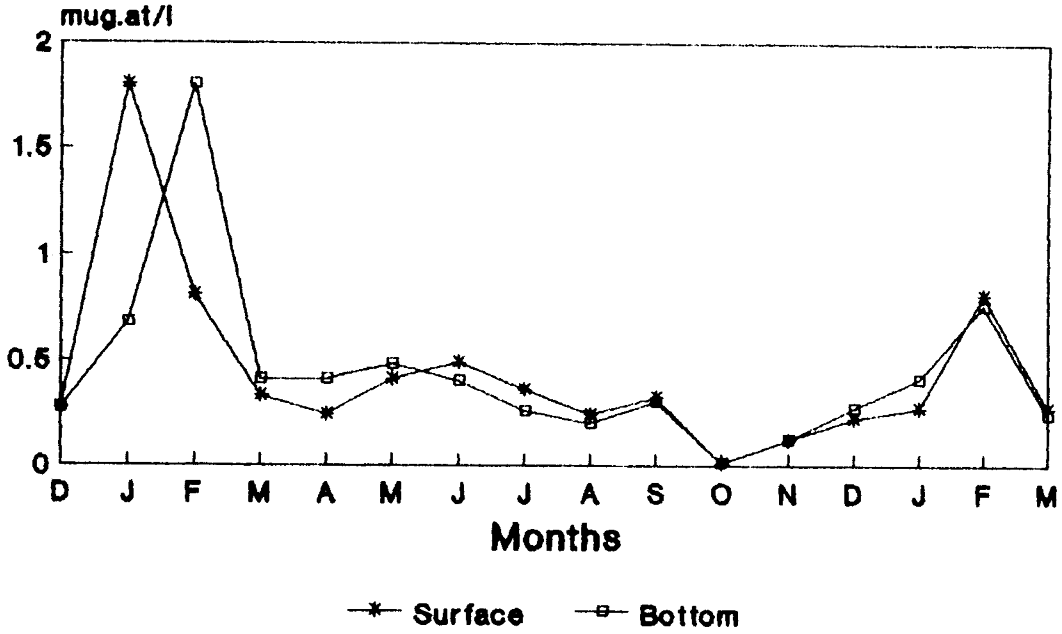
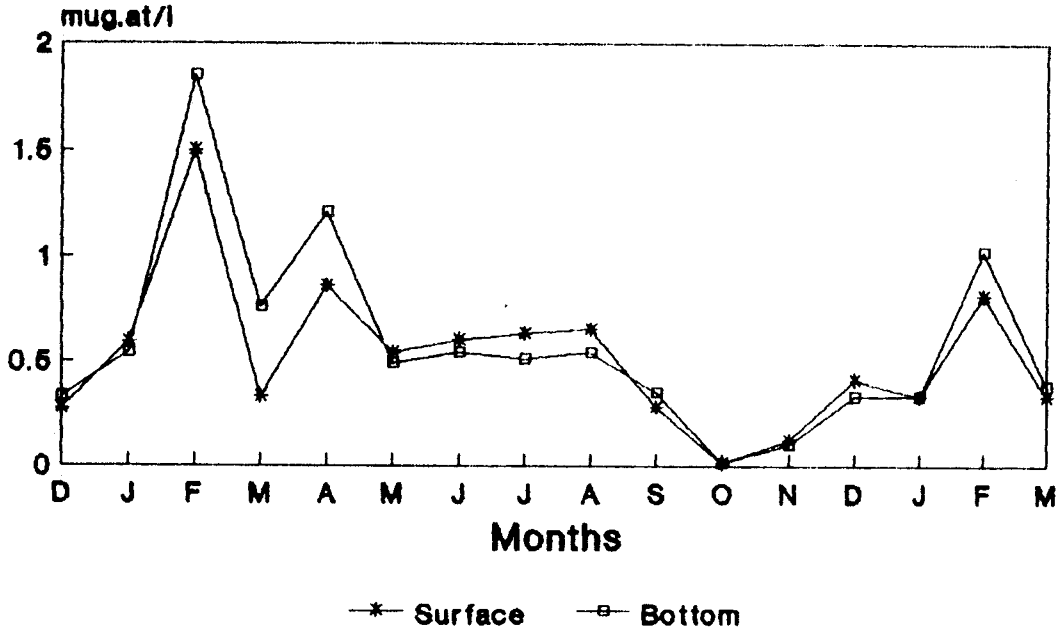


**Fig. 11** Monthly changes in phosphate at stations 1 and 2.



Station 3



Station 4

**Fig. 12** Monthly changes in phosphate at stations 3 and 4.

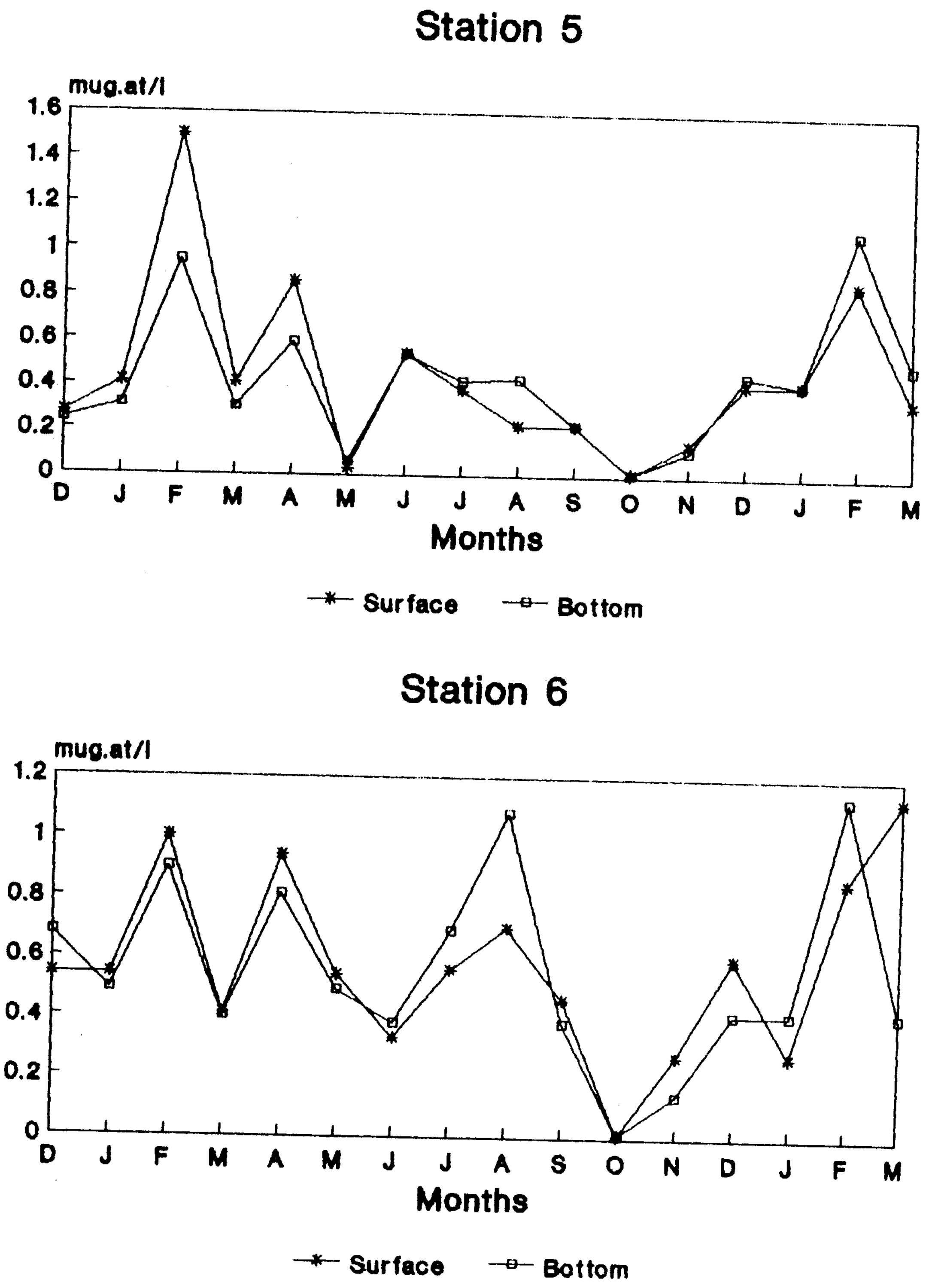


**Fig. 13.** Monthly changes in phosphate at stations 5 and 6.

erratic trends with peaks during January and February and near absence in October in all the stations. Abnormally high values in January at station 1 and in August at station 4 are the main features of nitrite (Fig. 14, 15 and 16). As in the case of phosphate, peaks during January and February and low in October was also observed in nitrite. A gradual increase from May resulting in a peak during August and a relatively minor increase starting in November with peak in January are the characteristics of nitrate in most of the stations (Fig. 17, 18 and 19). Low values of about 2 mug.at/l of silicate during September-October was noticed in all stations (Fig. 20, 21 and 22) and higher values were maintained through other months.

## DISCUSSION

Water mass structure in the ocean environs of reefs are determined by three principal factors. They are seasonal wind patterns producing annual cycles of surface wind stress and of evaporation ; regional precipitation controlling direct and fluvial inputs of freshwater to the ocean ; and net radiation resulting in surface heating and cooling (Andrews and Pickard, 1990). The strong winds from the west, the influence of southwest monsoon and the abundant light energy available at Lakshadweep, will therefore, influence the nature of water bodies in this island group. Water temperatures in reef waters generally follow a sinusoidal pattern (Walker, 1981; Andrews,

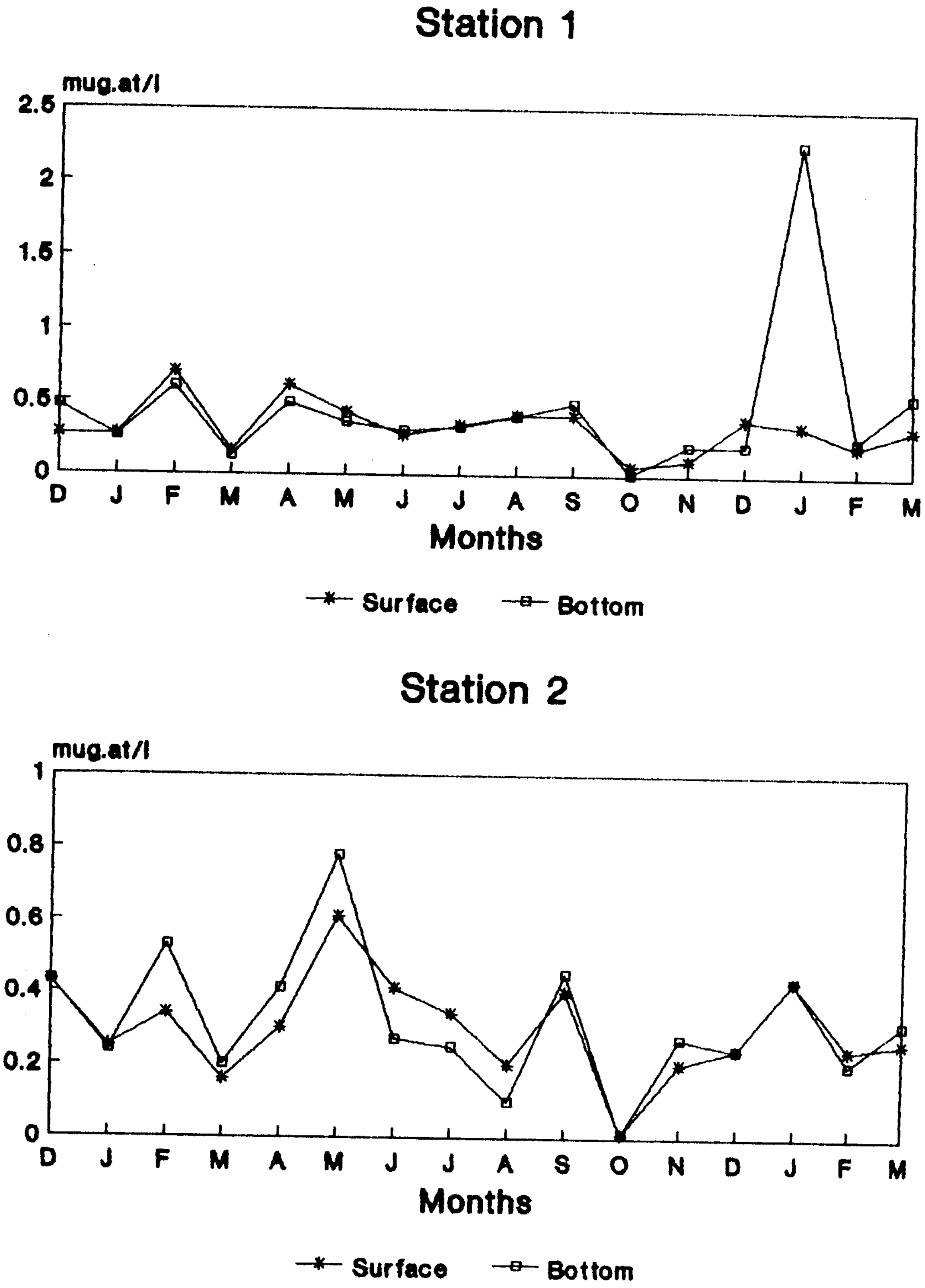


**Fig. 14** Variations in nitrite at stations 1 and 2

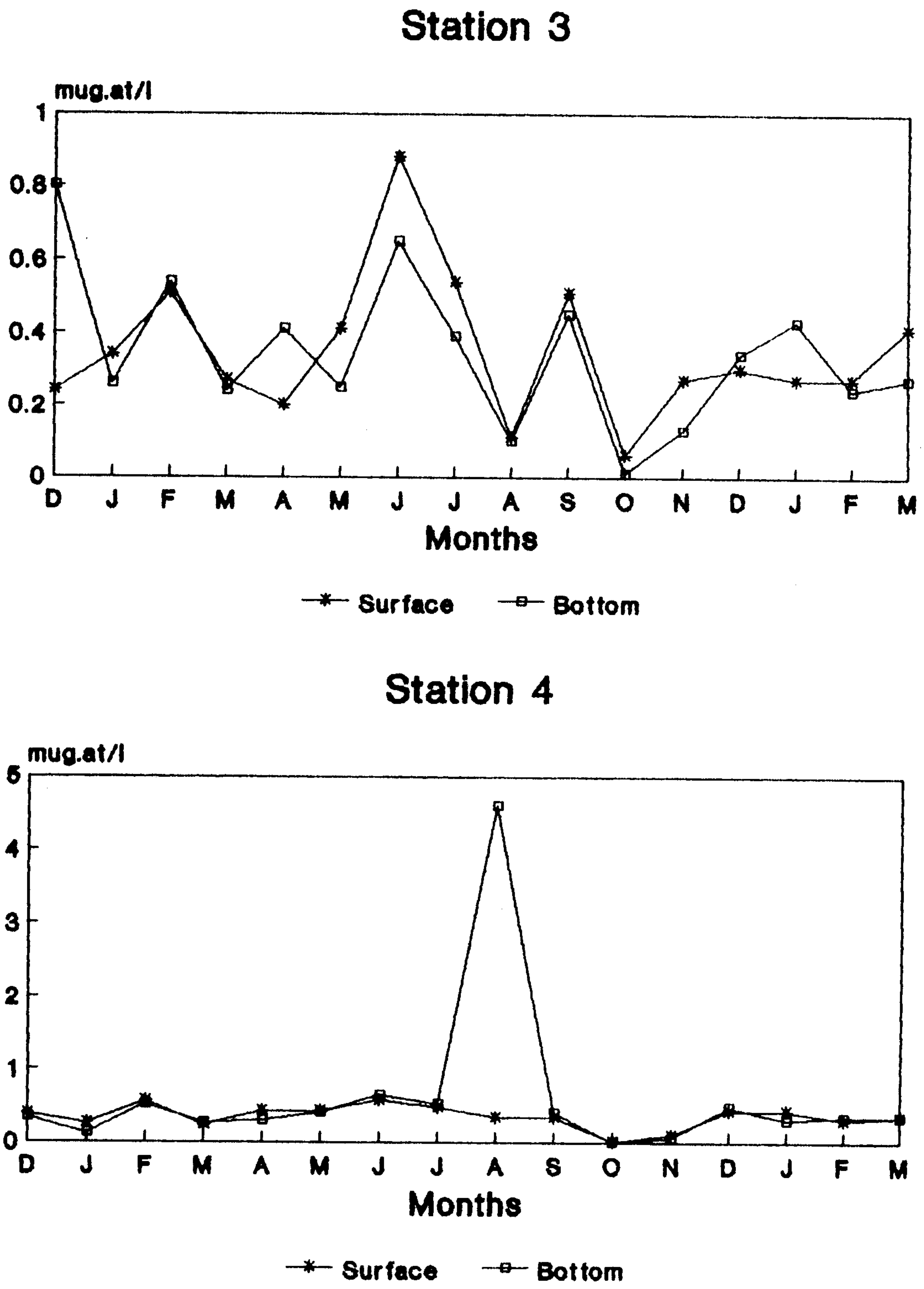
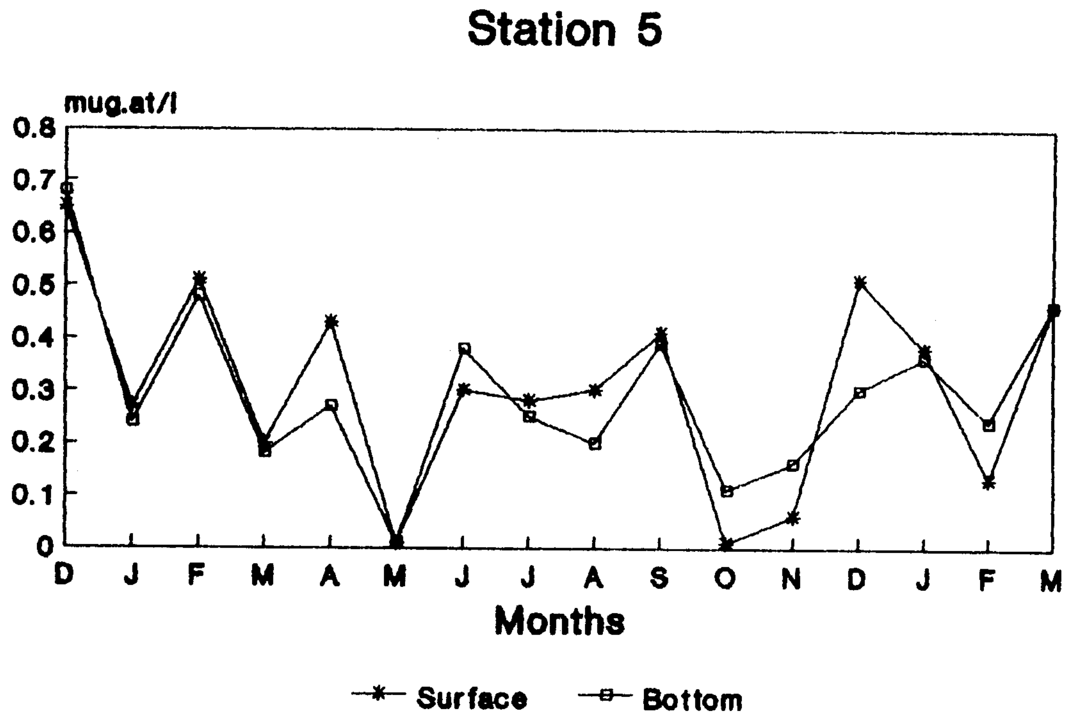


