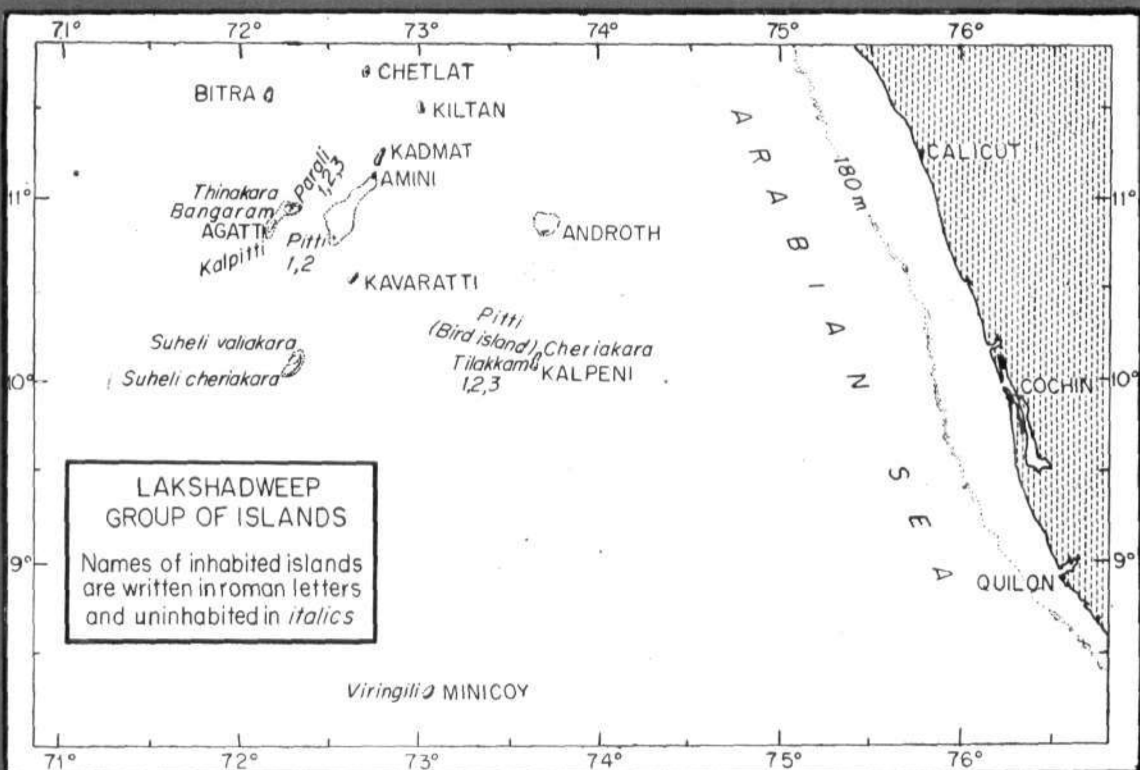
MARINE FISHERIES INFORMATION SERVICE

SPECIAL ISSUE ON LAKSHADWEEP



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CENTRAL MARINE FISHERIES RESEARCH INSTITUTE

COCHIN, INDIA

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

THE MARINE FISHERIES INFORMATION SERVICE: Technical and Extension Series envisages the rapid dissemination of information on marine and brackish water fishery resources and allied data available with the National Marine Living Resources Data Centre (NMLRDC) and the Research Divisions of the Institute, results of proven researches for transfer of technology to the fish farmers and industry and of other relevant information needed for Research and Development efforts in the marine fisheries sector.

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PREFACE

The Central Marine Fisheries Research Institute established a research centre in 1958 at Minicoy in Lakshadweep for studying the marine fisheries resources and related environmental features around the island. The centre initially conducted investigations on the fish fauna of the islands and later intensified observations on the tunas and related fishes. As years passed by, the research programmes of the Institute were further enlarged to cover the live-bait fish resources and coral ecology. The work of the centre could not be extended to other islands in view of the lack of infrastructural facilities and man power constraints. However, when required, certain special observations were made by scientists going from the mainland for short periods. As a result of the work done in the past 28 years, a number of scientific papers and reports have been published by the scientists of the Institute.

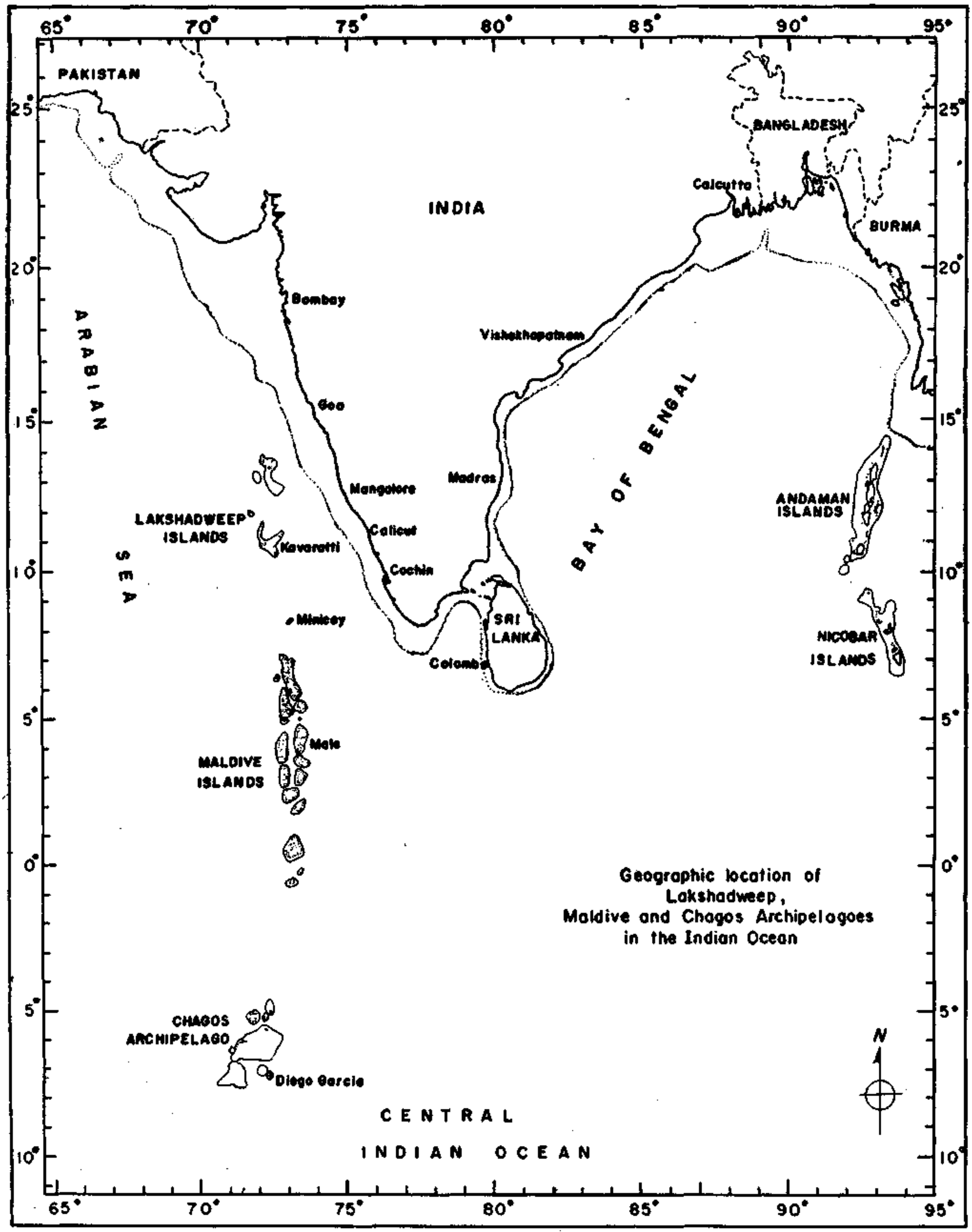
The present issue of the MFIS is devoted to include a series of articles especially selected to briefly review the marine fisheries research so far conducted in the Archipelago, the present status of various marine fishery resources, the environmental features, the productivity of the sea around the Lakshadweep, the environmental stress and ecological disturbances, the ancillary resources and future prospects for development of marine resources of the islands.

Keeping in view the work that has been done sofar, the Institute identified priority areas for research on tunas, live-bait fishes, conservation of coral reefs and total assessment of marine fishery resources during the Seventh Plan period. The CMFRI has also been actively participating in the meetings concerning the futurology for Lakshadweep and it is hoped that this special issue on Lakshadweep would provide necessary back-stop for perspective planning and development of the living resources of the Lakshadweep. The bibliography on Lakshadweep given at the end of this publication is expected to serve as a ready reference to aid in formulating future programmes for the region.

I deeply appreciate the interest taken by the contributors of various articles in this issue, especially Dr. S. Jones, the former Director of the Institute. Shri T. Jacob and Dr. K. J. Mathew, scientists of this Institute spared no efforts to get together the articles and processing the same through press for which I thank them sincerely.

P. S. B. R. James
Director
Central Marine Fisheries
Research Institute

Cochin - 682 031,
15th July, 1986.


PAKISTAN
INDIA
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Bombay
Vishakhapatnam
ARABIAN SEA
BAY OF BENGAL
Goa
Mangalore
Madras
Calicut
Cochin
Kavaratti
LAKSHADWEEP ISLANDS
Minicoy
SRI LANKA
Colombo
ANDAMAN ISLANDS
NICOBAR ISLANDS
MALDIVE ISLANDS
Male
Geographic location of Lakshadweep, Maldive and Chagos Archipelagoes in the Indian Ocean
CHAGOS ARCHIPELAGO
Diego Garcia
CENTRAL INDIAN OCEAN
N
65°
70°
75°
80°
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90°
95°
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Fig. 1

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Back cover photo:
A coral garden formed of *Acropora* thicket in Minicoy reef-flat. In the foreground many are dead.

LAKSHADWEEP – GENERAL FEATURES AND SOME CONSIDERATIONS

S. Jones*

Rtd. Director, Central Marine Fisheries Research Institute

The Union Territory of Lakshadweep, internationally known as the Laccadives, consists of 10 inhabited islands and 17 uninhabited islets with a total land area of 28.5 sq. km lying between 8° and 12° 30′ N latitudes and 71° and 74° E longitudes. These consist of coral formations built up on a submarine ridge rising steeply from a depth of about 1500 m to 4000 m off the west coast of India. In fact the Laccadive, Maldive and Chagos Archipelagoes form an interrupted chain of coral atols** and reefs on a contiguous submarine bank covering a distance of over 2000km (Fig. 1). Comparatively the Maldives form the largest group among these with about 1100 islands of which 204 are inhabited and having a total land area of 320 sq. km. The population of Maldives is about 1,80,000 as against about 35,000 in Lakshadweep. The Chagos never had any indigenous population and was colonised only in the last century when it formed a part of the Mauritius Administration under the British. It has since been given to the Americans for the establishment of the naval base of Diego Garcia.

The Lakshadweep came under the Central Administration in 1956 with the reorganisation of states on linguistic basis and with it one can rightly say that the area entered into a new phase of progressive development. Till then there was hardly any unified or concerted administration and the islands were under the control of the collectorates of Malabar and South Kanara districts of the erstwhile Madras State, a continuation of the legacy of British suzerainty over these islands that came in two phases, the southern islands in 1792 with the fall of Cannanore and the northern islands in 1799 with the death of Tippu Sultan at the battle of Seringapatnam. The people of the southernmost island of Minicoy are ethnically related to Maldivians and speak the Mahl or Divehi language while the rest speak Malayalam with a characteristic local slang as a result of isolation.

Information in detail about Lakshadweep relating to its geographical features, land fauna and flora, history etc. can be had from Ellis (1924) and Mannadiar (1977). The particulars regarding the inhabited islands are given in Table-1.

The uninhabited islands numbering 17 have a total land area of only 2.3 sq. km and of these Bangaram as a tourist resort and Suheli as a coconut growing and fishing centre are of special interest. Pitti or the bird island is a small reef with a sand bank covering an area of 1.21 hectare lying 24 km northwest of Kavaratti where terns in thousands nest.

The atols** rest on an under water platform of about 100 fathoms deep. Corals cannot grow very deep in the ocean and what we see at present depicts millenia of interaction between the submarine bank, tectonic activity and the level of the ocean, particularly during the Pleistocene period, when a great quantity of water was locked up in continental glaciers. The rims of the atols can grow only to a height which would prevent its exposure during low tides. A reef rimming an atol may be about 300 metres or more across with channels in its perimeter allowing the inflow and outflow of water in the lagoon with the tides. The islands are formed by the accumulation of coral sand in the form of sand bars which eventually get stabilised with vegetation and in course of time get compressed into soft sandstone. Generally the height of land above sea level is about one to two metres, rarely in some places a little more. Some of the islands, subjected to heavy storms, have coral boulders heaped up on one side.

Androth has no lagoon unlike the other atols. Bitra has perhaps the most magnificent lagoon; the island having a land area of only 10.52 hectares. Similarly Minicoy also has a large and deep lagoon, with a

* Santinivas, Nanthancode, Trivandrum.

** "Atoll" or "atol" is derived from the Divehi (Maldivian) world "*atolu*". According to Bell (1940) the eminent archaeologist who did the pioneer research in the Maldives, the word should be spelt "atol" and not "atoll".

Table 1. *Inhabited Islands (Alphabetically arranged)**

Sl. No.	Name	Geographic location	Distance from Cochin in nautical miles	Area in sq. km	Popula-tion (1971 census)	Language
1.	Agatti	Lat. 10° 51′ N				
		Long. 72° 11′ E	248	2.7	3155	Malayalam
2.	Amini	Lat. 11° 07′ N				
		Long. 72° 44′ E	220	2.6	4542	„
3.	Androth	Lat. 10° 49′ N				
		Long. 73° 41′ E	158	4.8	5425	„
4.	Bitra	Lat. 11° 36′ N				
		Long. 72° 10′ E	261	0.1	112	„
5.	Chetlat	Lat. 11° 41′ N				
		Long. 72° 43′ E	233	1.0	1200	„
6.	Kadmat	Lat. 11° 13′ N				
		Long. 72° 47′ E	220	3.1	2416	„
7.	Kalpeni	Lat. 10° 05′ N				
		Long. 73° 39′ E	155	2.3	3152	„
8.	Kavaratti	Lat. 10° 33′ N				
		Long. 72° 38′ E	213	1.6	4420	„
9.	Kiltan	Lat. 11° 29′ N				
		Long. 73° E	218	3.6	2046	„
10.	Minicoy	Lat. 8° 17′ N				
		Long. 73° 04′ E	215	4.4	5342	Mahl (Divehi)

boat channel on the north-eastern side giving safe access and anchorage to vessels of about 3 m draught.