**Fig. 15** Variations in nitrite at stations 3 and 4



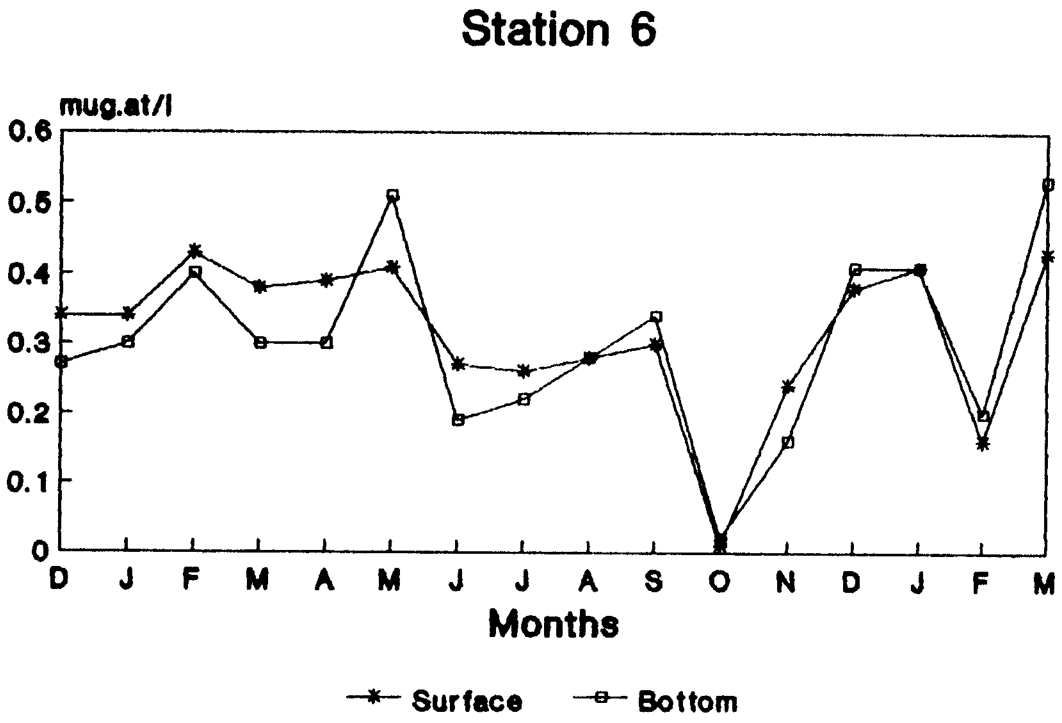
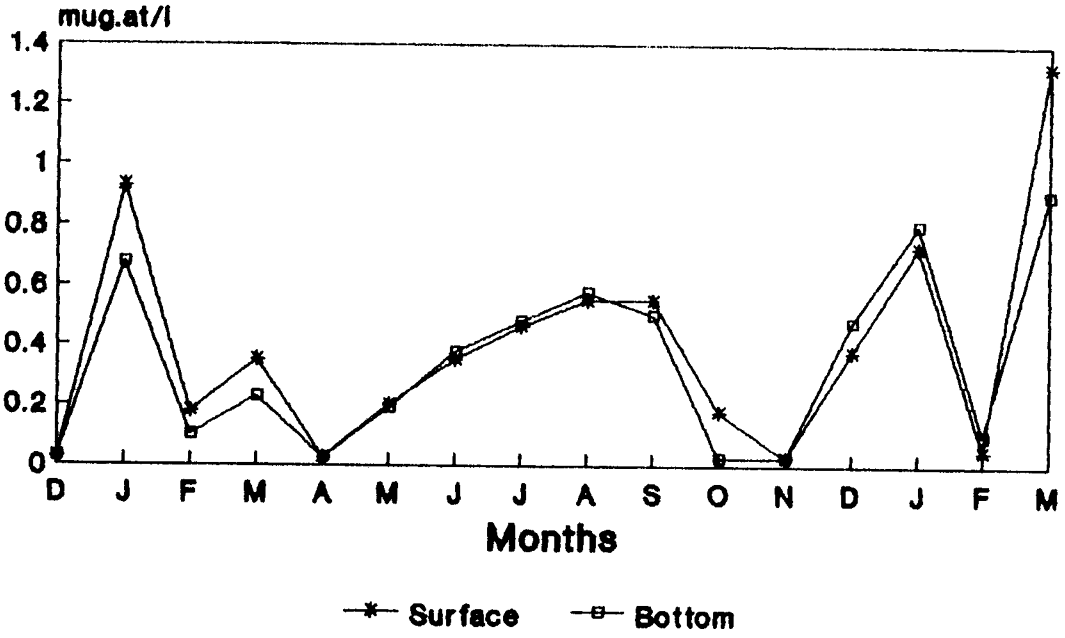
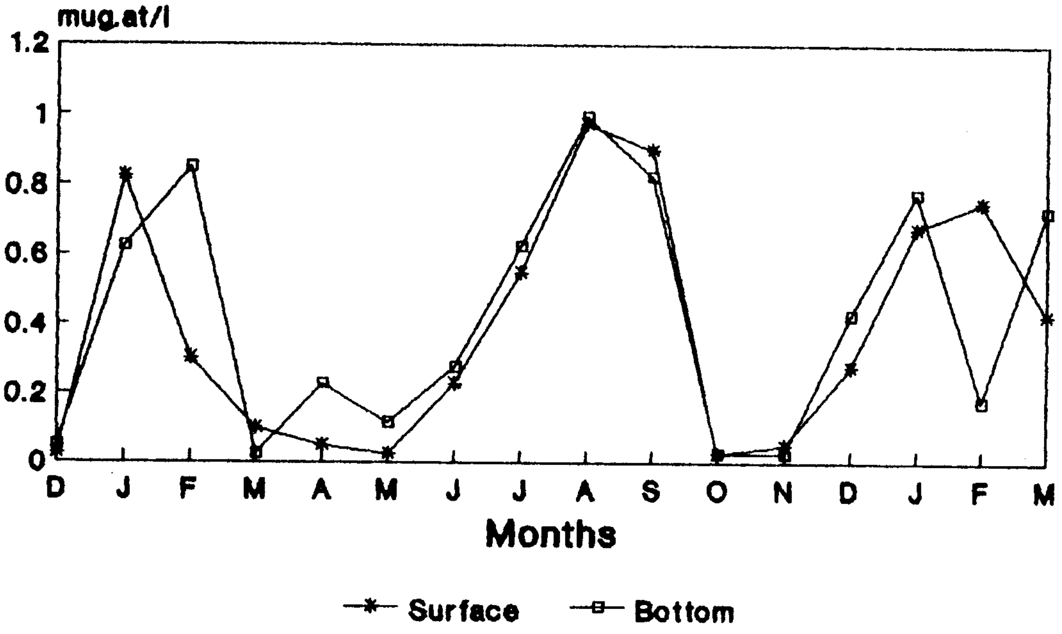


**Fig. 16** Variations in nitrite at stations 5 and 6

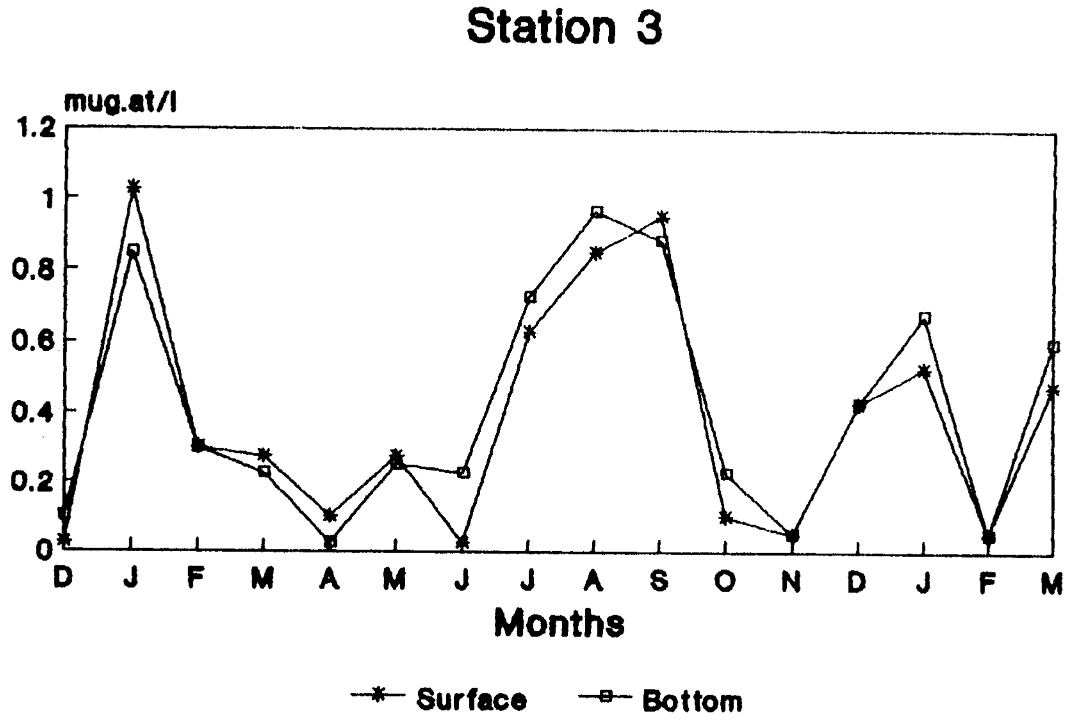


Station 1



Station 2

**Fig. 17** Changes in nitrate at stations 1 and 2



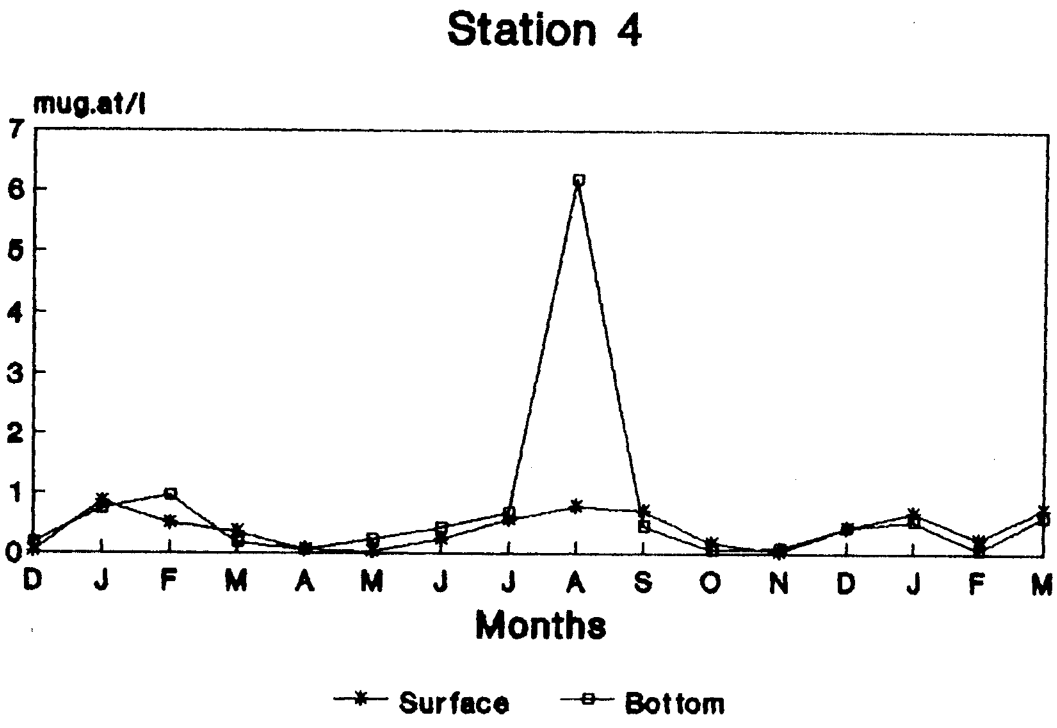
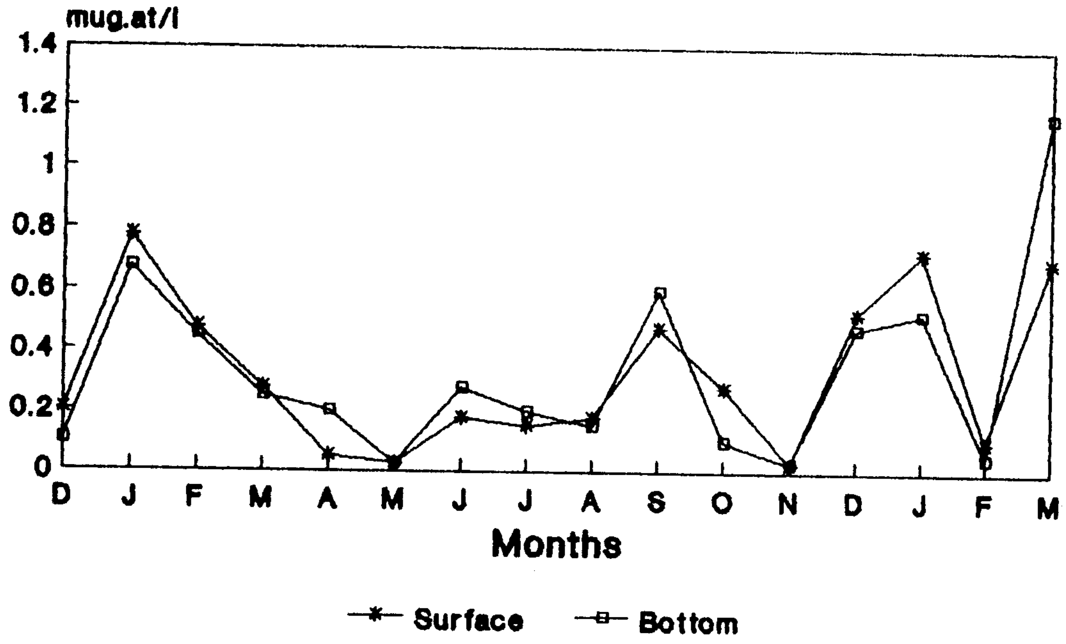


**Fig. 18** Changes in nitrate at stations 3 and 4

Station 5



Station 6

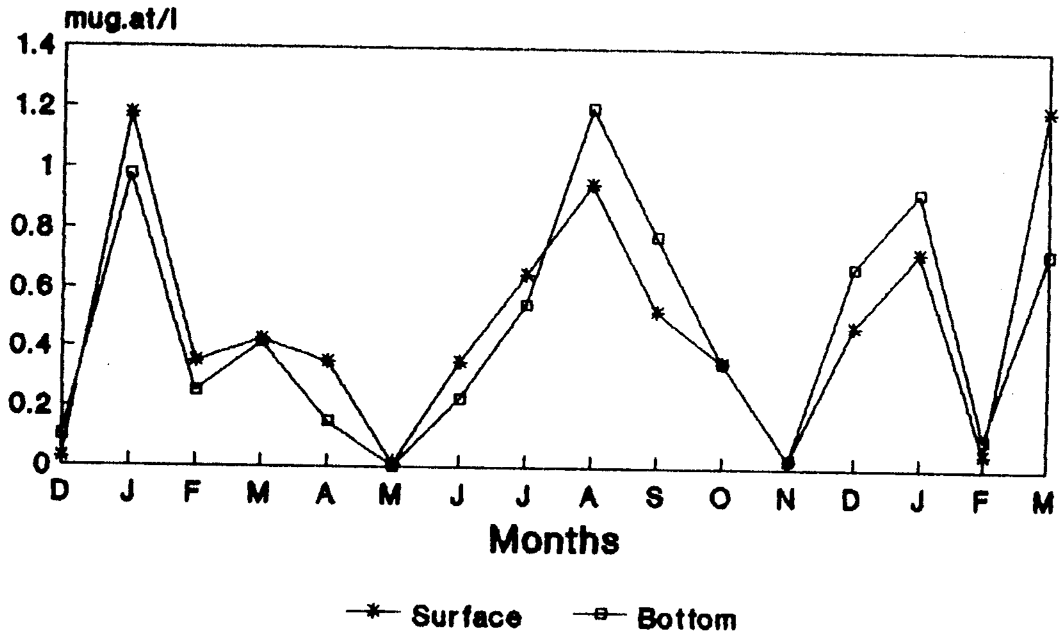


**Fig. 19** Changes in nitrate at stations 5 and 6

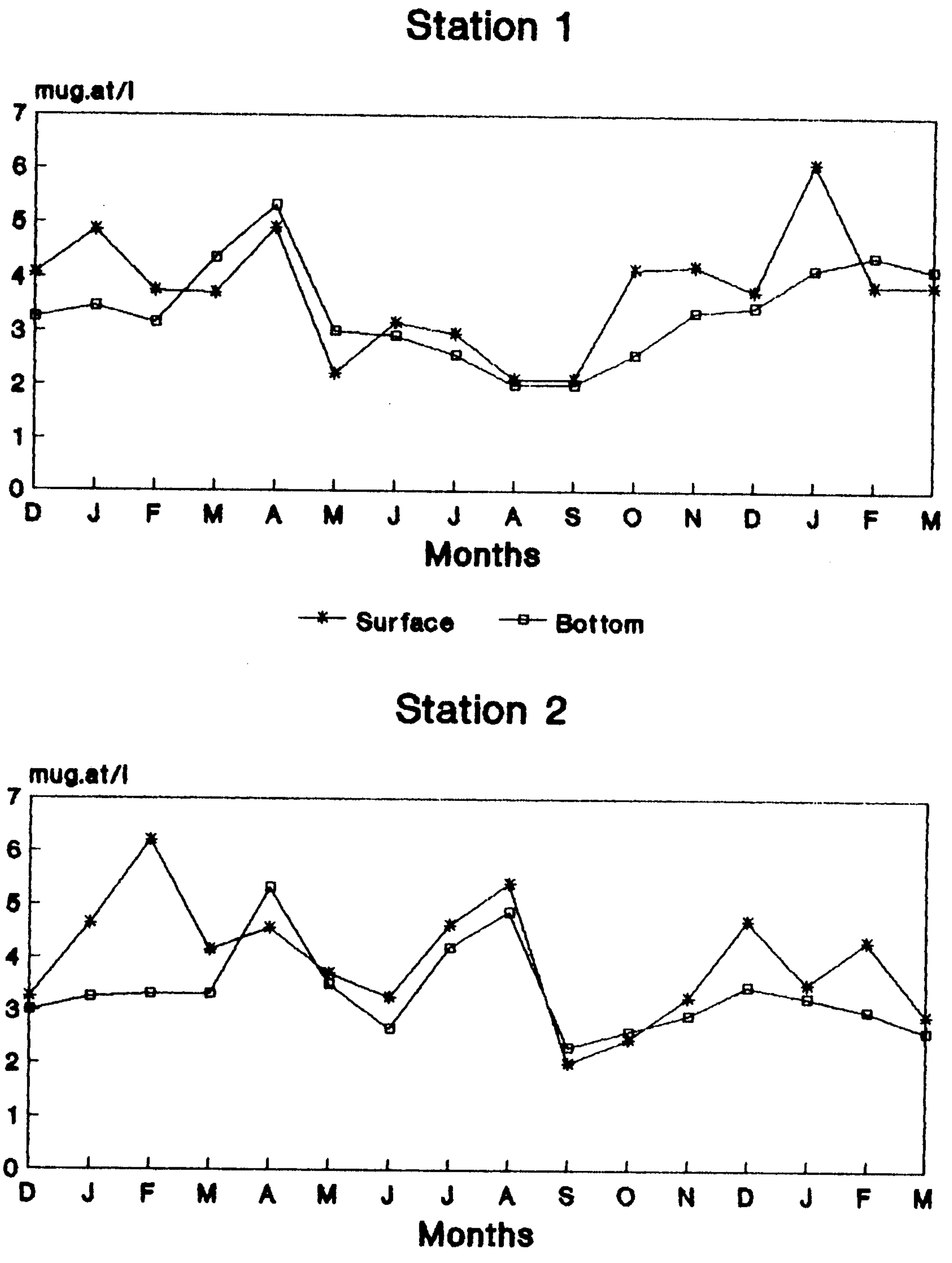


**Fig. 20** Fluctuations in silicate at stations 1 and 2

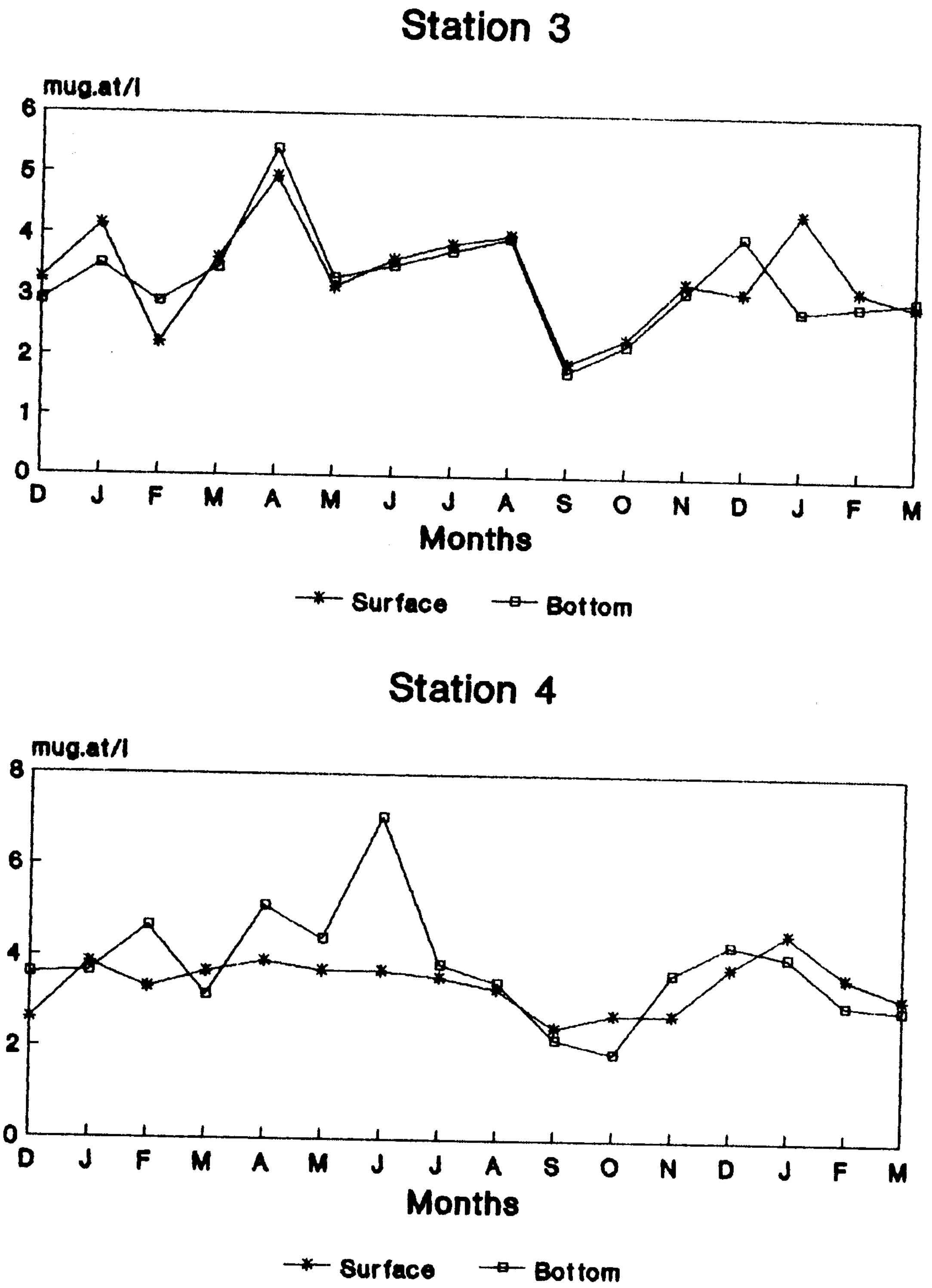
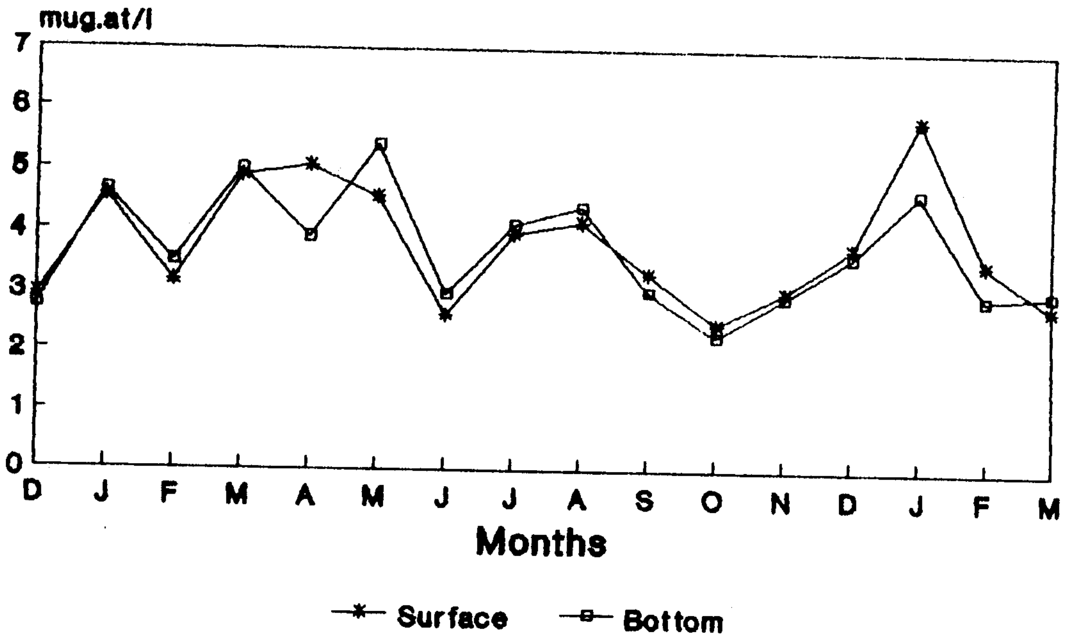


**Fig. 21** Fluctuations in silicate at stations 3 and 4

Station 5



Station 6

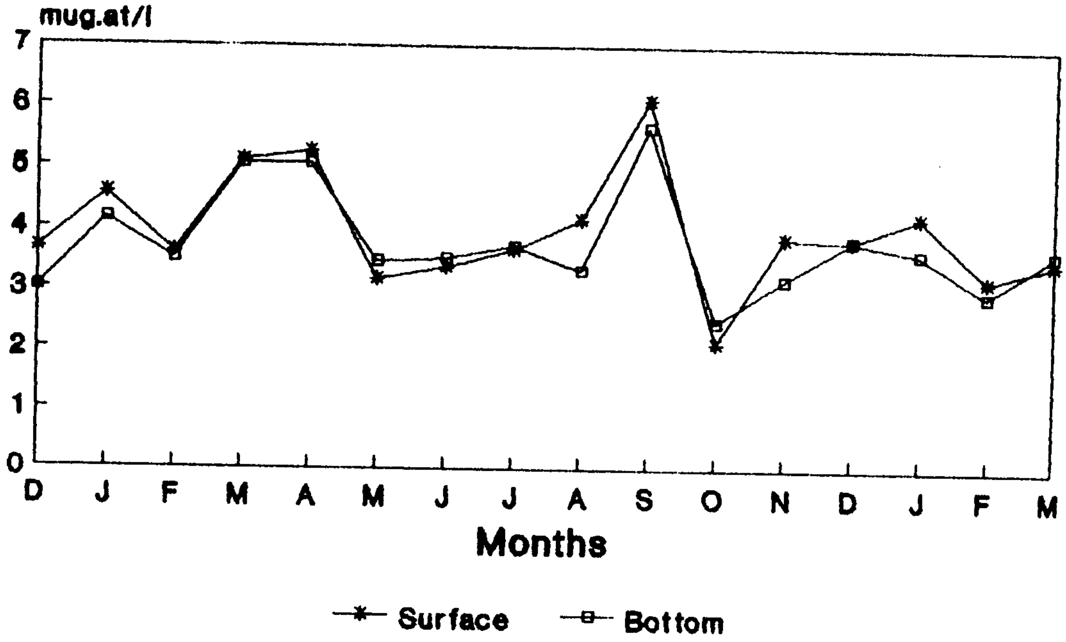


**Fig. 22** Fluctuations in silicate at stations 5 and 6

1983; Andrews et al., 1984). The range in variation at Minicoy is less than 3 deg. C and variations are highly correlated with annual cycles of air temperature. Salinity variations are more erratic than that of temperature and are influenced by land discharge (Wolanski and Jones, 1981) and upwelling (Andrews, 1983). In water bodies away from the nearshore influence of river run-off, the three significant determinants of salinity structure are rainfall, evaporation and advection (Andrews and Pickard, 1990). Glynn (1973) showed a close negative correlation between rainfall and salinity which was attributed to river run-off. Rainfall does not seem to influence the salinity of waters at Minicoy as the values are comparable to the pre and postmonsoon periods. Even if there is an impact it would be temporary and there may be flow over reefs from deeper water (ocean or lagoon) to maintain the salinity to normal levels. In fact, Stoddart (1966) observed higher salinities over a reef flat following heavy rain than before the precipitation. Rainfall is the only source of freshwater to atolls like Minicoy as the absence of rivers precludes river run-off. Seepage of groundwater into lagoons is also unlikely due to the lack of a sharp gradient between atoll land and lagoon water. Buddemeier (1981) points out that, as the water level in atoll lagoons is generally higher than that of the ocean outside, the resulting head would tend to drive such surface water of land toward the ocean rather than having an impact on the lagoon waters.

For atoll lagoons, vertical variations of water properites appear to be small and the degree of stratification is therefore also small (Andrews and Pickard, 1990). Munk et al. (1949) stated that the temperature difference between surface and bottom rarely exceeded 0.3 deg. C. An anlysis of the data at Minicoy for the various stations through the different seasons, indicates that the difference in average values between surface and bottom waters are low (water temperature, 0.3 deg. C; salinity 0.3 ppt; dissolved oxygen 0.2 ml/l). Ford (1949) observed some salinity stratification but the maximum difference between surface and bottom was only 0.2. Atkinson et al. (1981) noted that the temperature in the water column varied by nor more than 0.5 deg. C and the salinity by not more than 0.2 at Enewetak lagoon. Stoddart (1966) reported that surface and bottom termperatures were identical in Addu Atoll lagoon. A possible reason for this lack of stratification may be due to the intense vertical mixing taking place in the lagoon at each tidal exchange. Parnell (1986) proposed a dispersive type of water movement when reef flat is submerged and advection being significant when reef flat is exposed for water movement in a fringing reef.

Except for the observation of Qasim and Shankaranarayan (1970) there is virtually no information on the currents and circulation patterns of the lagoon of Lakshadweep. Water circulation in the lagoon has been indicated as a source of variation for many hydrophysical parameters and their stratification (Ford, 1949; Von Arx, 1954; Gallagher et al., 1971; Atkinson, et al., 1981). Smith and Jokiel (1975) described the water composition of a atoll 12 km long and mean depth of about 6 m. The lagoon at Minicoy being about 10 km long and having a mean depth of about 5 m, the findings of Smith and Jokiel (1975) may be applied with some reservations. They calculated that on each high tide the inflow was about 11% of the lagoon volume and the average evaporation of 8 mm/day much exceeded the average rainfall of about 0.6 mm/day. During the study period the lowest rainfall of 0.1 mm/day was recorded at Minicoy in March 90 and a high of 14 mm/day in June 89. If a evaporation of 8 mm/day is considered for Minicoy also, it would be higher than the rainfall received on most days. This would explain the increased salinity observed in certain months which may be due to net evaporation. Smith and Jokiel (1975) calculated a residence time (rate at which entrapped water is renewed) of 50 days. But this would be a high estimate for Minicoy as its lagoon is more open to tidal influence than that described by Smith and Jokiel (1975). Residence time would be more appropriately assumed at less than 10 days which is the rate estimated for an open lagoon by Kimmerer and Walsh (1981). Qasim and Shankaranarayan (1970) stated that there is a undirectional flow in the lagoon at Kavaratti. A cursory examination of the fragmentary data available on the circulation at Minicoy (available in the office of Lakshadweep Harbour Works, Minicoy) indicate that there is no clear pattern of circulation in the lagoon. This is to be expected as the lagoon at Minicoy is large and a major part of the western reef is never exposed even at lowest low tide as against those of some northern islands such as Kavaratti. More details on the current and circulation patterns at Minicoy would be required for understanding dynamics of the water mass. This would also help in knowing the distibution of pelagic organisms such as larvae of reef fishes including livebaits (Leis, 1991b).

There are only a few studies on the seasonal and spatial variation of nutrients on coral reefs. One such observation is that of Hatcher and Hatcher (1981) at One Tree Reef Lagoon, Great Barrier Reef. They found that the Reef is not dependent on the surrounding ocean for input of inorganic 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 nutrients showed a distinct seasonal pattern and variation in space. The reasons for such changes cannot be fully comprehended or explained due to paucity of related information from Lakshadweep. 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 do apply to atolls, they have completely different characteristics and structure.

Values of inorganic phosphorus less than 0.4 mug.at/l are common in reef areas and at times are so low that they approach the limit of detection (D'Elia and Wiebe, 1990). The range of mean phosphorus observed at Minicoy (0.22 to 0.62 mug.at/l) compares well with the values reported from other islands of the Indian Ocean (Johannes _et al_., 1983b; Rayner and Drew, 1984; Wafar _et al_., 1985). Coral reefs do not flourish in areas of strong upwelling. However, they occur near regions of weak upwelling at equatorial current divergences (Smith and Jokiel, 1976; Kimmerer and Walsh, 1981). Rao and Jayaraman (1966) reported upwelling in the Minicoy region of the Arabian sea. The negative correlation observed between phosphorus and water temperature and salinity, especially in stations 2, 3 and 4 may suggest an input of nutrients to Minicoy lagoon by upwelling. It is unlikely that other sources of phosphorus such as terrestrial run-off, guano deposits and groundwater inputs will be significant. More work on the sources of phosphorus will have to be carried out before arriving at a firm conclusion. Another source that could be checked is the recent concept of "endo-upwelling" (Rongerie and Wauthy, 1988). This ia a process in which deep, nutrient-rich ocean water seeps into the porous substrate of atolls, is warmed by geothermal heating and thereby caused to rise in the substrate. The nutrient-rich water is then discharged into the water near the surface in the coral reef building areas inside and outside the atoll lagoon.

The phosphorus cycle, in general, is affected by both chemical and biological processes (Webb, 1981). But the various events in phosphorus cycle of coral reefs such as assimilation, excretion and hydrolysis, precipitation, adsorption and dissolution has not been well quantified (D'Elia and Wiebe, 1990). Pilson and Betzer (1973) also reported the lack of significant differences in the concentration of phosphorus between the surface and bottom collections. They concluded from their limited observations that there is no notable support for the statement that more phosphorus may be found in deeper water in the lagoon. But Atkinson (1981) based on diurnal studies showed that reef benthic communities exchange phosphate readily with the water column. Such distinct interactions were not discernible at Minicoy even for shallow regions such as stations 3 and 6. Extensive sampling for a full day spanning longer periods is necessary to understand net benthic fluxes of phosphorus at Minicoy.

As in the case of phosphorus, equatorial upwelling is also considered to be an important source of nitrogen to coral reefs (D'Elia and Wiebe, 1990). Abnormally high values were observed in open sea samples in certain months and this can only be attributed to nutrient-rich water being brought up from below. Nitrogen concentrations in atoll and microatoll lagoons tend to be higher and more variable than in offshore waters. Many factors can contribute to this variability in concentration, which is a function of differential rates of supply and demand from advection, nitrogen fixation, denitrification, autotrophic uptake, regeneration, etc. (Hatcher, 1985; Hatcher and Hatcher, 1981). Hatcher and Frith (1985) have shown that there are seasonal, tidal and spatial variations in nutrient concentrations at One Tree Reef Lagoon. A significant seasonal variation in nitrogenous nutrients are evident at Minicoy while spatial changes are minimal. However, Kinsey (1983) has emphasized that different zones of coral reefs function differently with regard to biogeochemical fluxes. Seasonal variability of coral reefs has been overlooked because of the general perception that, in contrast to temperate ones, tropical communities lack season-to-season variability. But it is now known that high-latitude reefs may undergo striking seasonal variations in primary productivity (Kinsey, 1977). Johannes et al. (1983a) observed that dissolved inorganic nitrogen concentrations impinging on reefs varied with season. They reported three patterns of nutrient flux for one site : (1) concentration-dependent fluxes (2) fluxes variable over the diel cycle, but not concentration-dependent and (3) neither.

The nitrogen cycle, unlike those of other nutrient elements such as phosphorus and silicon, is primarily mediated by biological, not chemical processes (Webb, 1981). This means that, in addition to its role as a nutrient, nitrogen at the different oxidation states can serve as either an oxidant or reductant, and is important to the energetics of many bacteria (D'Elia and Wiebe, 1990). Nitrogen fixation is now known to be an important feature of the nitrogen cycle of most coral reefs. Webb et al. (1975) reported increases in dissolved inorganic nitrogen and dissolved organic nitrogen concentrations between fore-reef and back-reef stations which implied that net nitrogen export from reef occurs. This nitrogen export is believed to result from high rates of nitrogen fixation. The amounts fixed appear to be significant with regard to community requirements (Webb et al., 1975; Capone, 1977; Hatcher and Hatcher, 1981). Nitrogen fixation is associated with a host of reef biota. While many of these organisms are available in the lagoon of Lakshadweep, their role, rate and dynamics of nitrogen fixation has not been assessed. Similarly, the consequent steps in nitrogen cycle such as ammonification, nitrification and assimilatory nitrate and nitrite reduction at Lakshadweep is warranted.

Silicon dynamics of coral reefs have received less attention primarily because coral reef sediments are typically calcareous, not siliceous, and silicon is not an essential element for most reef organisms. As for dissolved inorganic phosphorus and nitrogen, silicic acid concentrations near reefs in region of equatorial upwelling may be elevated (Smith and Jokiel, 1978). The negative relationship observed between salinity and silicic acid may indicate the importance of terrestrial run-off or groundwater as a source of silicic acid. Smith and Jokiel (1978) and Johannes et al. (1983a) found no clear correlation between silicic acid concentration and salinity, and inferred that little significant net utilization of silicon occurs in most reef environments. Johannes et al. (1983a) found seasonal differences in net flux patterns of silicic acid.