The outer edges of the atols drop precipitously to the ocean floor. Mostly on the eastern side, the outer edge of the atol overhangs the precipitous shelf. The eastern side is generally more sheltered from wind and current facilitating anchoring of vessels.

Availability of drinking water is the most essential requirement for the colonisation of the islands. The rainfall is a little more in the south than in the north showing an average of about 1,640 mm for Minicoy and 1,504 mm for Amini. The rainiest months are from June to September with June receiving the maximum amount. The rain-water sinks into the porous sand of the islands to form a subsurface layer of fresh water lens which is utilised by digging small wells about 2 to 3 metres deep.

* The area of Androth is given as 4.8 sq km. and that of Minicoy as 4.4 sq. km. Minicoy is considered the largest of the islands in the Laccadive Archipelago with an area of 1,120 acres with Androth coming next with an area of 1,067 acres (Ellis 1924). It therefore remains to be checked if the areas given for the two islands in the gazetteer should be interchanged.

The climate is more or less comparable to that of the coastal areas of Kerala, warm and humid but bearable. Maximum temperature may range from 35°C to 38°C and the minimum may come down to 17°C to 18°C. Occasionally cyclonic storms occur, the oldest and the most serious recorded being the one that struck Kalpeni and Androth on April 15, 1847. The subsequent ones were in 1891, 1922, 1948, 1963 and 1965 but never of the magnitude of the first one.

The mineral resources of the islands consist of low grade phosphates, derived out of bird droppings before the islands were colonised by man, and calcium carbonate sands. Exploitation of these are linked with the very existence of these islands and any attempt made in this direction should not turn out suicidal.

The two most important items coming under the flora and fauna of the islands are the coconut and fishes which form the mainstay of the people of the islands. Coconuts form the real tree of life of the islanders and every part of it is of use to them in one way or other. There are several kinds of plants in the islands but none

of such importance as the coconut tree. No cereal of any significant importance is grown in the islands. Plantains and a variety of ordinary vegetables are grown for home use. There are some trees like jack, mango, breadfruit, Indian laurel, portia etc. The drumstick plant is widely distributed. Tubers and underground stems like tapioca, yam and colocasia, gourds, legumes etc are cultivated in small quantities for local use. A variety of wild herbs and shrubs grow and new plants are occasionally introduced from the mainland. The area available is so limited and the population is registering such a steady increase that there is very little space for any large scale cultivation. Further, there is limitation regarding availability of water for any extensive agricultural operations.

Until the territory came under Central Administration, large scale fishing was in vogue only in Minicoy. Within the last quarter of a century remarkable strides have been made in fishery development. The Central Marine Fisheries Research Institute has made a comprehensive study of the fish fauna of the entire Archipelago (Jones & Kumaran, 1980). The progress made in fishery development will be dealt with in detail by the concerned persons elsewhere in this volume. There is no land fauna of any special importance except perhaps the tree rat which is of a very destructive nature.

The people there are all muslims who are very devoted to their religion. They are very peace loving, and criminal records are few and far between, perhaps the lowest in the Indian Union. Till it became a Union Territory no permanent police force was stationed in the islands. Records of criminal assaults are reported to be very few and murders are practically unknown, perhaps one in a few decades. However, their propensity to litigation is said to be rather high, an outlet for their emotions being probably found in this sort of diversion! A certain type of caste system was in existence evidently based on their background as migrants from India before islamisation. The social structure in Minicoy bears close affinities with that in the Maldives. The *Athiri* or the village system is of a special kind there and the women there have a very dominant position in the society, perhaps unlike anywhere else among the Muslims. Even in ancient days it had a special status and was reported to have been ruled by queens. The inhabitants of all the other islands are migrants from Kerala several centuries ago. Maloney (1980) after a comprehensive study of the social conditions in the Maldives has compared the same with those of Lakshadweep. This and the publication by Kutty (1972) may be referred for details.

General remarks

Having had the opportunity to visit all the inhabited islands in Lakshadweep and make a general study of the conditions there, I take the liberty of offering some general remarks as my personal views for the consideration of the planners who contemplate to develop the economy of these islands in the coming years. The 27 islands ranging in area from about a hectare to nearly 5 sq. km have total land area of only 28.5 sq.km forming nothing but little specks in the Indian Ocean, with a water spread of over 73 million sq.km. The tiny bits of land rising hardly 2 m above sea level has perhaps the most mysterious origin covering millions of years owing to a continuous process of growth, destruction and consolidation, involving millions of tiny organisms, mostly colonial. The submarine bank that supports the atols rise from depths ranging from 1,500 metres to 4,000 metres. In short the islands arise more or less steeply from great depths. The particulars of the great cyclonic storm of April, 1847 that hit Kalpeni and Androth as stated briefly in the Gazetteer (Mannadiar, 1977) are given below.

"...It commenced in Kalpeni about 8 P.M. on 15th April, passed to Androth and finally reached Kiltan after devastating these two islands. All the houses in Kalpeni were damaged and many were entirely washed away. The population of that island prior to the hurricane was reckoned at 1,642. Of these, 246 were drowned or washed away by the storm. One hundred and twelve perished in the ensuing five months from famine or from the diseases engendered by unwholesome and insufficient food, 376 escaped to the coast, leaving in the island 908, of whom nearly four-fifths were women and children. The plantations in the island were completely destroyed. Out of upwards of 1,05,000 full grown coconut trees, the number before the storm, only 768 survived. In Androth, the population before the storm was 2,576. Many people perished in the storm and large numbers of the survivors migrated to other islands. Those left in the island numbered only 900. The coconut trees were almost completely destroyed".

The above will give an idea of the conditions of existence of these islands. They are beautiful, idyllic and exhilarating but once any rise happens to the sea level - a mere metre and a half - the yawning and precipitous sea bottom is the fate! We have to bear in mind the above fact while planning.

Development of cottage industries, I am sure, will receive the attention of planners and these are therefore,

left to the experts in the field. However, in this connection, it would be necessary to bear in mind the availability of the well disciplined and hardworking women folk of the islands who form a potential labour force of great importance.

The land and the resources available therein being very limited we have necessarily to look towards the sea around the islands for further development. There is a vast expanse of oceanic waters and it is best that we think of the optimum utilisation of the resources therein. As already stated the progress made in fishery development by the Lakshadweep Administration is appreciable. Pole and line fishing with live-bait has been extended to all the islands while previously it was confined only to Minicoy. Sea is an area from where we can harvest without sowing. The living resources therein are of the renewable category under proper management, though not inexhaustible in the strict sense. He who takes it gets it. It is the property of all or *res communis* and at the same time the property of none or *res nullius*. According to international convention each country has its right over its territorial waters and exclusive economic zone (EEZ). The Lakshadweep Sea is estimated to have an annual fishery potential of about 90,000 tonnes while the present yield as per statistics of 1984 is reported to have reached only about 5,000 tonnes a year. This gulf has necessarily to be narrowed till an optimum level of catch is reached. It is needless to say that there are constraints for achieving this. As usual it is a chain of requirements, one affecting the other. Some of the major ones are availability of live-bait, man power, craft and gear and adequate infrastructure facilities on the shore. At present the skipjack catch which forms the major fishery is almost entirely dependent on the availability of live-bait fish. Long line brings in the other tuna and related fishes apart from sharks and some pelagic fishes. The fishing as practised now is bound to limit the catches at more or less the present level unless a break-through is made.