Much remains to be learnt about nutrient biogeochemistry in atolls of Lakshadweep. Particularly important will be to (1) identify the sources of nutrients (2) process of nitrogen fixation and its quantification (3) organisms involved and the mechanism of nutrient cycle and (4) the causes of seasonal and spatial variation of nutrients.

## CHAPTER 6

# PRIMARY PRODUCTION

## INTRODUCTION

Coral reefs are often defined as shallow-water, tropical marine ecoystems, characterised by a tremendous variety of plants and animals and by high rates of production in nutrient-poor and plankton-impoverished coeans (Lewis, 1981). Estimates of gross production in waters over reefs vary between 300 - 5000 gc/sq.m/yr (Sargent and Austin, 1954; Odum and Odum, 1955; Kohn and Helfrich, 1957; Odum et al., 1959; Gordon and Kelly, 1962; Kinsey, 1972; Nair and Pillai, 1972; Smith and Marsh, 1973; Smith, 1974). In general, rate of production (P) to community respiration (R) are greater than one; that is, most reefs produce more organic matter than is utilised in the system. Sargent and Austin (1954) and others confirmed the general conclusion that the production in the waters flowing over reefs greatly exceeds production in oceanic waters in the vicinity. Further extension of this work indicated that the sources of autochthonous production are much greater than the allochthonous inputs from the plankton system. The source of this high internal production is cheifly the large statnding crop of benthic algae. Benthic algae along with symbiotic algae, phytoplankton and seagrasses constitute a mojor portion of the coral reef. Some authours even think that reefs are misnamed and instead of "coral reefs" they should be named "biotic reefs" or even "algal reefs" (Hillis-Colinvaux, 1986).

Benthic primary producers predominate over phytoplankton in reef ecosysystems. These benthic plants are diverse and exhibit specialised habit, and include: 1. fleshy macrophytes, 2. filamentous endolithic algae, 3. filamentous epilithic and sand-dwelling algae, 4. encrusting coralline algae, 5. symbiotic zooxanthellae and 6. seagrasses (Lewis, 1981). In conditions where herbivores are active, frondose macrolagae are grazed to a height of 1 to 2 cm above the substrate with a tight compact appearence which has been named turf (Borowitzka, 1981).

A fundamental reason for the high rates of production is the abundant light energy available for benthic producers in warm, shallow, well-lit waters (Lewis, 1981). A second important reason concerns the fixation of atmospheric nitrogen. It now appears that nitrogen is not, after all, a limiting nutrient but is fixed in substantial quantities and is readily available to primary producers (D'Elia and Wiebe, 1990). A third mechanism involves the retention and recycling of nutrients within the reef system. Kinsey and Domm (1974) obtained evidence for nutrient retention in artificially fertilised, isolated reef pools in the Great Barrier Reef. As a result of fertilisation and nutrient retentions the test areas were maintained as autotrophic systems. Recycling of nutrients is the other important factor (Johannes *et al*., 1972; Pilson and Betzer, 1973; Pomeroy *et al*., 1974).

Fleshy algae are not often a conspicuous element on coral reefs and their importance as primary producers has not been recognized (Dahl, 1974; Doty, 1974). The calcareous green algae of the genus *Halimeda* are common on reefs and are important as contributors of reef sediments. Hillis-Colinvaux (1980) summarized a decade of woork on *Halimeda* and points out that productivity appears to be of the same order of magnitude as that of *Thalassia* and species of intertidal Cyanophyta. Qasim *et al*. (1972) estimated the production of 3 green algae and a red alga at Kavaratti and found that they produced more organic matter than they consume. Other studies on macroalgae of coral reefs include Wanders (1976), Penhale and Capone (1981), Hawkins and Lewis (1982), Borowitzka *et al*. (1983), Untawale and Jagtap (984) and Naito and Russel (1989). In areas where there is luxuriant growth, macrophytic algae make an important contribution to primary production.

A consensus of opinion regarding phytoplankton as producers in coral reefs is that it contributes very little to community production (Lewis, 1977). Most values of production by phytoplankton are low when compared with production by the whole community (Milliman, 1969; Sorokin, 1974; Sournia and Ricard, 1976). Ricard and Delesalle (1981) classified Scilly atoll on the basis of primary production along with the other relatively oligotrophic and weakly productive atolls of the tropical South Pacific. Wafar (1977) observed that the contribution of larger phytoplankton to the reef production of two atolls in lakshadweep is not significant while nannoplankton accounted for 65-75% of the total phytoplankton production. Furnas et al. (1990) found that lagoonal phytoplankton production was directly related to standing crop and inversely related to lagoon flushing rates.

The majority of reef corals as well as other reef-dwelling cnidarians are inhabited by symbiotic dinoflagellates (=zooxanthellae). Zooxanthellae are among the dominant primary producers in tropical reef communities. A major goal in coral research has been to understand the flux of carbon and energy in the primary production of zooxanthellae and to determine the impact of these fluxes on the metabolism of the host coral (Muscatine, 1990). Carbon fixed by zooxanthellae, and not consumed by respiration or growth of zooxanthellae, is potentially available for release and translocation to the animal host. Translocated carbon is used either in animal respiration (Muscatine et al., 1981; Fitt et al., 1982; Davies, 1984; Farrant et al., 1987) or in animal growth (Edmunds and Davies, 1986). The translocated carbon is also released as soluble carbon by corals (Crossland et al., 1980; Muscatine et al., 1984). Depending on such factors as habitat irradiance, density of zooxanthellae, and adaptations of the host animal for acquisition of particulate and dissolved organic substances, corals, as well as other zooxanthellate marine organisms, demonstrate resource partitioning along an autotrophic-heterotrophic axis (Porter, 1976; Schlichter, 1982).

Seagrass communities are highly productive and species such as *Thalassia testudinum* ranks among the most productive of all plants (Odum, 1956; Westlake, 1963). Qasim and Bhattathiri (1971) and Qasim *et al*. (1972) recorded high values for *T. hemprichii* at Kavaratti and McRoy (1974) also found comparatively higher values with average net production of 1500 gc/sq.m/yr for both tropical and temperate seagrasses. Similar values of production has also been reported from other areas (Patriquin, 1973; Greenway, 1974; Thom, 1988). A seagrass bed in the Gulf of Mannar was found to be autotrophic and another heterotrophic by Balasubramanian and Wafar (1975). Similarily, Amini atoll in Lakshadweep which is rich in *Cymodocea serrulata* showed 65% more productivity than the nearby Kadmat atoll which is totally lacking seagrass vegetation (Kaladharan and David Raj, 1989). Jagtap and Inamdar (1991) estimated the total seagrass cover from six major islands of Lakshadweep to be 112 ha with standing crop of ca 800 metric tonnes. Jagtap (1991) attributed the rich growth of seagrasses at Lakshadweep manily to high salinity, clarity of the water and sandy substratum. Seagrass meadows harbour denser and richer macroinvertebrate assemblage when compared with the density of nearby unvegetated areas (Ansari *et* al., 1991). Sorokin (1990b) summarizes the factors that make coral reef areas highly productive albeit located in areas of limited nutrient supply. Environmental conditions favourable for high production in reefs (including nutrient supply) are controlled by the biological activity of organisms inhabitating it. Secondly, the autotrophic benthic communities of macrophytes, seagrasses, periphyton, microphytobenthos, reef symbionts, and sometimes the phytoplankton, form dense populations on the reef, which have a high potential for photosynthesis.

As a part of the ecological studies, observations on productivity of phytoplankton, seaweeds, seagrasses and a coral were made at Minicoy. The difficiulities in measuring community production limited the study to individual production capabilities of these autotrophs. Primary prodcution studies are are recognized as an important aspect of reef ecology for further development of such activities as tropical sea farming. The construction of artificial reefs and their role in increasing fish population is one such example. With this in view, the study is intended to understand the primary productivity of the habitat of tuna live-baits.

## MATERIALS AND METHODS

The algae used in the study were phytoplankton, green algae - Caulerpa reacemosa and Halimeda gracilis, brown algae - Turbinaria ornata and Padina tetrastomatica. Seagrasses, Thalassia hemprichii and Syringodium isoetifolium collected from the seagrass bed in front of Tuna Canning Factory were used. The branching coral Acropora formosa collected from the southern sandy area of Minicoy lagoon was employed to understand the productivity of coral. Procedure followed was basically that of Qasim et al. (1972). Freshly collected specimens were carefully washed with filtered seawater and a small quantity of each (2-3 g) was weighed while still wet and kept in jars of 300 ml capacity. These jars were filled with filtered seawater and closed tightly while immersed in a bucket of seawater to prevent entry of atmospheric oxygen. Jars painted black, covered in aluminium foil and further enclosed by black was used as dark bottles. A sample of seawater was fixed with Winkler A and B which was sued as the intial concentration of oxygen. The jars were then suspended in the lagoon approximately 20 cm from the surface where the total depth of the lagoon was about 2 m. In each experiment triplicae sets were used and incubated for a period of 3 hrs. 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 from the initial value were taken as photosynthesis and respiration respectively. Winkler determinations were carried out to calculate the oxygen produced and consumed in ml/cub.m/hr for phytoplankton and ml/g/hr for others. These values were then converted for carbon equivalents employing the factor 0.536/1.25. To esstimate the biomass of various plants, a quadrat of 20x20 cm was randomly placed in beds containing the seaweeds and seagrasses utilized in the study. They were then removed, cleaned, wiped and weighed. The values for different quadrets were averaged and results are presented in g/sq.m of plant cover. The biomass for corals was also determined in a similar manner by removing the live and growing regions of branches in the quadret. Biomass estimation was carried out to cover all the seasons. However, seasonal variation in biomass was not significant and therefore an average from all the quadrat sampling was applied in the calculation.

## RESULTS

The mean gross and net productivity for the seasons are presented in Table 1. Gross production by phytoplankton during premonsoon was much higher than in the other two seasons. Among the green algae, H. gracilis showed the maximum gross production of 0.53 mgC/g/hr in monsoon with the lowest production also recorded by Halimeda in premonsoon. T. ornata had a maximum production of 0.68 in monsoon while that of P. tetrastomatica was higher at 1.46 mgC/g/hr. The maximum production by Thalassia hemprichii was during postmonsoon with a value of 3.95 and in

Table 1: Mean and standard deviation of gross and net productivity by phytoplankton, seaweeds, seagrasses and coral during the different seasons. First horizontal line against a species is the mean and the other standard deviation. Values for phytoplankton are in mgC/cub.m/hr and others in mgC/g/hr.

| Species | Premonsoon |  | Monsoon |  | Postmonsoon |  |
|---|---|---|---|---|---|---|
|  | GPP | NPP | GPP | NPP | GPP | NPP |
| Phytoplankton | 6.00 | 2.64 | 2.86 | 1.56✓ | 2.92 | 1.73 |
|  | 2.82 | 2.49 | 0.31 | 0.07 | 0.88 | 1.05 |
| *Caulerpa racemosa* | 0.36 | 0.24 | 0.44 | 0.38 | 0.43 | 0.33 |
|  | 0.05 | 0.16 | 0.19 | 0.15 | 0.29 | 0.29 |
| *Halimeda gracilis* | 0.32 | 0.20 | 0.53 | 0.39 | 0.37 | 0.21 |
|  | 0.22 | 0.14 | 0.13 | 0.15 | 0.16 | 0.13 |
| *Turbinaria ornata* | 0.63 | 0.42 | 0.68 | 0.56 | 0.54 | 0.37 |
|  | 0.24 | 0.29 | 0.12 | 0.15 | 0.26 | 0.28 |
| *Padina tetrastomatica* | 1.08 | 0.79 | 1.46 | 1.21 | 1.13 | 0.87 |
|  | 0.40 | 0.40 | 0.42 | 0.36 | 0.11 | 0.20 |
| *Thalassia hemprichii* | 1.82 | 1.69 | 1.57 | 1.19 | 3.95 | 3.28 |
|  | 0.95 | 0.89 | 1.20 | 1.03 | 2.55 | 2.25 |
| *Syringodium isoetifolium* | 0.60 | 0.53 | 0.82 | 0.77 | 0.58 | 0.52 |
|  | 0.33 | 0.35 | 0.16 | 0.15 | 0.40 | 0.39 |
| *Acropora formosa* | 0.40 | 0.23 | 0.39 | 0.16 | 0.41 | 0.26 |
|  | 0.04 | 0.11 | 0.22 | 0.17 | 0.09 | 0.13 |

Table 2: Production by seaweeds, seagrasses and coral in terms of area.

| Species | Average Biomass (g/sq.m) | Gross Production (gC/sq.m/yr) | Net Production (gC/sq.m/yr) | P/R |
|---|---|---|---|---|
| *C. racemosa* | 60 | 82 | 60 | 3.7 |
| *H. gracilis* | 100 | 133 | 94 | 3.4 |
| *T. ornata* | 300 | 659 | 475 | 3.6 |
| *P. tetrastomatica* | 200 | 878 | 684 | 4.5 |
| *T. hemprichii* | 400 | 3917 | 3269 | 6.3 |
| *S. isoetifolium* | 300 | 680 | 616 | 10.6 |
| *A. formosa* | 1000 | 1440 | 396 | 1.4 |

*Syringodium isoetifolium* it was 0.82 mgC/g/hr during monsoon. *Acropora formosa* indicated maximum production in postmonsoon (0.41 mgC/g/hr) and a minimum during monsoon (0.39 mgC/g/hr). Table 2 shows production and production to respiration ratios in terms of area. The highest production of 3917 gC/sq.m/yr was by *T. hemprichii* and the lowest of 82 gC/sq.m/yr by *C. racemosa*.

A two-way ANOVA indicated that both GPP and NPP varied significantly (P<0.01) between the various plants and coral studied while there was significant change between seasons (Table 3). The treatment comparisons showed a similar pattern for gross and net production with the production *Thalassia* being significant when compared to others. Correlation matrices were constructed between measurements of hydrography at station 5 and the seaweeds and coral collected from sandy area, namely, *Turbinaria*, *Padina*, and *Acropora* (Table 4). *Turbinaria* indicated positive significant relation with nitrate and silicate and *Padina* showed a similar relation with dissolved oxygen. The coral, *A. formosa* also recorded positive interaction with nitrate. Similarily, the variations in hydrography parameters of station 6 was tested for assocation with production by phytoplankton, *Caulerpa*, *Halimeda*, *Thalassia* and *Syringodium* (Table 5).

Figure 1 shows the net production and respiration values for phytoplankton and *Acropora* in the different months. Production by phytoplankton was generally high in the pre and

Table 3: Two-way ANOVA for gross production (A) and net production (B) between plants and coral in the various seasons.

|  | Source | df | SS | MSS | F | P |
|---|---|---|---|---|---|---|
| A. | Treatment | 6 | 10.088 | 1.681 | 6.27 | P < 0.01 |
|  | Replicate | 2 | 0.363 | 0.181 | 0.68 | P > 0.05 |
|  | Error | 12 | 3.218 | 0.268 |  |  |
| B. | Treatment | 6 | 7.610 | 1.268 | 6.47 | P < 0.01 |
|  | Replicate | 2 | 0.225 | 0.113 | 0.57 | P > 0.05 |
|  | Error | 12 | 2.354 | 0.196 |  |  |

TREATMENT COMPARISONS

|  | Caul. | Hali. | Turb. | Padi. | Thal. | Syri. | Acro. |
|---|---|---|---|---|---|---|---|
| T 1 | --- | n.s | n.s | n.s | sig | n.s | n.s |
| T 2 |  | --- | n.s | n.s | sig | n.s | n.s |
| T 3 |  |  | --- | n.s | sig | n.s | n.s |
| T 4 |  |  |  | --- | sig | n.s | n.s |
| T 5 |  |  |  |  | --- | sig | sig |
| T 6 |  |  |  |  |  | --- | n.s |

Table 4: Correlation matrix for hydrochemistry of station 5 and production by *Turbinaria*, *Padina* and *Acropora*.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.00 | | | | | | | | |
| 2 | 0.53* | 1.00 | | | | | | | |
| 3 | 0.16 | 0.26 | 1.00 | | | | | | |
| 4 | -0.34* | -0.32* | -0.37* | 1.00 | | | | | |
| 5 | -0.35* | -0.29* | -0.08 | 0.12 | 1.00 | | | | |
| 6 | -0.21 | -0.17 | -0.16 | 0.08 | 0.44* | 1.00 | | | |
| 7 | -0.32* | -0.57* | -0.28* | 0.41* | -0.31* | 0.09 | 1.00 | | |
| 8 | 0.25 | -0.02 | 0.24 | -0.01 | 0.04 | 0.42* | 0.28* | 1.00 | |
| 9 | -0.02 | 0.04 | 0.37* | -0.14 | 0.07 | 0.17 | 0.13 | 0.53* | 1.00 |
| 10 | 0.06 | -0.07 | -0.09 | -0.14 | 0.21 | 0.43* | -0.07 | 0.23 | -0.24 |

Parameters :
1. Water temperature
2. Salinity
3. Dissolved oxygen
4. Phosphate
5. Nitrite
6. Nitrate
7. Silicate
8. Production by *Turbinaria*
9. Production by *Padina*
10. Production by *Acropora*

Table 5: Correlation matrix for hydrochemistry of station 6 and production by phytoplankton, *Caulerpa*, *Halimeda*, *Thalassia* and *Syringodium*.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.00 | | | | | | | | |
| 2 | -0.33* | 1.00 | | | | | | | |
| 3 | -0.71* | 0.29* | 1.00 | | | | | | |
| 4 | -0.02 | 0.29* | 0.24 | 1.00 | | | | | |
| 5 | -0.36* | 0.09 | 0.37* | 0.21 | 1.00 | | | | |
| 6 | -0.56* | -0.01 | 0.27 | -0.13 | 0.40* | 1.00 | | | |
| 7 | -0.01 | 0.25 | 0.12 | 0.21 | -0.19 | -0.15 | 1.00 | | |
| 8 | -0.27 | 0.07 | 0.44* | -0.12 | -0.05 | 0.08 | 0.63* | 1.00 | |
| 9 | 0.36* | -0.51* | -0.40* | -0.11 | -0.18 | -0.40* | -0.52* | -0.35* | 1.00 |
| 10 | 0.45* | -0.16 | -0.24 | 0.35* | -0.09 | -0.27 | -0.08 | -0.31* | 0.21 |

Parameters :
1. Salinity
2. Phosphate
3. Nitrite
4. Nitrate
5. Silicate
6. Production by phytoplankton
7. Production by *Caulerpa*
8. Production by *Halimeda*
9. Production by *Thalassia*
10. Production by *Syringodium*

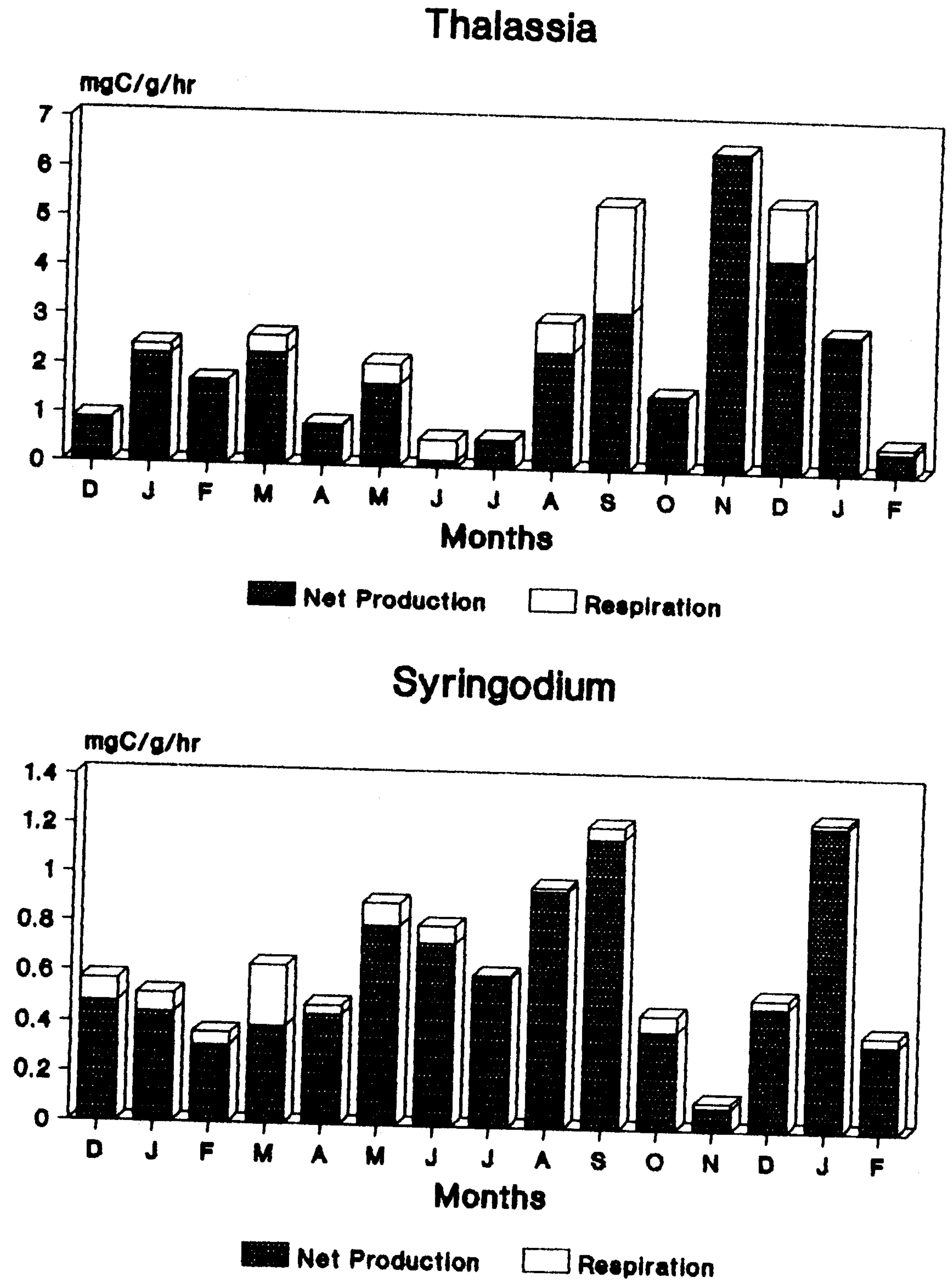


Fig. 1 Monthly variations in net primary production and respiration by phytoplankton and _A. formosa._

postmonsoon months. Production also indicated higher values than respiration in most months. Net production by Acropora fluctuated at about 0.4 mgC/g/hr with respiration in most cases being higher than production. Peaks of production by Caulerpa was noticed in December and July and in Halimeda during December, February and the monsoon months (Fig. 2). Production was prominent over respiration. Turbinaria exhibited elevated production in the premonsoon and monsoon months and relatively decreased values in postmonsoon. Values of 1.2 mgC/g/hr and above was obtained for Padina with production being prevalent to respiration (Fig.3). Net production by seagrasses was near supreme with respiration being negligible in most months (Fig. 4). The months of September, November and December were periods of high production by Thalassia while the monsoon months and January was important for Syringodium.

## DISCUSSION

Reef water sometimes contain abundant phytoplankton. Primary phytoplankton production varies largely within the same reef area. They reflect a usual decrease of the phytoplankton at the transitions from the shallow flat areas to the the lagoon side or to the open ocean (Sorokin, 1990a). The production range of 15-82 mgC/cub.m/day at Minicoy although high compares well

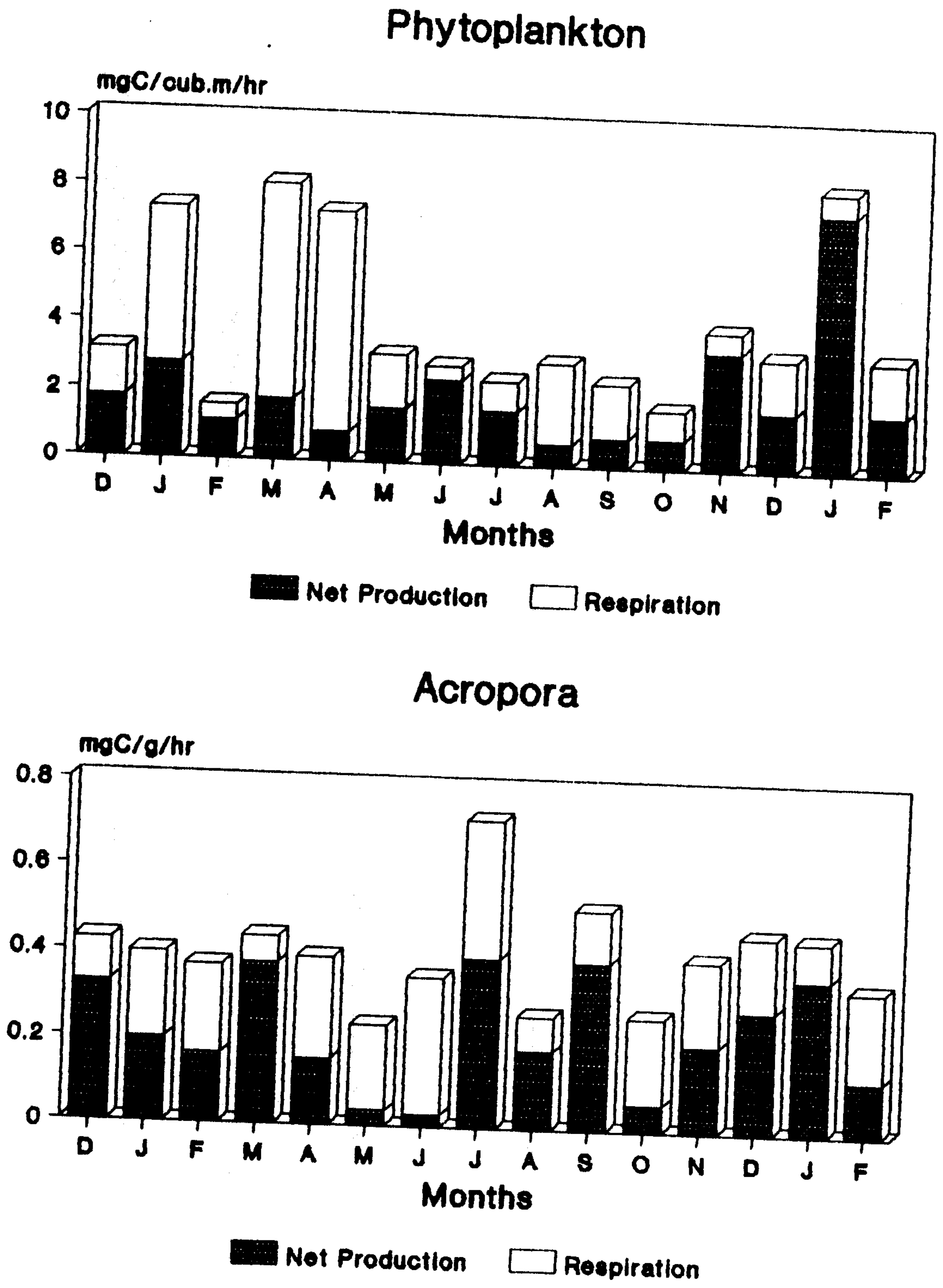
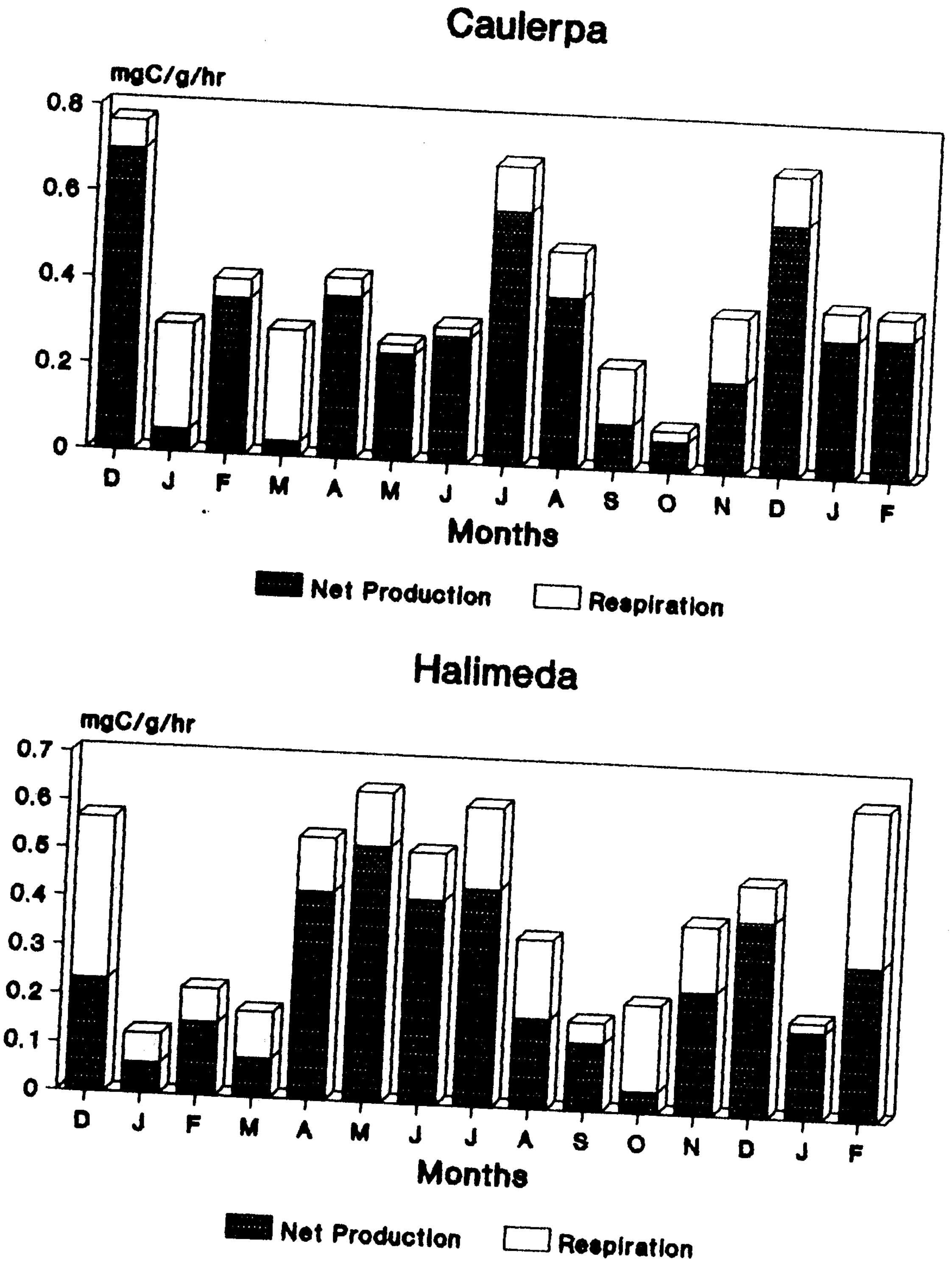


Fig. 2 Fluctuations in net production and respiration by green algae C. racemosa and H. gracilis.


Caulerpa

Halimeda

**Fig. 3** Changes in rate of production and respiration by brown algae _T._ _ornata_ and _P._ _tetrastomatica_.

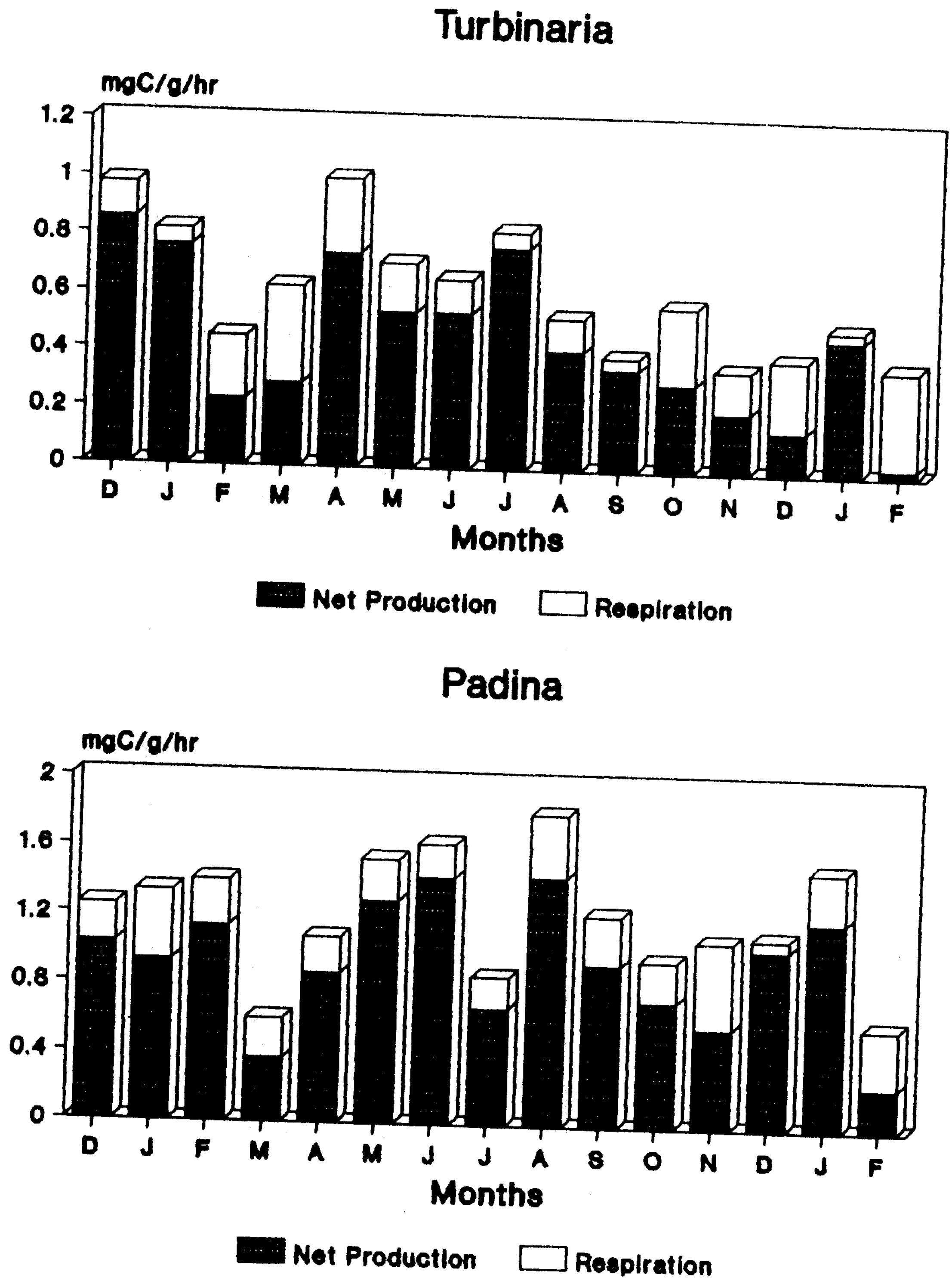


**Fig. 4** Net production and respiration rates of seagrasses *T. hemprichii* and *S. isoetifolium*.

with the values reported from other atolls (Sorokin, 1990a, p 299). They also collate with observations at Lakshadweep (Prasad and Nair, 1964; Qasim _et al_., 1972; Wafer, 1977). Sorokin (1990a) attributed variations in phytoplankton productivity to the season, diurnal fluctuations and to their physiological activity. Usually, in lagoon waters primary production is about an order greater than in the surrounding oligotrophic waters. This appears to be the case at Minicoy also as Prasad and Nair (1964) observed a six-fold increase in the production by lagoon waters. The factors that inhibit phytoplankton production in shallow areas of the reef are the changes in environmental condition, such as increase in temperature, excess of light, increase of pH and oversaturation with oxygen (Sorokin, 1990a). Production by phytoplankton at Minicoy is negatively affected by salinity and positively by silicate. It appears that an increase in salinity due to increased evaporation therefore hampers the productivity. Silicon is not an essential element for most reef organisms. Although diatoms, silicoflagellates, radiolarians are known to require silicon, these taxa are not dominant features of the reef environment (D'Elia and Wiebe, 1990). Recent observations on the taxonomic groups, however, indicate that diatoms are a prominent part of the phytoplankton (Sorokin, 1990a).

The amount of oxygen produced by zooxanthellae is equal to, or greater than the respiratory requirements of the corals

(Kanwisher and Wainwright, 1967; Pillai and Nair, 1972; When the oxygen produced is converted in terms of carbon fixed, the values obtained are sometimes as high as that of reef community production (Lewis, 1977). Gladfelter et al. (1989) observed that the terminal 5 cm of a branch of *Acropora palmata* exhibited significantly higher respiration rates and significantly lower net production rates than regions of the branch proximal to 10 cm from the tip. They also noted that density of zooxanthellae increases with distance from tip. In the study of production by *A. formosa* at Minicoy only the tips were used which may explain the high rates of respiration. Rogers and Salesky (1981) also observed high rates of respiration in *A. palmata*. Further, the Winkler techniques give only the net photosynthesis of the coral and not as in the case of free-living phytoplankton, net photosynthesis of the algae. Therefore, net productivity of zooxanthellae associations will always be underestimated by a factor related to the ratio of algal and animal respiration (Muscatine, 1980). Chalker et al.,(1984) showed that seasonal changes in primary production by *A. granulosa* is influenced by incident light. Light may not be limiting factor at Minicoy especially in the shallow regions. The importance of production by zooxanthellae and their role in sustaining larger animals observed in coral reefs is highlighted by Scott and Jitts (1977).

Production by brown algae was considerably higher than that of the green algae at Minicoy. This is in agreement with observations reported (Goreau, 1963; Johnston, 1969). Rogers and Salesky (1981) reported that macroscopic algae produced more oxygen than algal turf or live coral. They concluded that macroscopic algae 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. It is clear that macrophytic algae at Minicoy are an important component of the primary producers. The estimated production rate of 200-800 gC/sq.m/yr by macroalgae implies that about 25-35% of the total reef production could be attributed to benthic algae. This does not take into account the production by other prominant algae of the genus _Enteromorpha_, _Dictyota_, _Sargassum_, _Acanthophora_ and _Gelidiella_. Similarily, the production by seagrasses is also high at Minicoy. An important aspect of seagrasses with respect to livebaits is that it could act as a nursery and also serve as a feeding ground for some resident livebaits such as apogonids.