We have not been successful in purse seining for skipjack. However, it is reported that a very successful purse seine fishery has been built up in Seychelles mainly by the French, but also Spanish, Ivory Coast and British vessels raising the catch from 1,000 tonnes in 1981 to 1,00,000 tonnes in 1984. The catches consist mainly of skipjack and yellow fin. If things are to continue at this rate the repercussions it will have on the tuna stocks in the Indian Ocean are quite obvious. Tunas are highly migratory fishes. Nature does not allow a vacuum to exist in the biological complex of the ocean. It is only natural that tuna shoals from the surrounding areas should migrate to the intensively fished zone where more abundant food should become available. As the fishing range increases, tuna stocks in a progressively wider area will get affected by a gradual process of thinning out. It is therefore felt that a complete reorientation in the development programme of our oceanic fisheries is called for to be taken up at national level. This will enable the islands to be used as a reconnoitering base and a springboard for a greater expansion of our fishing range. Fishing being a concurrent subject it is only appropriate that the development of the same in Lakshadweep and surrounding areas is taken as a national problem.

The adjacent Republic of Maldives where the skipjack fishery constitutes the mainstay of the islanders, the current annual catch is 60,000 tonnes. It is steadily on the increase. The coral reefs and atols there are quite extensive and support live-bait fishes of considerable magnitude, perhaps unknown anywhere else. Their mainstay is *Spratelloides japonicus* and *S. delicatulus* followed by *Lepidozygus tapeinosoma* and a variety of small fishes caught from the vicinity of reefs and from lagoons. Survival of certain species in bait-wells is a problem and experimental research to mitigate this disadvantage is called for. It is desirable that we keep a close watch and make a study of the work done elsewhere for solving similar problems.

It has been said that some visitors to these islands seeing the beautiful and peaceful set up there give vent to their feelings, in their enthusiasm, in terms of air strips, helipads, factories etc without taking into consideration the existing limitations of space, man power, local resources etc. These ideas might even tend to appear exciting and plausible to many of the innocent local people who would not have understood properly what these would ultimately lead to. At the same time we hear the cry for the need to protect the ecological and environmental conditions there which for obvious reasons are very delicately poised by nature. These islands are nature's precious gifts and it is left to us to look after and develop them with the utmost care and foresight without destroying them.

MARINE FISHERIES RESEARCH IN LAKSHADWEEP – A HISTORICAL RESUME

P. S. B. R. James, C. S. Gopinadha Pillai, P. P. Pillai, P. Livingston and Madan Mohan
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The Lakshadweep

The Lakshadweep is located on the Laccadive-Chagos ridge which is supposed to be the continuation of the Aravali mountains, and the islands are believed to be the remnants of the submerged mountain cliffs. The archipelago is composed of 22 islands and 5 attached islets scattered between latitudes 08°00′ N and 12°30′N and between longitudes 71°00′E and 74°00′E. Except Androth, all the islands have a lagoon, some of which, as in Kiltan and Minicoy, are fast getting filled up by calcareous sand. Only ten islands are inhabited. Coconuts and tuna are the mainstay of the economy of this Union Territory. The vast stretches of blue waters around the islands are rich in tunas which are exploited by both mechanised and non-mechanised vessels which use pole and line method with the help of live-baits.

The history of the fishery of Lakshadweep should be as old as the history of human settlement in these tiny tots of islands. The marine biological and fishery research in the Lakshadweep Sea dates back to the end of the 19th century, when the surgeon naturalist A. Alcock set sail on 17th October, 1891 by R.M.S. *Investigator*. For two months he cruised in the Lakshadweep Sea, "sketching and checking the position of the islands, running lines of deep-sea soundings and occasionally taking a turn with the deep-sea dredge" (Alcock, 1902). He also left short but graphic descriptions of many islands. An account of the deep-sea fishes collected from the Lakshaweep Sea has also been presented by Alcock (1894).

The Cambridge University Expedition under the leadership of Prof J. Stanley Gardiner was the next significant event in the marine research of Lakshadweep, though, the expedition touched only Minicoy at the southern tip of the Archipelago. The results of the marine biological and oceanographic research were reported in the two volumes of *'Fauna and Geography of the Maldive and Laccadive Archipelagoes* (J. S. Gardiner (Ed.) 1903–1906). Later Hornell (1910) and Ayyangar (1922) described briefly the tuna fishing methods in the Lakshadweep. The establishment of the research centre of Central Marine Fisheries Research Institute and the Department of Fisheries in the Lakshadweep in 1958 and 1959 respectively gave a fillip to the fisheries research in this remote area. In the last 28 years scientists of the CMFRI and the National Institute of Oceanography have furthered our knowledge on the environmental characteristics, fishery resources, fishing methods and fishery biology of important tunas and live-bait fishes of the Lakshadweep Sea. Researches on corals and coral reefs have also been strengthened.

The icthyofaunal studies

A valuable contribution towards the knowledge of the icthyofauna of Lakshadweep is that of Balan (1958). He set sail in March, 1954 and after a hazardous journey visited the islands of Agatti, Kavaratti, Amini and Kadmat. He has documented from these islands 80 species of fishes belonging to 65 genera. Jones and Kumaran (1959) while describing the fishing industry of Minicoy also listed 154 species of fishes from the lagoon and reef, many of which being new records. The list was further elaborated by Jones (1960a, 1960b, 1969) and Jones and Kumaran (1967a, 1967b, 1967c) and culminated in the publication of the *'Fishes of the Laccadive Archipelago'* (Jones and Kumaran, 1980). In the book they have documented information on 603 species of reef fishes including many bathypelagic forms. Due consideration has been given to the systematics of commercially important tunas and related fishes as well as the common live-bait fishes. This work remains to be the most comprehensive account on the fish fauna of the Lakshadweep.

Exploratory surveys

As early as 1928 the erstwhile Madras Fisheries Department conducted experimental trawling in the Lakshadweep Sea using the Steam Trawler *Lady Goschen* (Sundara Raj, 1930). Material brought up from the Basses de Pedro Bank included *Lethrinus* spp., *Epinepheles* (reef cod), *Lutjanus* spp., and a variety of invertebrates. Jones (1959a) has given a detailed account of the co-operative oceanographic investigations carried out by R.V. *Kalava* in the Lakshadweep waters. During the cruises of this vessel many valuable information on the oceanographic conditions and fishery resources of the seas around Lakshadweep were collected. The

larval fishes collected from this area included those of *Xiphias gladius, Istiophorus gladius, Katsuwonus pelamis, Euthynus affinis* and *Auxis* sp. (Jones, 1958). The results of the exploratory surveys of R.V. *Varuna* in the sea around the islands have been well documented by Silas (1969, 1972).

Assessment of fishery potential of the Lakshadweep Sea

The steady increase in landings and decrease in mean length of the yellowfin tunas exploited by the Japanese tuna fishing fleet had caused much concern over the tuna populations in this area since 1950s. Therefore, studies on the assessment of stock of tunas in the Lakshadweep and nearby seas were given priority in the research programmes of the CMFRI. The earlier estimates revealed that only a total of 650 tonnes of fish were being fished from the Lakshadweep waters annually against a potential yield of 3,300 t of pelagic and demersal fishes, most of which being tunas (Jones, 1968). George *et al.* (1977) estimated a projected exploitation potential of 50,000 t of tunas against the total local annual exploitation of 2,740 t.