# CHAPTER 7

# SECONDARY PRODUCTION

## INTRODUCTION

Opinions differ on the adequacy of zooplankton in satisfying the food requirements of corals and other planktivorous organisms on reefs. Regarding corals, one view is that the biomass of zooplankton is insufficient to supply the energy needs of corals ( Johannes and Tepley, 1974; Johannes *et al*., 1970; Tranter and George, 1972; Glynn, 1973). On the other hand, Goreau *et al*. (1971) support the view that corals, as specialized carnivores, are dependent upon zooplankton as a food source. The general conclusions regarding the importance of zooplankton to support reef production indicate that while there is substantial removal of plankton by benthic organisms, zooplankton biomass from oceanic water flowing over reefs is too low even to supply the daily energy requirements of the corals present (Lewis, 1977). Additional food must be supplied by resident plankton and other external sources.

In most studies of reef zooplankton, the collection was made by plankton nets by horizontal or vertical tows during the daytime. Nevertheless, some authors understood the inadequacy of the sampling as a result of the demersal nature of a significant part of the reef zooplankton. The demersal zooplankton emerges from the bottom substrates of the reef at night, and cannot be counted by daytime tows. Emery (1968) used night tows with a plankton net driven by a diver and an airlift technique to extract zooplankton hiding during the day in the reef crevices and holes. He arrived at the conclusion that ordinary oceanic zooplankton species, when they inhabit the coral-reef environment, behave like typical reef plankters. They form swarms, sheltering during the daytime. Thus, the oceanic species as well as the endemic reef species form a specific community of reef zooplankton which lives in reef environments, uses its resources, and actually becomes a part of the coral-reef ecosystem (Sorokin, 1990a). This view is quite different from that of Johannes et al. (1970), who observed that reef zooplankton consists mostly of plankton from oceanic waters which passes over the reef. The advent of a number of traps to sample demersal plankton confirmed the basic conclusions of Emery (1968). Different types of traps have been developed (Alldredge and King, 1977, 1980; Porter, 1978; Porter et al. 1977; Sale et al. 1976; Hobson and Chess, 1979). Hobson and Chess (1979) discuss the disadvantages of traps; nevertheless, traps are recognized as an efficient tool for qualitative and quantitative zooplankton studies in reef environments. Another simple way for the catching of demersal zooplankton in shallow reef areas appears to be the passing of water, taken at night with a bucket, through a plankton net (Suresh, 1991).

Nets and traps have the disadvantage in that they catch only mesozooplankton and macrozooplankton - that is, animals more than 0.2 mm in size. The zooplankton of small size - microzooplankton - is not included in these methods, but can comprise a significant part of the total zooplankton biomass in pelagic marine planktonic communities (Sorokin, 1981). Ayukai (1991) suggests that a lack of information on the standing stock of microzoopalnkton on coral reefs has led to an underestimate of the allochthonous energy input to coral reef systems. Lewis and Boers (1991) found that microzooplankton and copepodites comprised 96% of the abundance and 66% of the biomass of coral reef demersal plankton. It is supposed that its role in coral reef waters are important because of their enrichment with bacteria and other particulate organic matter (Sorokin, 1990a). The microzooplankton includes three main groups : the nanozooplanktonic Protozoa, cilicates and multicellular animals, mostly the larvae of copepods and appendicularians. This group is the least studied among reef zooplankton (Sammarco and Crenshaw, 1984). The term "reef zooplankton" which is used by most researchers means the total zooplnakton caught in nets and by traps. Actually it includes gelatinous plankton (salps, medusae), macrozooplankton (mysids, amphipods, decapods), mesozooplankton (copepods, cladocerans, appendicularians, various larvae) and a small proportion of the microzooplankton accidentally retained by the net (Sorokin, 1990a).

During the daytime, copepods swarm close to the bottom near possible shelters. As shelters they use the crevices or holes in the rocks, the fans of gorgonians, the nests of fishes dug out in the sand bottom, and even the spines of sea urchins (Emery, 1968; Hamner and Carleton, 1979). Similar behaviour is seen in mysids endemic to the reef which swarm near their shelters during the daytime (Carleton and Hamner, 1989). Walter _et al_. (1981) found that 55.4% of zooplankton emerged from branching coral patch reefs at night and the remianing 44.6 during the day. One cause for the formation of migrating shoals of reef zooplankters may be the lack of shelters on the bottom (Sorokin, 1990a). The second may be better avoidance of grazing by individual specimens in shoals rather than in random populations (Emery, 1968). The reasons ffor migration in demersal zooplankton are, however, not so obvious. Most demersal zooplankters emerge from the bottom to the water colum only at night. One of the probable reasons for this could be the avoidance of grazing by day-active predators. The other possible factors could be hunting for food, for reproduction and to occupy new bottom areas (Alldredge and King, 1980).

An important component of zooplankton collected from coral reefs are fish larvae. Determination of where larval coral reef fish spend their pelagic phase may help answer the question of how localized adult populations are (Leis, 1981; Victor, 1984). Almost every bony fish on the reef has passed through a pelagic phase, and a substantial portion of this life, expressed as either size or age, may have taken place in the pelagic environment (Leis, 1991a). The larvae are dispersed widely on the reef and lagoon probabily as an adaptation for survival in an unpredicatable pelagic habitat (Leis, 1984; Doherty et al., 1985). Leis (1982) and Leis and Miller (1976) studied the offshore distributional patterns of Hawaiian fish larvae and found that the larvae of reef species with non-pelagic eggs are abundant near shore, while those with pelagic eggs are abundant offshore. Currents, taxonomy, seasonality and horizontal and vertical distribution are emphasized in the study of reef larvae (Leis, 1986a; Leis and Goldman, 1983). Leaf density is an important factor determining settling of larvae in seagrass beds (Bell et al., 1987). Leis (1991b) found that day/night changes were apparently due to randomization or spread rather than active migration. Leis and Goldman (1984) suggest that the view which considers fish larvae to be passively - drifting particles is unjustified without more information on larval behaviour.

Information on the zooplankton of the atolls of Lakshadweep are restricted to short term observations, mostly at Kavaratti. Tranter and George (1972) studied the zooplankton abundance at Kavaratti and Kalpeni atolls. They found that the biomass was depleted en route. from ocean to lagoon suggesting that the reef community is nourished by oceanic zooplankton.

Similar observations are reported by Goswami (1973, 1979, 1983). Copepod formed the dominant component of zooplankton at Kavaratti, Agatti and Suheli Par atolls and no endemic fauna was encountered in the lagoons (Madhupratap et al., 1977). Nair (1975) observed considerable reduction in chaetognaths inside the lagoon. Achuthankutty et al. (1989) found that the composition of zooplankton in the lagoons of Kalpeni and Agatti were quite different from that of the sea, and to a large extent, was independent of oceanic influence. They also listed several striking similarities in the zooplankton composition between the coral and coastal lagoons. Diel variations in zoopalnkton at Minicoy and Kavaratti is reported by Goswami and Goswami (1990). Madhupratab et al. (1991) reports about 25 times higher densities of demersal zoopalnkton when direct sampling was done with a corer at Agatti.

Zooplankton were collected and analysed qunatitatively and qualitatively from different regions of the Minicoy lagoon. The major food of tuna livebiats being zooplankton an estimate of its abundance could throw light on the trophic relationships of livebaits. Another factor is the distribution and availability of larvae which has implications on migration, location of spawning and settlement of livebiats.

## MATERIALS AND METHODS

Four locations with different bottom conditions were selected for zooplankton studies for a period of 16 months from December 1988 to March 1990 at Minicoy. Location 1 (coral bottom) was in the lagoon near station 1 (Fig.1, Chapter 5), the bottom of which is dominated by live coral. This station was considered as representative of the lagoon for comparison with the adjacent sea. Location 2 was near station 4 about 0.5 km away frm the reef in clear, blue oceanic waters. Sandy bottom (location 3) was adjacent to station 5 and seagrass bed (location 4) situated at station 6. Horizontal tows were made between 0700-1000 hrs at the surface with a zooplankton net. The net was 1.2 m long with a circular mouth of 0.5 m diameter and made od nylon guaze of mesh width 0.3 mm. Tows were made at a constant speed for about 3 minutes so as to cover a distance of approximatly 150 m. Zooplankton collected was fixed in 5% formalin. In the laboratory, each sample was carefully sorted to remove the debris and the displacement volume and wet weight was measured. Plankton were identified and grouped into major holoplanktonic, meroplanktonic and demersal plankton groups as givn by Sorokin (1990a). An estimate of volume of water sampled by the net was made using the formula $3.14 \times r^2 \times d$, where r is the radius of the net aperture and d the distance of tow assuming that the net could filter all the water in its path (Mathews, 1992).

A diurnal study for 1 year was conducted at the seagrass bed by pouring 1000 l of water through the net at 6 hourly intervals. The zooplankton collected at 0900 and 1500 were grouped as day samples and 2100 and 0300 were combined as night samples.

## RESULTS

The average number of zooplankton in a month, minimum and maximum, total and number per cub.m of holoplankton, meroplankton and demersal plankton are presented in Tables 1 to 3. Copepod was the dominant holoplankton at all locations with maximum total number at open sea and minimum at seagrass bed. Siphonophores and chaetognaths were next in order of importance. Decapod larvae constitued the bulk of meroplankton at coral bottom, open sea and sandy bottom locations. At seagrass bed, fish eggs was the major item. Zoea was also present in significant quantities at all locations. Coral bottom had comparatively higher fish larvae than the other regions. Among demersal plankton, Lucifer was the abundant form at all stations. As high as 375 numbers per cub.m was obtained at open sea while the lowest of 95 numbers per cub.m was recorded at coral bottom. Amphipods, mysids and pteropods formed only a small percentage of the total demersal plankton.

Results of two-way ANOVA between seasons and stations and between groups and stations are given in Tables 4 and 5. Zooplankton numbers per cub.m was not significant between the

Table 1: Average number, minimum and maximum per tow and total of groups of holoplankton collected at the different regions from December 88 to March 90.

| Group | Station | Number of plankton | | | | Number per cub.m |
|---|---|---|---|---|---|---|
| | | Mean | Min. | Max. | Total | |
| Copepod | Coral bottom | 449 | 1 | 2052 | 7186 | 248 |
| | Open sea | 865 | 8 | 5648 | 13841 | 477 |
| | Sandy bottom | 215 | 7 | 1408 | 3437 | 119 |
| | Seagrass bed | 81 | 0 | 452 | 1292 | 45 |
| Siphonophore | Coral bottom | 47 | 0 | 737 | 754 | 26 |
| | Open sea | 109 | 0 | 439 | 1736 | 60 |
| | Sandy bottom | 18 | 0 | 139 | 280 | 10 |
| | Seagrass bed | 1 | 0 | 8 | 17 | 0.6 |
| Chaetognath | Coral bottom | 14 | 0 | 8 | 223 | 8 |
| | Open sea | 115 | 0 | 836 | 1847 | 64 |
| | Sandy bottom | 50 | 0 | 336 | 795 | 27 |
| | Seagrass bed | 3 | 0 | 18 | 50 | 2 |
| Appendicularia | Coral bottom | 7 | 0 | 38 | 106 | 4 |
| | Open sea | 26 | 0 | 159 | 422 | 15 |
| | Sandy bottom | 10 | 0 | 90 | 166 | 6 |
| | Seagrass bed | 0.5 | 0 | 2 | 8 | 0.3 |
| Medusa | Coral bottom | 0.1 | 0 | 0.1 | 2 | 0.1 |
| | Open sea | 7 | 0 | 34 | 116 | 4 |
| | Sandy bottom | 2 | 0 | 19 | 37 | 1 |
| | Seagrass bed | 1 | 0 | 8 | 16 | 0.6 |
| Tunicate | Coral bottom | 3 | 0 | 38 | 54 | 2 |
| | Open sea | 15 | 0 | 56 | 240 | 8 |
| | Sandy bottom | 6 | 0 | 64 | 96 | 3 |
| | Seagrass bed | 0.8 | 0 | 7 | 12 | 0.4 |
| Ostracod | Coral bottom | 15 | 0 | 216 | 234 | 8 |
| | Open sea | 3 | 0 | 42 | 46 | 2 |
| | Sandy bottom | 2 | 0 | 32 | 35 | 1 |
| | Seagrass bed | 0.3 | 0 | 3 | 4 | 0.1 |

Table 2: Mean number, minimum and maximum per tow and total of groups of meroplankton from various locations during December 88 to March 90.

| Group | Station | Number of plankton | | | | Number per cub.m |
|---|---|---|---|---|---|---|
| | | Mean | Min. | Max. | Total | |
| Zoea | Coral bottom | 95 | 0 | 558 | 1520 | 52 |
| | Open sea | 91 | 0 | 502 | 1457 | 50 |
| | Sandy bottom | 69 | 0 | 248 | 1106 | 38 |
| | Seagrass bed | 29 | 0 | 109 | 466 | 16 |
| Decapod larva | Coral bottom | 442 | 4 | 4272 | 7064 | 244 |
| | Open sea | 291 | 0 | 1458 | 4657 | 161 |
| | Sandy bottom | 249 | 0 | 2139 | 3985 | 137 |
| | Seagrass bed | 103 | 1 | 875 | 1645 | 67 |
| Fish egg | Coral bottom | 29 | 2 | 157 | 456 | 16 |
| | Open sea | 150 | 0 | 608 | 2396 | 83 |
| | Sandy bottom | 53 | 5 | 265 | 846 | 29 |
| | Seagrass bed | 319 | 0 | 4458 | 5099 | 176 |
| Gastropod larva | Coral bottom | 2 | 0 | 8 | 30 | 1 |
| | Open sea | 37 | 0 | 236 | 593 | 37 |
| | Sandy bottom | 15 | 0 | 97 | 238 | 8 |
| | Seagrass bed | 8 | 0 | 40 | 126 | 4 |
| Bivalve larva | Coral bottom | 0.2 | 0 | 1 | 3 | 0.1 |
| | Open sea | 3 | 0 | 14 | 44 | 1.5 |
| | Sandy bottom | 2 | 0 | 10 | 24 | 0.8 |
| | Seagrass bed | 0.1 | 0 | 1 | 1 | 0.1 |
| Stomatopod larva | Coral bottom | 8 | 0 | 96 | 127 | 4 |
| | Open sea | 19 | 0 | 144 | 299 | 10 |
| | Sandy bottom | 10 | 0 | 64 | 167 | 6 |
| | Seagrass bed | 6 | 0 | 56 | 9 | 3 |
| Polychaete larva | Coral bottom | 0.2 | 0 | 3 | 3 | 0.1 |
| | Open sea | 19 | 0 | 144 | 299 | 10 |
| | Sandy bottom | 0.6 | 0 | 3 | 9 | 0.3 |
| | Seagrass bed | 0.3 | 0 | 2 | 5 | 0.2 |
| Fish larva | Coral bottom | 2 | 0 | 1 | 39 | 17 |
| | Open sea | 2 | 0 | 13 | 32 | 1 |
| | Sandy bottom | 0.5 | 0 | 3 | 8 | 0.3 |
| | Seagrass bed | 0.2 | 0 | 3 | 3 | 0.1 |

Table 3: Average number of demersal plankton per month, minimum and maximum per tow and total from the four locations at Minicoy from December 88 to March 90.

| Group | Station | Number of plankton | | | | Number per cub.m |
|---|---|---|---|---|---|---|
| | | Mean | Min. | Max. | Total | |
| Amphipod | Coral bottom | 4 | 0 | 25 | 61 | 2 |
| | Open sea | 6 | 0 | 64 | 99 | 3 |
| | Sandy bottom | 6 | 0 | 40 | 88 | 3 |
| | Seagrass bed | 13 | 0 | 75 | 210 | 7 |
| Mysid | Coral bottom | 9 | 0 | 100 | 140 | 5 |
| | Open sea | 21 | 0 | 241 | 332 | 11 |
| | Sandy bottom | 18 | 0 | 146 | 285 | 10 |
| | Seagrass bed | 17 | 0 | 100 | 275 | 10 |
| <u>Lucifer</u> | Coral bottom | 172 | 0 | 2082 | 2754 | 95 |
| | Open sea | 680 | 0 | 6096 | 10883 | 375 |
| | Sandy bottom | 373 | 0 | 5536 | 5962 | 206 |
| | Seagrass bed | 234 | 0 | 3088 | 3747 | 129 |
| Pteropod | Coral bottom | 0.5 | 0 | 2 | 8 | 0.3 |
| | Open sea | 8 | 0 | 36 | 129 | 4 |
| | Sandy bottom | 6 | 0 | 80 | 101 | 4 |
| | Seagrass bed | 1 | 0 | 11 | 17 | 0.6 |

Table 4: Two-way ANOVA between stations (treatments) and seasons (replicates) for number of zooplankton per cub.m.

| Source | df | SS | MSS | F | P |
|---|---|---|---|---|---|
| Treatment | 3 | 172249 | 57416 | 2.36 | $P > 0.05$ |
| Replicate | 2 | 528122 | 264061 | 10.84 | $P < 0.05$ |
| Error | 6 | 146160 | 24360 | | |

Table 5: Analysis of variance between stations and groups (replicates) of number of plankton per cub.m.

| Source | df | SS | MSS | F | P |
|---|---|---|---|---|---|
| Treatment | 3 | 172254 | 57418 | 4.07 | $P > 0.05$ |
| Replicate | 2 | 10014 | 5007 | 0.35 | $P > 0.05$ |
| Error | 6 | 84736 | 14123 | | |

four stations but was significant ($P < 0.05$) between seasons. The seasonal differences is attributable to the high zooplankton abundance during premonsoon. Variation in numbers in the three groups of holoplankton, meroplankton and demersal plankton were not significant. Table 6 shows the comparison in abundance of various forms in lagoon and sea samples and the differences between day and night collections. Except for ostracod, the other holoplankton were more in ocean samples than in lagoon. Similarly, the meroplankters zoea and decapod larvae exhibited preference for lagoon waters and fish larvae were in equal numbers at the two locations. Demersal plankton indicated greater presance in ocean samples. Copepods in night collections far exceeded that of day. Although not as conspicuous as copepods, appendicularians and ostracods were also higher in night samples. The only meroplankton that was observed more in day was fish eggs while fish larvae were of equal abundance. Demersal plankters Lucifer and pteropod were not observed in either day or night collections.

The lowest average biomass by volume and weight was observed in postmonsoon for coral bottom samples and the highest for premonsoon collections from open sea (Table 7). Maximum biomnass at location 1 (coral bottom) was noticed during monsoon while at the other three locations it was during premonsoon.

The predominance of copepods over other holoplankters are deplicted in Figs. 1 and 2. In coral bottom samples,

Table 6: Comparison of various groups of zooplankton from the lagoon and adjacent sea and in day and night samples.

| Taxonomic group | Average Number of zooplankton (per cub.m.) | | | | | |
|---|---|---|---|---|---|---|
| | Lagoon (a) | Sea (b) | a/b | Day (c) | Night (d) | c/d |
| Copepod | 15.48 | 29.83 | 0.52 | 64 | 18649 | 0.01 |
| Siphonophore | 1.62 | 3.76 | 0.43 | 2 | 0 | - |
| Chaetognath | 0.48 | 4.00 | 0.12 | 0 | 4 | 0 |
| Appendicularia | 0.24 | 0.90 | 0.27 | 2 | 6 | 0.33 |
| Medusa | 0.01 | 0.24 | 0.04 | 0 | 77 | 0 |
| Tunicate | 0.10 | 0.52 | 0.19 | 0 | 0 | 0 |
| Ostracod | 0.52 | 0.10 | 5.20 | 1 | 59 | 0.02 |
| Zoea | 3.28 | 3.14 | 1.04 | 17 | 260 | 0.07 |
| Decapod larva | 15.24 | 10.03 | 1.52 | 200 | 701 | 0.29 |
| Fish egg | 1.00 | 5.17 | 0.19 | 128 | 25 | 5.12 |
| Gastropod larva | 0.07 | 1.28 | 0.05 | 8 | 14 | 0.57 |
| Bivalve larva | 0.01 | 0.10 | 0.10 | 1 | 0 | - |
| Stomatopod larva | 0.28 | 0.66 | 0.42 | 3 | 13 | 0.23 |
| Polychaete larva | 0.01 | 0.07 | 0.14 | 3 | 5 | 0.60 |
| Fish larva | 0.07 | 0.07 | 1.00 | 1 | 1 | 1.10 |
| Amphipod | 0.14 | 0.21 | 0.67 | 2 | 35 | 0.06 |
| Mysid | 0.31 | 0.72 | 0.43 | 0 | 17 | 0 |
| *Lucifer* | 5.93 | 23.45 | 0.25 | 0 | 0 | 0 |
| Pteropod | 0.02 | 0.28 | 0.07 | 0 | 0 | 0 |

Table 7: Average biomass estimated by displacement volume (ml) and wet weight (mg) of total zooplankton during the different seasons.

| Season | CB | | OS | | SB | | SG | |
|---|---|---|---|---|---|---|---|---|
| | Vol. | Wt. | Vol. | Wt. | Vol. | Wt. | Vol. | Wt. |
| Premonsoon | 0.66 | 624 | 1.80 | 1868 | 0.80 | 780 | 0.74 | 710 |
| Monsoon | 1.00 | 925 | 1.30 | 1075 | 0.40 | 389 | 0.35 | 293 |
| Postmonsoon | 0.20 | 179 | 1.16 | 1305 | 0.28 | 493 | 0.26 | 199 |
| Total | 1.86 | 1728 | 4.26 | 4248 | 1.48 | 1662 | 1.35 | 1202 |

CB - Coral bottom OS - Open sea
SB - Sandy bottom SG - Seagrass bed

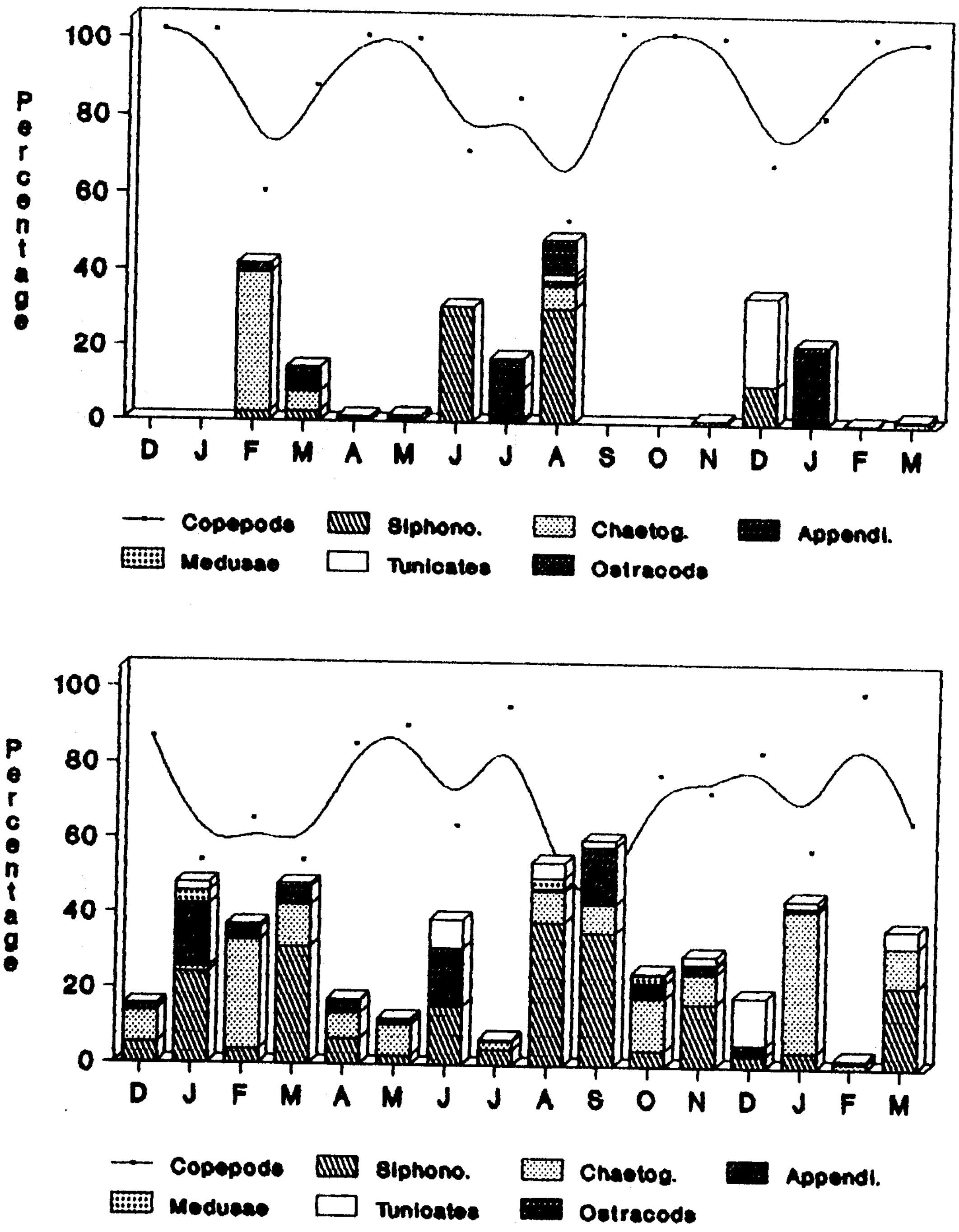


**Fig. 1** Percentage abundance of holoplankters at coral bottom (above) and open sea (below).

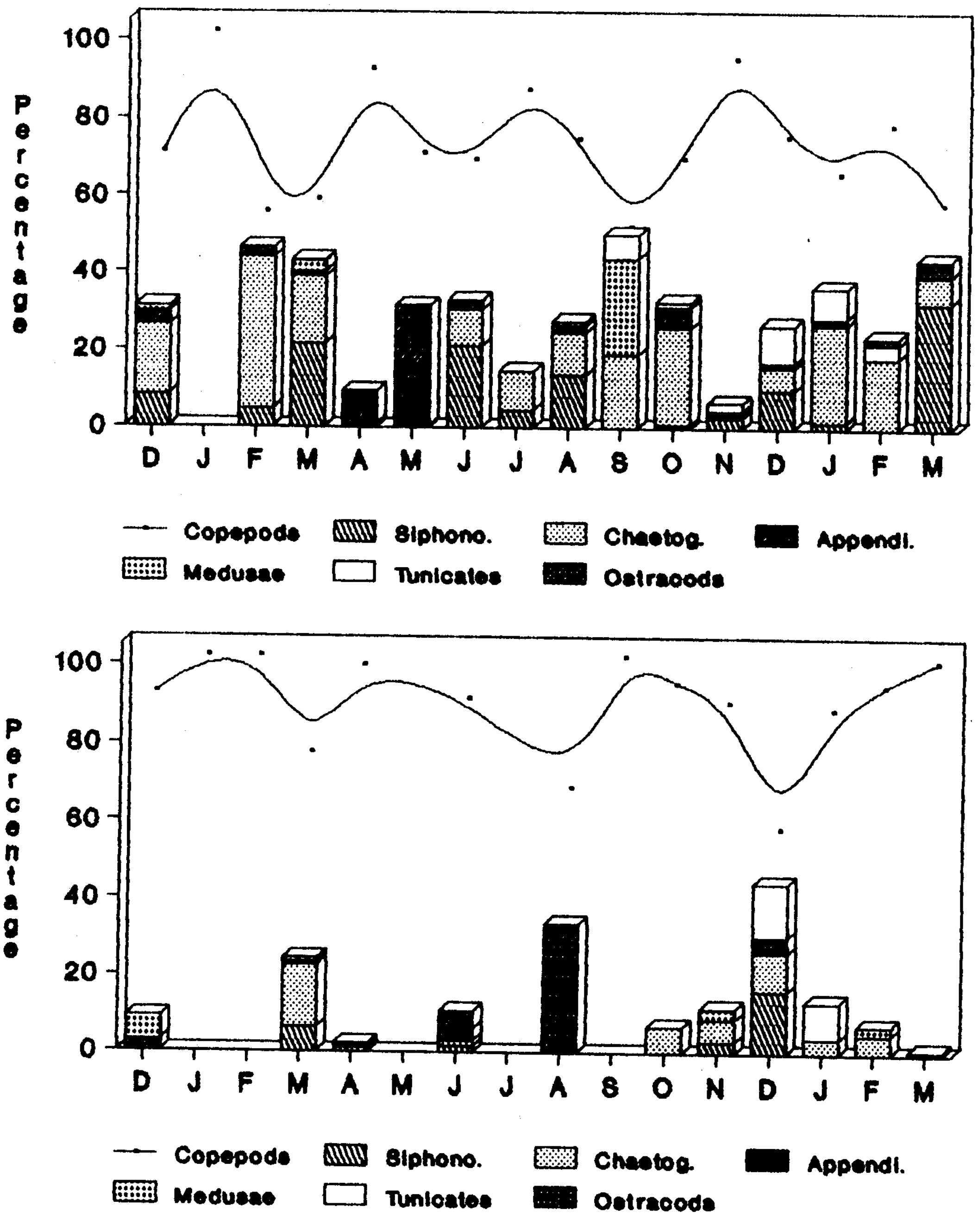


**Fig. 2** Variations in occurrence of holoplankters at sandy bottom (above) and seagrass bed (below).

copepods were the only item observed during most months while in open sea other forms such as siphonophores and chaetognaths were also represented. About 50-100% of the total holoplankton of sandy bottom areas were copepods with chaetognaths next in order of abundance. In seagrass bed samples, the absence of most holoplankters resulted in complete prominence of copepods during the entire period. Decapod larvae were the most common meroplankton at coral bottom while decapod and fish eggs were striking at open sea (Fig. 3). In general, decapod larvae, fish eggs and zoea were the major forms at sandy bottom and seagrass bed (Fig. 4). The importance of Lucifer in demersal plankton group is especially evident in the months of April, January and February (Figs. 5 and 6). In the absence of Lucifer, amphipods and mysids were the dominant forms.

The fish larvae were identified to family level and comprised in order of abundance, Carangidae, Scombroidae, Exocoetidae, Clupeidae, Sillaginidae and Gobiidae.

## DISCUSSION

Among the holoplanktonic zooplankton of coral reefs, the cyclopoid and calanoid copepods are dominant. These pelagic forms, which are randomly distributed when living in pelagic communities of the open ocean, behave as typical reef forms when

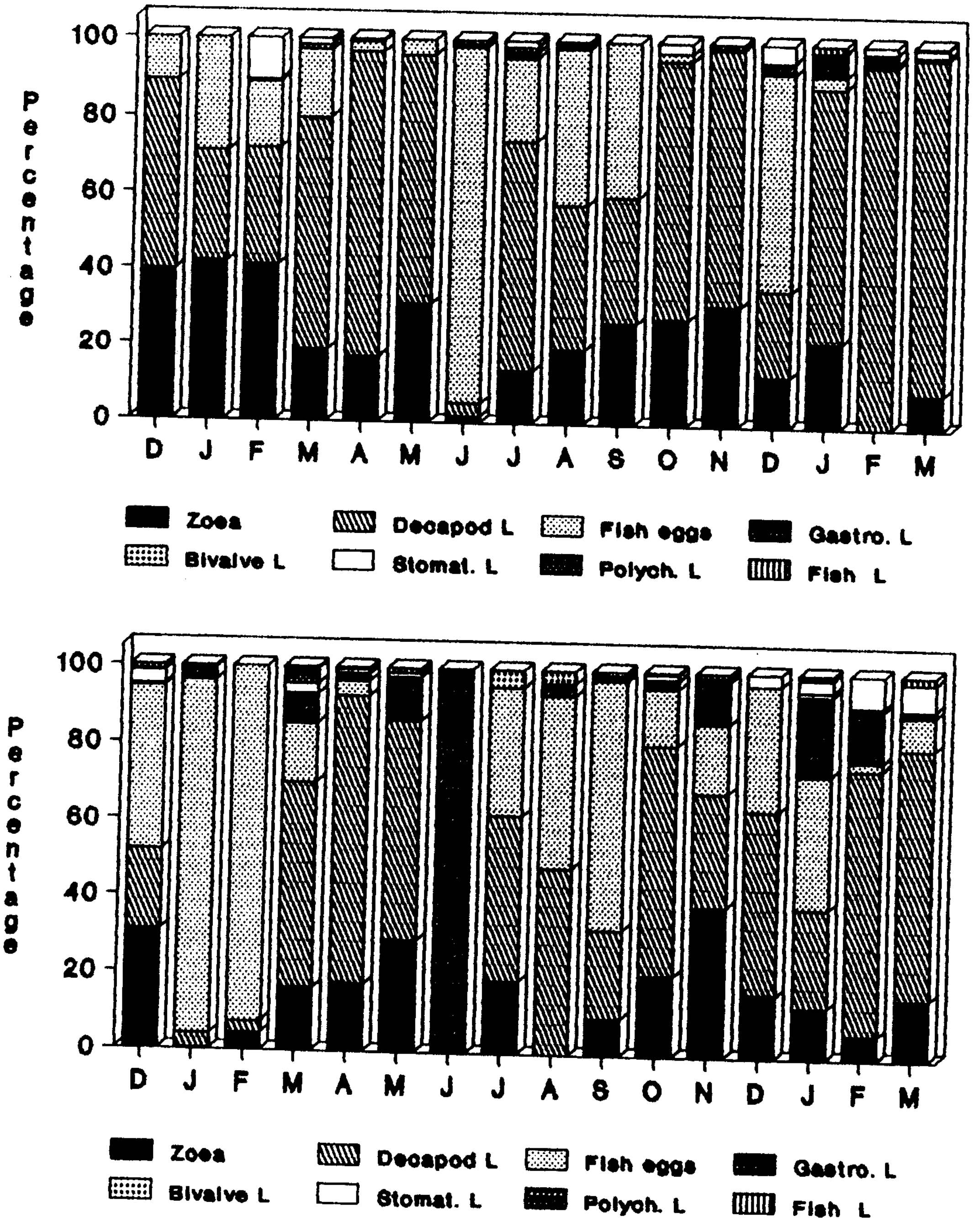


Fig. 3 Meroplankton abundance at coral bottom (above) and open sea (below).

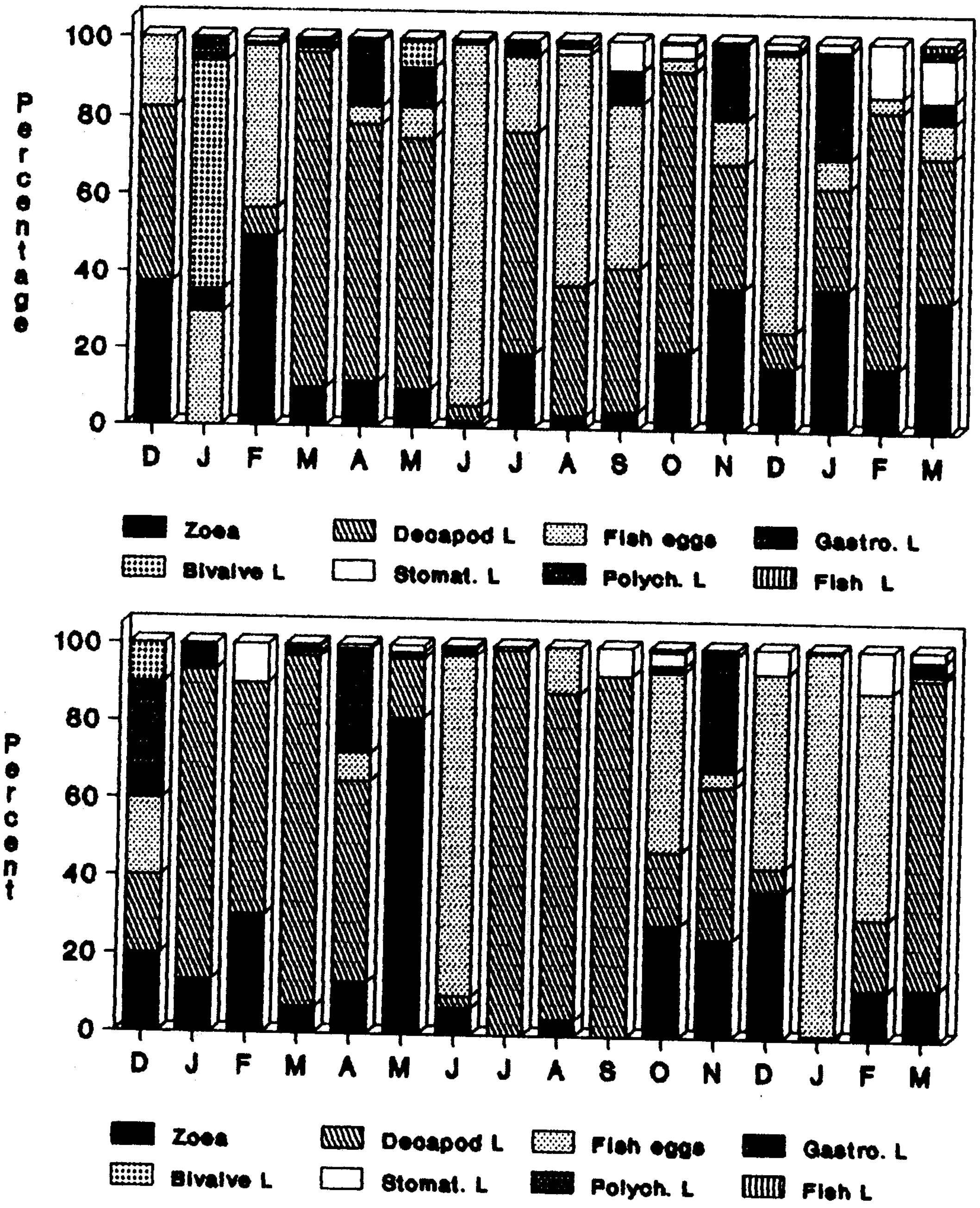


Fig. 4 Percentage meroplankton at sandy bottom (above) and seagrass bed (below).