Research on tunas and related fishes, and their fishery

Scientific observations on the craft and gear and fishing methods began under the erstwhile Madras Fisheries Department. Hornell (1910), Ayyangar (1922) and Ellis (1924) recorded their valuable observations on the fishing tackles and tuna fishing industry in the islands. Hornell (1910) gives an account of the 'pole and line' fishing method of Minicoy. Jones and Kumaran (1959) described the fishing craft, the gear and the method as they existed just at the end of the pre-mechanisation era. The mechanised 'skipjack-boat', its fishing gear and fishing methods for skipjack as well as for live-baits are described in Ben Yami (1980) and Silas and Pillai (1982).

Studies on the fishery and biology of commercially important species of tunas and tuna live-bait fishes are being undertaken by the CMFRI at Minicoy since its establishment in this Union Territory. Aspects such as length-frequency distribution, age and rate of growth, length-weight relationship, maturity and spawning and food and feeding habits of the two commercially important tunas viz. the oceanic skipjack and the yellowfin have been studied (Appukuttan *et al.*, 1977; Raju, 1964a, 1964b, 1964c; Thomas, 1964a; Madan Mohan & Koya, 1981). Data on the fishing effort, catch, species composition and catch per unit of effort, relating to the tuna fishery have also been collected.

Investigations on live-bait resources

Realising the importance of live-baits for a successful and sustained tuna fishery, Jones (1960-1980) carried out long-term researches on them. During the cruises of R.V. *Kalava* he observed the occurrence of *Spratelloides delicatulus* around many islands and pointed out its importance as potential live-bait (Jones, 1960a). Subsequently, in 1961 he recorded *S. japonicus*. Later Jones (1964a) published the results of a preliminary survey of the live-bait fishes of the Lakshadweep wherein 45 species have been listed. A detailed account on the fishing method, storage and utilisation of the live-bait fishes has been published (Jones, 1958).

The next major contribution towards our knowledge on the live-baits of Lakshadweep is that of Thomas (1964b) who during 1960-'61 period made some observations on the fluctuations of live-bait fishes in Minicoy. He observed that 11 species of these fishes were being regularly fished. Studies on the length-frequency distribution of *Lepidozygus tapeinosoma, Archamia fucata, Caesio caeruleus, C. tele, C. crysozona, Dipterygonotus leucogrammicus, Chromis caeruleus* and *Spratelloides* sp. were also made (Thomas, 1964b). Jones (1964b) thought of *Tilapia mossambica* as an alternative source for live-baits and sent a consignment of 21 specimens to Minicoy. Today, the species has established throughout the Lakshadweep; in all fresh water wells and ponds, and is found in purely marine conditions also in some of the tidal pools at the southern tip of Minicoy. However, *Tilapia* has not been a successful alternative to the other live-baits.

Pillai and MadanMohan (MS) paid some attention to the ecology and biology of reef fishes at Minicoy with special reference to live-baits during the 1981-'84 period. Based on two years data, the biology of several species was worked out for the first time. These included *Spratelloides japonicus* and *S. delicatulus* (Madan Mohan and Koya, 1986c), *Chromis caeruleus* (Madan Mohan, Pillai and Koya (in press), *Dascyllus aruanus, Acanthurus triostegus* and *Abudefduf glaucus* (Pillai, Madan Mohan and Koya) (MS).

The microhabitat and coral association of the live-bait-fishes of the lagoon of Minicoy was elucidated by Pillai (1983). A correlation between the lunar cycle and the occurrence of pelagic bait fishes was also demonstrated (Madan Mohan) (unpub.). Based on prolonged observations on the corals of Minicoy, Pillai (1983) pointed out the impact of mass mortality of corals on reef associated fishes including live-baits.

Fishery environmental studies

The physical, chemical and biological parameters of the marine environment and also some oceanographic features such as currents, water masses, upwelling etc. have been studied by the CMFRI, in the recent past, during the cruises of R.V. *Kalava* and R.V. *Varuna*.

The investigations of Ramasastry (1959) and Jayaraman *et al.* (1960) have revealed the existence of four distinct water masses in the southern Arabian Sea. Prasad (1951) and Jayaraman *et al.* (1960) have brought to light the influence of the nutrient rich Antarctic bottom water in the Lakshadweep sea area. The physico-chemical characteristics of the water studied by Jayaraman *et al.* (1960) showed that the highly nutrient rich water was maintained around the islands for considerable length of time by the geotrophic pattern of circulation existing around the islands. Later Ramamirtham (1979) showed that a large cyclonic gyre type circulation exists in the northern region while an anticyclonic gyre type circulation exists in the southern region of the islands mainly in the sub-surface layers associating with the convergence and divergence in the sea. Other works of oceanographic importance done in the Lakshadweep seas and adjacent waters are those of Patil and Ramamirtham (1963), Rao and Jayaraman (1966), Sankaranarayanan (1973) and Sen Gupta *et al.* (1979).

Productivity studies

The early studies on the primary production of the tuna grounds of the Lakshadweep is by Prasad and Nair (1964). Later Nair and Pillai (1972) estimated the productivity of the reefs in Minicoy lagoon. Qasim *et al.* (1972) made a fairly comprehensive study on the primary production of the ambient waters and reefs of Kavaratti atoll. The primary production of the sea grass beds of Kavaratti atoll has been determined by Qasim and Bhattathiri (1971). Other major investigations on primary production of Lakshadweep waters are those of Bhattathiri and Devassy (1979) and Qasim *et al.* (1979).

The earliest work on zooplankton of the Lakshadweep is that of Wolfenden (1906) on copepods. Jones (1959) carried out some studies on the zooplankton assemblages around some of the northern Lakshadweep islands. During the cruises of R.V. *Varuna*, Silas (1972) estimated the zooplankton biomass closer to the reefs of the islands. He has also made some studies on the Deep Scattering Layers closer to the islands and suggested that the DSL constituted an important source of forage to pelagic fishes. A quantitative study of the zooplankton of the Kavaratti and Kalpeni atolls has been made by Tranter and Jacob (1972) who accounted for the loss of zooplankton over the reefs. Others who did creditable work on the zooplankton assemblages of the Lakshadweep waters are Prasad and Tampi (1959), Goswamy (1973, 1979, 1983), Madhu Pratap *et al.* (1977), Nair and Rao (1973) and Mathew (M.S.).

Marine invertebrates

Early information on the marine fauna of Lakshadweep are mostly based on the various articles published in the two volumes of *'Fauna and Geography of Maldive and Laccadive Archipelagoes'* (Gardiner(Ed.) 1903–1906). Nagabhushanam (1972) made a detailed ecological survey for the marine fauna of the Minicoy atoll. The marine animals so far studied, mostly from Minicoy, include foraminifera (Chapman, 1895); corals (Gardiner,1903b,1906a,b,c; Cooper, 1906; Pillai, 1971a, 1971b, 1972); sponges (Thomas, 1979); other coelenterates (Borradaile, 1906 d; Browne, 1906a, 1906b), nemertines (Punnet, 1903); echiuroids (Shipley, 1903a); sipunculoids (Shipley, 1903b); stomatopods (Lanchester, 1903); crabs (Borradaile, 1903a, 1903b, 1903c, 1903d, 1906a, 1906b, 1906c; Kathirvel (MS); Sankarankutty, 1961); lobsters (Meiyappan and Kathirvel, 1978; Pillai *et al.*, 1984a); alphids (Coutiere, 1903, 1905, 1906); molluscs (Eliot, 1906; Hoyle, 1906; Smith, 1906; Hornell, 1910; Rao *et al.*, 1974; Nair and Dharmaraja, 1983; Panicker, (unpub.); Appukuttan and Pillai (MS) and echinoderms (Bell, 1903; Sivadas, 1977; Murty *et al.*, 1980; James (MS).

Though the marine fauna of Lakshadweep is rich and varied the present day information is mostly confined to Minicoy. The living marine resources of the northern Lakshadweep islands need further study. The CMFRI has programmes for indepth surveys of the islands with a view to furthering our knowledge on the marine ecosystem, the fauna and the resources. While the resources may be exploited rationally, measures for conservation of the ecosystem, especially the corals and coral reefs have to be given due importance in future plans for the development of the islands.

ENVIRONMENTAL FEATURES OF THE SEA AROUND LAKSHADWEEP

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Introduction

The sea around Lakshadweep forms a part of the southeastern Arabian Sea, also known as the Lakshadweep Sea. The importance of the waters in this region with their special ecological conditions has been shown by Jones (1959c). The submarine Laccadive-Chagos ridge located in this region greatly influences the water masses and Cooper (1957) suggested the importance of the ridge in the enrichment of the upper waters of the mid-ocean in the Arabian Sea. The region also supports a rich pelagic fishery. A knowledge of the environmental conditions of the waters around Lakshadweep, would help in understanding several problems of oceanographic and fishery nature. The Central Marine Fisheries Research Institute was the first to initiate detailed oceanographic investigations on the environmental features in this region as early as 1959 (Jayaraman *et al.*, 1959, 1960) and since then a lot of information have been added by the same and others. The following is an account of the present day information available on the environmental characteristics of the waters around Lakshadweep.

Wind system

For a better understanding of the environmental characteristics of the Lakshadweep Sea, a knowledge of the general wind systems and currents prevailing in the northern Indian Ocean and Arabian Sea in particular is essential.

The Arabian Sea and Bay of Bengal which form parts of the northern Indian Ocean are subject to seasonal monsoon winds. During the summer the southwest monsoon and during the winter, the northeast monsoon prevail over this region. In summer, a seasonal low pressure area develops over the Central Asia which causes the winds to blow persistently from southwest forming the southwest monsoon winds. In winter, a high pressure zone develops over the Tibetan plateau and its neighbourhood. The winds from this high pressure region move towards the low pressure belt in the Equatorial Indian Ocean, blowing from northeast to southwest which form the northeast monsoon. The winds are southwesterly during southwest monsoon and northeasterly during northeast monsoon. During March–April and October–November the winds are weak and variable. The atmospheric circulation undergoes a complete reversal in direction during a year. In general, the winds are stronger and steadier during the southwest monsoon than during the northeast monsoon. In the Arabian sea, the southwest monsoon prevails during June–September and northeast monsoon during November – February, the transition being during October.

Sea surface circulation

The sea surface circulation in the Arabian sea, in general, follows the prevailing wind system over the area with stronger and steadier currents during the southwest monsoon compared to those in the northeast monsoon. During the southwest monsoon the surface currents in the open ocean are eastwards and clockwise in direction due to the coastal configuration. It flows northeastwards along the Arabian coast and southwards along the Indian coast as wind driven ocean current. This clockwise circulation strengthens with the progress of southwest monsoon. This coastal current is a continuation of the Somali Current flowing along the East African coast. During the N.E. monsoon the general surface circulation is more or less reversed in the open ocean and is northwestward with a counter-clockwise circulation along the coasts. Along the west coast of India the surface flow is mostly in the north-northwest direction upto 20°N changing to west-northwest direction thereafter, and off the Arabian coast it moves in the southwest direction. As stated earlier these directions of flow are direct effects of the monsoons and the clockwise or the counter clockwise patterns are set up during the transition periods when the winds are variable. The counter clockwise circulation ceases by the end of January and the clockwise coastal current is gradually established by May. This reversal of the coastal current system along the coasts in the Arabian sea is not simultaneous all over the area. During February–April the predominant flow in the open sea is towards west or northwest.

Hydrographic conditions

The oceanographic conditions in the sea around Lakshadweep reveal many interesting environmental features. During summer (Jayaraman *et al.* (1959), which is the period of the year when stable conditions exist in the environment in the Arabian sea, the distribution of temperature indicates the presence of a more or less isothermal layer down to 50 m. The temperature discontinuity layer (also known as the thermocline layer) is found to be between 75 and 150 m. The salinity maximum is observed to occur within a tongue of high saline water at about 100 metres. At deeper depths comparatively low saline waters are found indicating the presence of sub-antarctic drift.

The dissolved oxygen content from surface layers down to 50 m is more or less uniform in the region. From 75 m downward there is a rapid decrease in oxygen content and at 150 metres the oxygen concentration of the waters attains very low minimum values. This layer of sharp sudden decrease in oxygen content corresponds to the layer of the thermocline. This oxygen poor layer continues further below and extends down from 150–500 m. The density (sigma-t) values range between 25.00 and 27.00 within this layer. At deeper depths from 700–1000 m, the values increase and at 1000 m it is nearly double that of the minimum seen above. The oxygen minimum layer is several metres thick and the upper level of this is present at 150 metres as compared to about 300 m in the other open parts of the ocean. These features conclusively point to a rather high level of productivity of the Lakshadweep waters. Below 1000 m there is a remarkable increase in oxygen values up to 3.5 ml/l compared to 0.5 ml/l in the oxygen-deficit layer found above. This has been attributed to the south polar water sinking at the Antarctic and subtropical convergences and spreading in the deep bottom into the basins of the Indian ocean.

Water masses: Three main types of water masses are noticed during the summer in this region (Jayaraman *et al,* 1960). They are:

1) The water mass characterised by rather sharp salinity gradients of very small temperature range and density (sigma-t) values between 21.00 and 23.00 from surface down to 75–100 m, corresponding to the Arabian Sea upper sub-surface waters described by Sastry (1960) as the water mass which participates mostly in the upwelling and sinking phenomena.

2) The Arabian Sea lower sub-surface water mass characterised by a steep temperature gradient with a salinity range hardly exceeding 0.8‰, sigma-t values between 23.00 and 25.00 and much better defined than the first one.

3) The Indian Ocean equatorial water mass below 200 m having small temperature and salinity gradients and appearing like isohaline waters at certain places.

Water movements: The existence of circulatory water movements (eddies) around the islands at practically all levels down to 500 m has been observed from the nature of the density surfaces and geopotential anomalies. Anticyclonic movements (eddies) are present in the upper 100 m and reverse of that below that level. These eddy-like circulatory motion of the waters helps to keep the fish eggs and larvae within the highly productive waters in the vicinity of the islands for a considerable length of time.

It would be worth mentioning here that these circulatory water movements considered typical of island regions are responsible for high levels of productivity observed in the Lakshadweep Sea (Sen Gupta *et al.,* 1979). They have also found that patterns of distribution of nutrients and the nutrients-oxygen relationships were similar to those observed in the other parts of the Arabian Sea. The general upsloping of the water masses around the islands is attributed to the vertical turbulent mixing and wind induced upwelling in the area.