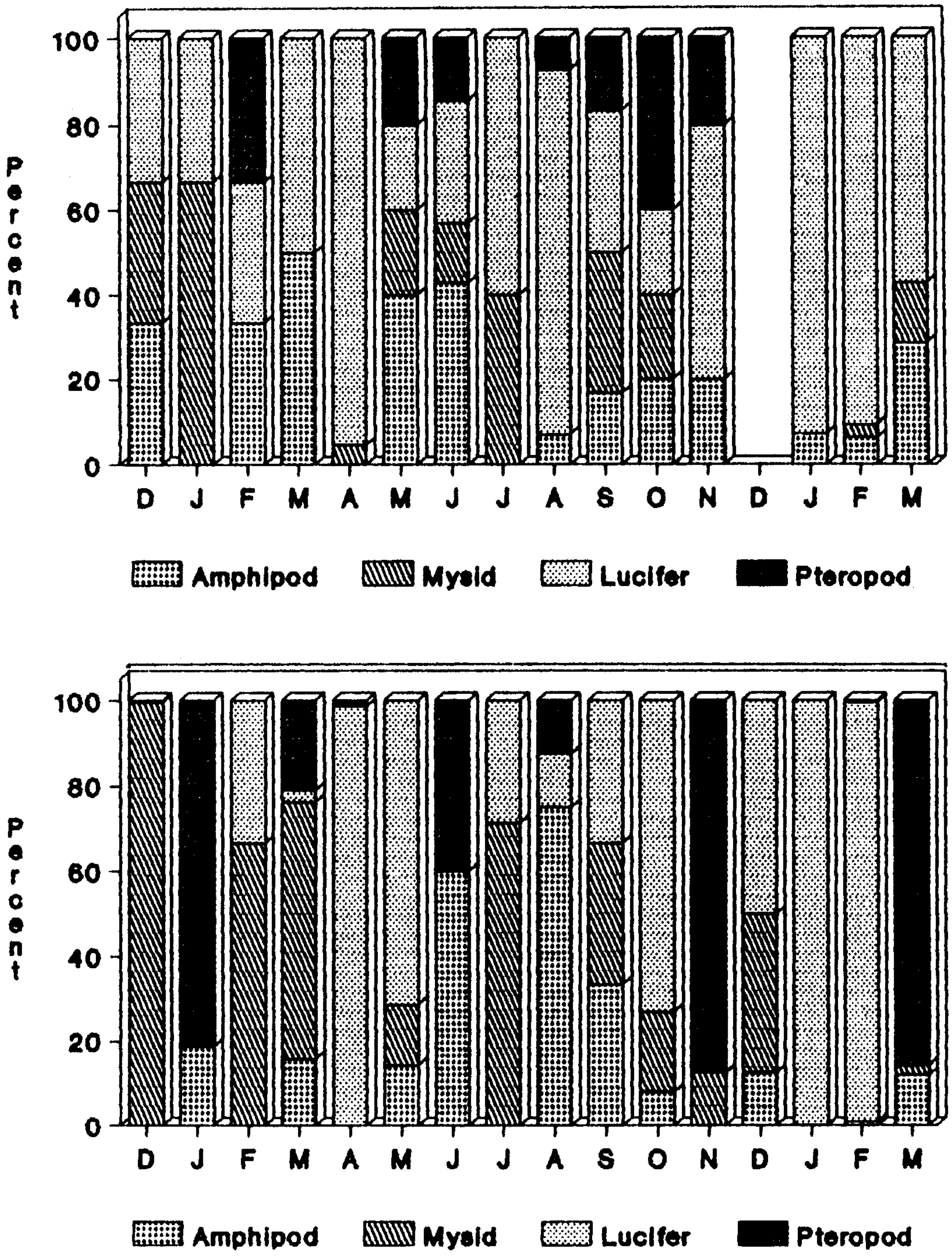


**Fig. 5** Abundance of various demersal plankton at coral bottom (above) and open sea (below).

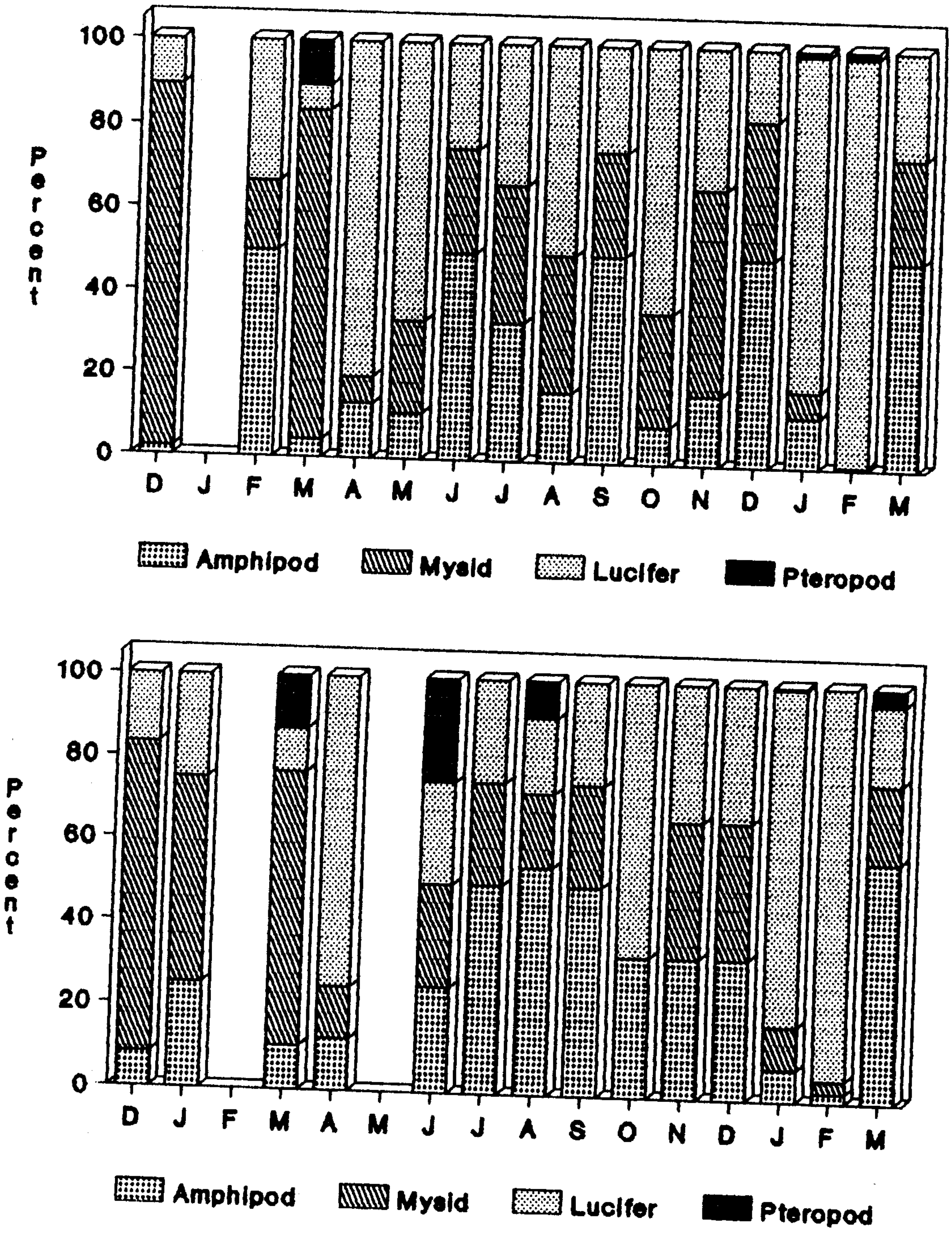


**Fig. 6** Variation in various forms of demersal plankton at sandy bottom (above) and seagrass bed (below).

living in coral reef waters. They form schools at daytime and oppose the current and move near the bottom as a whole body (Sorokin, 1990a). At night these shoals dissipate and next day they from again near the bottom shelters. Thus these typical pelagic copepods, when living in reef waters, adopt behabviour similar to the residents of reef ecosystems like the mysids and other demersal zooplankters. This abundance, has resulted in copepods being the primary food of diurnal reef planktivores and selected noturnal feeders (Hobson, 1991). Hamner and Carleton (1979) observes that previous investigations of reef zooplankton have not sampled copepods properly and estimates of food available to the reef community must be re-evaluated. Copepods are undoubtedly the major component of zooplankton at Minicoy and the fact that they rank as the most important food of livebaits underlines their valuable trophic role.

Earlier studies on reef zooplankton (Johnson, 1949; Bakus, 1964) and more recent ones (Sorokin, 1990a) indicate that plankton in lagoon waters are much more abundant than in the surrounding oceanic waters. But most reports from Lakshadweep where comparisons between lagoon and adjacent sea waters are available (Tranter and George, 1972; Goswami, 1973, 1979, 1983) and the present study proves that zooplankton abundance is more in the sea than in the lagoon. Sampling at Lakshadweep for open sea zooplankton have generally been made at distance of about 0.5 km or less from the reef. This proximity ot the reef may have resulted in the higher abundance of zooplankton. Another major factor is that the current patterns of atolls is different from that of either fringing or barrier reefs and this may have resulted in the retention of zoopalnkton close to the reefs. The changing current may also help in export of excess reef production to several kilometers into the open sea. Another point of difference between studies from other regions and that of Lakshadweep is that virtually all studies at Lakshadweep pertain to surface waters. Therefore, future studies of zooplankton for comparison between the lagoon and sea should consider such vital factors as distance from the reef, circulatory patterns of water around the island and also the depth at which tows are made. There are, however, no differences in opinion that the biomass of zooplankton at night are higher that of day. The demersal species appear in water column mostly at night when they emerge from the reef-bottom biotopes. At night the number and biomass of zooplankton in the waters of the reef areas increase many fold (Sorokin, 1990a). The various species which form demersal plankton are usually dominated by a variety of crustaceans such as copepods, amphipods and mysids. The composition of the reef zooplankton fauna varies in the estimates of different workers depending on the techniques of sampling, on the time, and on the place of sampling on the same reef (Alldredge and King, 1977; Hobson and Chess, 1979; Sorokin 1990a).

Although many workers have documented significant differences in species composition of reef zooplankton based on the place of its collection (Sale et al., 1976; McWilliam et al., 1981; Sammarco and Cranshaw, 1984), observations on spatial abundance are few. Emery (1968) observed that spatial differences are understandable as different species of reef plankton prefer different types of sheltering places on the bottom. At Minicoy, zooplankton seems to be spread more or less evenly on the lagoon bottom as there is no significant difference in their numbers between the stations. However, seasonal differences in zooplankton abundance was observed at Minicoy. Information on seasonal fluctuations in the biomass of reef zooplankton, like spatial variation, is also scarce. In the lagoon of the Great Barrier Reef, according to data from day tows, the maximum biomass in winter was several times more than the summer minimum. This maximum occurrence was directly related to input of river waters into the lagoon (Sammarco and Crenshaw, 1984). In lagoon waters which were not subjected to the influence of river waters, the maximum of zooplankton was documented in summer (Sale et al., 1976; McWilliam et al., 1981). It is significant that at Minicoy also the maximum biomass is observed during the premonsoon period.

Determination of where larval coral reef fish spend their pelagic phase may help answer the question of how localized adult populations are (Leis, 1981). A species with larvae that develop close to the adult habitat (or natal reef) should have localized populations compared with a species with widely dispersed larvae, all else being equal. There are only a few published information available on larval fish assemblages of atoll lagoons. Leis (1986) reports that lagoons that are small and shallow do not, generally serve as nursery for reef fish larvae. He opines that there may be some lagoon size below which most larvae cannot find suitable habitat conditions and above which many types of larvae find suitable habitat conditions. This may be one reason that fish larvae were not recorded in large numbers and are not species-rich at Minicoy. The absence of older larvae also seem to indicate that relatively few types of fish larvae complete their pelagic phase within the Minicoy lagoon. Among those that may complete their pelagic phase in the lagoon, of special interest from the livebait point of view are Clupeidae (Spratelloides) and some apogonids. Larvae of baitfishes did not form a significant portion of the total fish larvae collected from Lakshadweep. Leis and Miller (1976) and Leis (1982) reports that larvae of reef fishes with pelagic eggs (clupeids, caesionids) are not abundant in the near shore region and were probable to be found more than 3 km offshore. Also, the larvae of most other fishes with demersal eggs (pomacentrids) or brooded eggs (apogonids) prefer deeper water (> 3 m) during the day and moved upward only at night (Leis, 1986). Therefore, studies of livebait ichthyoplankton will have to concentrate on areas away from the reef and also in deeper waters.

Secondary production at Minicoy as seen from the present study indicates that zooplankton is more in the surrounding sea than in the lagoon. Spatial variations are insignificant while seasonal fluctuations are profound with maximum biomass in postmonsoon period. Plankton in the night are many orders higher than that of day. The lagoon at Minicoy does not serve as a major sursery for many reef fishes and livebaits. More informations on the quantity of plankton available, its identification and behaviour are necessary. Also needed are suitable methods to collect the various forms both during the day and at night. Ichthyoplankton surveys must sample offshore and also deeper areas in addition to the inshore adult habitat to obtain a complete picture.

# SUMMARY

The present investigation deals with the fishery biology and ecology of baitfishes employed in the pole-and-line tuna fishery at Lakshadweep. The period of study was from December 1988 to April 1990 and covered the islands of Minicoy, Agatti, Bangaram and the reef at Perumal Par.

Fishery and biological studies include population characteristics, food and feeding habits and reproduction of livebaits. A total of 11 species contributed to the fishery at Minicoy during the two seasons of study. They are the sprats, Spratelloides delicatulus and S. gracilis; fusiliers, Gymnocaesio argenteus, Caesio striatus, Pterocaesio pisang and P. chrysozona; damsel fishes, Chromis caeruleus and Lepidozygous tapeinosoma; and the cardinal fishes, Archamia fucata, Apogon thermalis and Rhabdamia gracilis. At the commencement of fishery in September, S. delicatulus is the important bait used. By November, caesionids enter into the lagoon in large numbers and forms the major group that contributes to livebait fishery. Pomacentrids and apogonids are taken only in small quantities mainly in the absence of clupeids and caesionids. Livebait fishery at Agatti, Bangaram and Perumal Par are monospecific being dependent on the sprat, S. delicatulus. The catch of livebaits per month at Minicoy varied between 0.22 to 1.6 tonnes with CPUE ranging from

1.6 to 2.7 kg. At Agatti, Bangaram and Perumal Par, the catch of S. delicatulus per month was between 0.43 to 7.19 tonnes with CPUE from 8.1 to 9.3 kg.

The size of S. delicatulus at Minicoy ranged from 18 to 63 mm with mode at 33 mm. S. gracilis on the other hand, peaked at 53 mm with size ranging from 33 to 48 mm. Among caesionids, G. argenteus with lengths of 58 and 68 mm were prominent in the fishery while C. striatus showed peaks at 83 and 93 mm. P. pisang were considerably smaller with peak at 73 mm and P. chrysozona were observed in higher percentges at sizes of 73, 78 and 88 mm. In the case of pomacentrids, C. caeruleus had a mean size of 28 mm and L. tapeinosoma showed a peak at 48 mm. The major sizes in the fishery of apogonids varied widely with A. fucata at 53 mm, A. thermalis at 38 and R. gracilis at 28 mm. S. delicatulus at Agatti were of smaller sizes with peak at 38 mm when compared to that of Bangaram and Perumal Par where the dominant size was 43 mm.

Length-weight relationships of all species from the different locations were established. S. gracilis showed a higher mean length and weight than S. delicatulus. C. striatus was the largest fusilier followed by P. chrysozona and G. argenteus. L. tapeinosoma averaged higher length than C. caeruleus and A. fucata was the largest among cardinal fishes at Minicoy. The length-weight relationship was significantly different for males and females of S. delicatulus at Perumal Par while in all the other cases, the relation between sexes were insignificant.

Population studies require continuous length frequency data over a period of time. Fishery at Minicoy involved many species of bait and hence adequate data for any single species was not available. Therefore, studies on population dynamics were attempted only for *S. delicatulus* from Bangaram and Perumal Par. Growth parameters of *S. delicatulus* calculated by the computer programme ELEFAN showed $L_{oo}$ to be between 70 and 74 mm and K 4 to 4.25 per year. Natural mortalities at both sites were almost similar while fishing mortality at Perumal Par was nearly double that of Bangaram. Recruitment pattern showed a higher percentage during August and November at Bangaram while at Perumal Par a delayed pulsing was evident with modes at September and December.

The diet of 1059 fish belonging to 11 species at Minicoy and 1031 *S. delicatulus* from Agatti, Bangaram and Perumal Par were analysed. In terms of percentage frequency of occurrence and number, copepod was the major prey item in all the species studied. Other dominant food items were decapod larvae, mysids, amphipods and fish eggs. Feeding rates between months were significant in all species except *P. chrysozona* and *A. fucata*. At Minicoy, feeding rate between species was also significant. A comparison of diet of *S. delicatulus* from the four locations indicated that there is no significant variation in feeding habits.

Percentage maturity stages in different months and in relation to size, sex ratio, gonosomatic index, size at first maturity and fecundity were the parameters investigated in the chapter on reproduction of livebaits. S. delicatulus at Minicoy had mature stages in all the months of its occurrence except in October. Mature stages of S. gracilis was also noticed in all months with predominenece of ripe fishes during November, March and April. The gonads of caesionids, in general, were in immature condition in almost all the months. G. argenteus and C. striatus showed relatively advanced mature conditions in certain months. C. caeruleus had mature gonads during November and December while in L. tapeinosoma mature males were present during February. Among apogonids, A. fucata and R. gracilis revealed mature condition in March and in A. thermalis mature stages were observed in January. At Agatti, Bangaram and Perumal Par, S. delicatulus had mature stages in November and December.

Minimum gonosomatic index for ripening females of S. delicatulus was 2.08 at Minicoy and the maximum of 3.50 at Agatti. S. gracilis had similar GSI values for ripening ovaries as S. delicatulus. The comparatively mature ovaries of G. argenteus and C. striatus occupied only less than 1% of total body weight. C. caeruleus with values of above 4.0 were mature and at 6.0 were in ripe condition. The mature gonads of apogonids showed GSI values ranging from 2.01 for A. fucata to

3.58 for *A. thermalis*. The size at first maturity of *S. delicatulus* from Minicoy was 35 mm SL, whilst that of *S. gracilis* was 37 mm. For other species of baitfishes, length at sexual maturity could not be calculated with available data. At Agatti, Bangaram and Perumal Par the size at maturity of *S. delicatulus* was 32, 33 and 31 mm respectively. The mean absolute fecundity of *S. delicatulus* at Minicoy, Agatti, Bangaram and Perumal Par in sequence was 545, 261 and 387. Average absolute fecundity for *S. gracilis* was higher at 884. The mean total number of ova in the ovaries of *C. caeruleus* was 3507 while that of *A. fucata* was 1650.

Due to the difficulties in observing livebiats in wild, ecological studies were restricted to monitoring the lagoon ecosystem at Minicoy. Direct correlations of ecology with biology was not possible primarily because of inadequate data on biology and short duration of study. However, in the absence of studies on ecology of lagoons of Lakshadweep, some observations were made on the hydrography, primary and secondary production at Minicoy.

Fluctuations in water temperature, salinity, dissolved oxygen and nutrients were monitored in five locations of the Minicoy lagoon and at one station from the adjacent sea. Vertical stratification was lacking while stratification horizontally was evident in water temperature and phosphate. Distinct seasonal fluxes were evident in most factors studied.

Prominent positive relationship was observed between phosphate and nitrogenous nutrients.

The rich fauna found in coral reefs and atolls is attributed mainly to the high primary production by its benthic flora. At Minicoy, the highest production of 3917 gC/sq.m/yr was by the seagrass Thalassia hemprichii. High production rates were also observed for another seagrass, Syringodium isoetifolium and brown algae, Turbinaria ornata and Padina tetrastomatica. There was no significant change in production between seasons. Correlation matrices constructed between production and hydrography showed the importance of nutrients in primany production of coral reefs.

Zooplankton abundance and composition from four regions of the Minicoy lagoon was studied as it forms the chief food item of livebiats. The important holoplankton recorded were copepods, siphonophores and chaetognaths while the main meroplankton were zoea, decapod larvae and fish eggs. Demersal plankton was represented by Lucifer, mysids and amphipods. The abundance of zooplankton in the ocean samples contained more biomass than that of day. Open sea had maximum plankton in terms of both volume and wet weight followed by coral bottom and seagrass bed collections. In general, premonsoon was the period of high biomass production and postmonsoon the lowest.

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