These circulatory water movements are present during winter also, but with lesser intensity and particularly limited to a shallow depth of about 200 m (Patil, *et al.,* 1963). Significant circulatory movements are found in the northern region especially near Bitra Island where it is cyclonic while near Agatti and southeast of Kiltan islands it is anticyclonic. Superimposed upon this general circulatory movements around the islands, the northwesterly drift produced by the prevailing winds is noted in the upper 30 m towards west of Suhelipar, and further towards east due south of Agatti Island. North of Agatti and Androth islands an easterly drift in the upper layers was noticed. An important characteristic of the season is the sinking which was observed in the western region of Bitra-Agatti-Suhelipar along the 23.00 sigma-t surface. High surface salinities were also observed during winter especially in the north-northwestern region, that is the region of the Bitra-Chetlat-Kiltan region, compared to the summer season. This is supposed to be due to the excess of evaporation over precipitation which is characteristic of the winter season. The water masses viz., Arabian sea lower sub surface

water and the Indian Ocean Equatorial Water contribute mainly upto 2000 m depth and the presence of Antarctic Intermediate water especially in the eastern part of the Lakshadweep region below 2000 m depth was traced.

Chemical Characteristics of waters: The chemical characteristics of the waters of the lagoon and the sea around Kavaratti atoll such as salinity, pH, total alkalinity, dissolved oxygen, reactive phosphate, total phosphorus, chlorophyll and the particulate organic carbon showed high degree of variability except pH and alkalinity, with location in the lagoon. (Sankaranarayanan, 1973). A marked diurnal variation in the oxygen concentration of the waters of the lagoon was found whereas other chemical factors, mentioned above, did not show significant changes. It was also observed that most of the phosphorus present in the waters was bound organically. Sediment phosphorus showed very low values (0.04–0.06% as P_2O_5) indicating the poor retention of phosphorus with the sediments. It was noted that the benthic macrophytes play a role in the recycling of nutrients in the lagoon (Sankaranarayanan, 1973).

Sea surface temperatures: The sea surface temperatures in the open Arabian Sea were found high during May–June period while a lowering of temperature was observed in the month of July with the advance of the southwest monsoon. The lowered sea surface temperatures ranged from 1°C to as much as 4.5°C (Rao *et al.*, 1976).

Oxygen maxima and minima: The depths of occurrence of oxygen maxima (4.5–5 ml/l and above) during the summer, southwest monsoon, post-monsoon and northeast monsoon have been found to be in the upper surface layers up to 40m, 10m, 10m and 10m respectively whereas those of oxygen minima (0-1.0ml/l) during the same periods were at 300m, 150m, 100m and 300m respectively in this region (Rao *et al.*, 1970). These depths of occurrence of oxygen maxima and minima appear to be governed mainly by water movements, circulation and mixing, in addition to the biological processes.

Water characteristics around Minicoy Island: From the distribution of temperature, salinity, dissolved oxygen and density, it has been found that upwelling occurs in the very close vicinity of the Minicoy Island during the November – December period (Rao *et al.*, 1966). This phenomenon was found limited to the upper 150m. The presence of diverging current systems has been attributed to the causes of upwelling. During this period the general pattern of the current in the southern part of the Arabian Sea is westerly. Due to the coastal configuration, a north-northwesterly current develops off the west coast of India. These two currents diverge in the vicinity of Minicoy leading to upwelling in this region. The relatively low saline lighter water seen in the surface layers in the nearby regions can be the Bay of Bengal water possibly carried westward by the North Equatorial Current (Rao *et al.*, 1966). It would be worth mentioning here that this upwelling is also presumed to be due to seasonal variations in wind-induced upwelling (Sen Gupta *et al.*, 1979).

Convergence and divergence zones: From dynamical studies of the Indian Ocean Expedition data during winter one large divergence zone around 71°E and 9°30′N has been inferred and a convergence zone with an axis roughly along 74°E around 8°N has also been found. The distribution of oxygen at 75m depth further confirmed the area and extent of the divergence zone during the winter. A region of convergence has also been observed around 8°N and 71°30′E in the upper 200 m during the southwest monsoon period The divergence zone corresponds to the region of upwelling and the convergence relates to sinking. The divergence zone or upwelling area mentioned above is thus in region west of Minicoy and the sinking or convergence zone in the region east of Minicoy in the open ocean during winter. During the summer the sinking or convergence of waters is found in the region west of Minicoy in the open ocean. Boisvert (1966) has observed that in December the surface water mass (up to 100 m) originates in the Bay of Bengal and flows southward along the east coast of India, rounds off Sri Lanka and moves northward along the west coast of India and also enters the Lakshadweep region.

Environmental features in relation to fishery: The information on the environmental characteristics of the sea around Lakshadweep given above are very interesting and useful from the point of view of the local fishery. It is seen that the sea around these islands are highly productive. The circulatory movements (eddies), the vertical turbulent mixing and wind induced upwelling in the region are contributory to this high productivity. The coral island of Minicoy (8°07′N, 73°18′E) is a major tuna fishing centre in the Indian Ocean (Jones and Kumaran, 1959) and the importance of this region from the point of tuna fishery has been well recognised. The presence of divergence and convergence zones in the open ocean near to Minicoy, the presence of upwelling in the close vicinity of the Minicoy Island, the eddy systems present there, and the presence of the relatively low saline waters

seen in the surface layers during the November–December period contribute to the high productivity of the area. It has been shown that a stable eddy system present close to Barbados Island causes the littoral animals with long pelagic larval stage to be more abundant than in the exposed areas. Similar eddies are present downstream near the Lakshadweep islands, and it may be worthwhile to investigate whether this feature has any bearing on the tuna fishery. The existence of the anticyclonic eddies around these islands in the upper 100 m support a high productivity. The abundance of decapod larvae, including the red prawns observed in this area in plankton hauls is probably a result of these eddies. (Sen Gupta *et al.*, 1979). According to Jones and Kumaran (1959) in the Minicoy area, the tuna fishery is operative from September–April, the peak season being December–March. It is possible that the features mentioned above were observed during late November–December and these may have a considerable impact on the peak tuna catches of this region.

The importance of the sea around Lakshadweep from the point of tuna fishery is well known. The information on the environmental conditions of the waters here are insufficient for a better understanding and exploitation of the fishery. This is particularly noteworthy, since in many areas, in the world, tuna investigations have always been supported by large scale oceanographic studies. It may be mentioned here that one of the most important discoveries in oceanography, namely the Chromwell Current is also associated with systematic investigations for tunas in the Central and Equatorial Pacific by the Pacific Oceanic Fishery Investigations (POFI) group. It is, therefore, necessary, to follow the exact sequence of events for the ultimate correlation between the environmental processes and the tuna fishery of Lakshadweep. This requires more detailed knowledge on the environmental features and the fishery during different seasons of the year for deriving a better correlation.

PRODUCTIVITY OF THE SEAS AROUND LAKSHADWEEP

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The seas around the Lakshadweep and the reef lagoons are of great ecological significance as they influence the fauna and flora associated with the coral reefs and the high sea resources to a great extent. The waters have been found to be highly productive at the primary and secondary levels.

The euphotic zone of the Lakshadweep Sea is almost over 90 m. Hence though the production per unit volume in the surface waters may not be of higher order, the integrated values are high. The unit volume prodution varies from 8 to 34 mgC/m^3/ day with the maximum rates at Minicoy where the skipjack tunas are abundant. The integrated value for the whole water column is of the range of about 300 mgC/m^2/day which is rather high for oceanic waters. The observations made by the scientists of the Central Marine Fisheries Research Institute have also revealed the existence of an oxygen minimum layer of several metres thickness with the upper layer at 150 m which is closely related to the high organic productivity. Besides, it has also been observed that the geostrophic circulation prevailing in this area helps to maintain the highly productive waters around the islands for considerable length of time. The influx of Antarctic bottom water has its influence on the organic productivity (Jayaraman *et al.*, 1960).

Satellite imageries from Landsat and Indian Remote Sensing Satellite and ocean colour sensing from Coastal Zone Colour Scanner (CZCS) of NIMBUS–7 can provide the general level of productivity as well as water masses in the area of Lakshadweep (Silas *et al.*, 1985).

Therefore remote sensing of this region will open up new frontiers in the marine fisheries and help in the proper exploitation and management of tuna and other oceanic resources.

The waters have been found to be highly productive at the secondary level too. The zooplankton washed across the reef from the sea into the lagoons provides a rich source of food for the reef building animals as well as for the communities associated with the reefs. In spite of the importance of the zooplankters in the reef ecology these organisms in the Lakshadweep marine environment have received very little attention. What little information available are due to the works of Gardiner (Ed.) (1906), Silas (1972), Tranter and George (1972), Goswami (1973), Nair and Rao (1973), Madhu Pratap (1977) and Mathew (MS).

Eversince the classical work of Wolfenden (1906) on the copepods of the Lakshadweep and Maldives the zooplankton of the Lakshadweep Sea has received no attention until the work of Silas (1972) on the standing crop of zooplankton and on the Deep Scattering Layer. According to him the estimated monthly mean standing crop of zooplankton varied between 26 and 144 ml per 1000 m^3 of water in the sea around Lakshadweep.

Silas (1972) conducted surveys on bioscattering in the shallower depths off Minicoy, Agatti, Pitti, Kavaratti Kalpeni and Androth islands and off Suhelipar. The surveys indicated definite concentrations of, zooplankton and micronekton in the DSL which evince characteristic vertical migration.

The samples collected by Silas (1972) from the DSL from the vicinity of the islands contained zooplankton groups in the numerical proportion of, copepods (65.1%), ostracods (11%), chaetognaths (8.9%), appendicularians (5.5%), euphausiids and decapods (2.5%) and siphonophores (1.6%).

When considered volumetrically it was the euphausiids, the staple food of the tunas and bill-fishes that dominated over all the other zooplankters. The euphausiid fauna is especially rich in the sea around Lakshadweep. These purely oceanic organisms which form an important constituent in the DSL occur in large quantities even very close to the islands owing to the absence of any freshwater outlets or brackishwaters (Mathew, MS).

Among the euphausiids the most abundant species found were *Thysanopoda monacantha, T. tricuspidata, Euphausia diomedeae, E. sibogae, Nematoscelis gracilis, Stylocheiron armatum* and *S. affine*. Of these the first named two species are relatively larger, growing to about 30 mm in length. On one occasion, 1830 specimens of *T. monacantha* per hour of trawling were caught from the DSL observed near Suhelipar. The other species of euphausiids that occurred in appreciable quantities in the epi-and meso-pelagic zones of the seas around Lakshadweep islands are *T. astylata, T. orientalis, E. pseudogibba, E. tenera, Pseudeuphausia latifrons, N. tenella, Nematobrachion flexipes, S. longicorne, S. suhmi, S. microphthalma, S. abbreviatum* and *S. maximum*. However, there has been no record of catching any of these species from the coral lagoons and atolls.

Pursuing the problems of coral reef nutrition Tranter and George (1972) studied the zooplankton abundance at Kavaratti and Kalpeni atolls during the October–December period in 1968. They observed higher biomass values at surface by night when dense swarms of ostracods swarmed at a rate of 1000 individuals per 1 m^3 of water. The biomass was greatest seaward of the western lagoon of Kavaratti. The biomass, they found, to be depleted enroute from ocean to lagoon. The coral reef commonly nourish from the oceanic plankton.

In April 1971, Goswamy (1973) made studies on the zooplankton of the lagoons and seas of the Lakshadweep. Contrary to the finding by Tranter and George (1972) he obtained high biomass of zooplankton in the lagoon than in the open sea. He got upto 178 ml of zooplankton per 1000 m^3 of water from the lagoon and in the sea it was 58 ml per 1000 m^3 of water. The major groups of zooplankton encountered during the studies were: copepods (52 sp.), chaetognaths (8 sp.), mysids (3 sp.), polychaetes (5 sp.), amphipods (2 sp.), decapods, and fish eggs and larvae. Certain harpacticoid copepods, gammarid amphipods and mysids were found to be endemic to the lagoons.

A specialised study on chaetognaths of the Kavaratti and Kalpeni atolls and of the adjoining sea was carried out during the October–December period of 1968 by Nair and Rao (1973). Thirteen species belonging to four genera namely *Sagitta, Krohnita, Pterosagitta* and *Spadella* were found to be present. In the Kavaratti lagoon an average catch of 1,540 chaetognaths per 1000 m^3 of water were obtained while the number was 31,210 per 1000 m^3 of water from the seaside. At Kalpeni the numbers were 10,680 and 31,750 per 1000 m^3 of water for the lagoon and sea respectively. Thus as far as the chaetognaths were concerned the biomass

was always high on the sea side. The reason for this has been attributed following Tranter and George (1972) to the feeding intensity of the coral polyps and the coral dwelling animal communities.

Madhu Pratap *et al.* (1977) have studied the composition and abundance of various groups and species of zooplankton at Kavaratti, Agatti and Suhelipar atolls and in the seas around Kavaratti and Agatti. They found that higher biomass and diversity occurred in the sea surrounding atolls than in the lagoons. A maximum of 6.2 ml per 10 mts surface haul with a square net of 0.0625 m^2 mouth area was obtained from the sea. While the plankton in the sea averaged to 3.5 ml, in the lagoon it was 1.6 ml per 10 mts haul. This confirmed the finding of Tranter and George (1972) that zooplankton was lost in transit across the reef into the lagoon and is probably utilised by the reef communities.

Madhu Pratap *et al.* (1977) found that among zooplankton the copepods dominated over the others except in Kavaratti lagoon where the planktonic molluscs were abundant forms. Their samples included eight species of siphonophores, five species of chaetognaths, zoea of crab, pagurid, sergestid and caridean larvae, mysids, gastropods, lamellibranchs, pteropods, polychaetes, appendicularians, amphipods, ostracods, salps, doliolids etc. The studies suggested the role of zooplankton in the nutrition of the coral reef community.

The studies so far made have revealed that the coral lagoons and the seas of the Lakshadweep islands are comparatively rich in their zooplankton assemblages. According to Silas (1972) several factors are responsible for the enrichment and subsequent abundance of zooplankton they being, terrigenous products that diffuse or carried by the currents from the islands, the presence of islands in the boundary zones of major oceanographic features, perturbations produced by the islands in adjacent waters and the accumulation of inorganic nutrients by the benthic algae from the passing water. Further studies on the quantitative distribution, seasonal variation and the role of environmental parameters on the occurrence and abundance of zooplankton in general and of various groups in particular are to be made in the lagoons and seas of the Lakshadweep to augment our present knowledge.

EXPLOITED AND POTENTIAL RESOURCES OF TUNAS OF LAKSHADWEEP

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Introduction

Oceanic species of tunas such as skipjack *(Katsuwonus pelamis)* and yellowfin tuna (*Thunnus albacares*) constitute the major tuna resources taken from the Lakshadweep waters from September-October to May every year. They are being exploited from these islands by pole and line fishery with live-baits (Silas and Pillai, 1982). At Minicoy, an organised fishery for tunas is in vogue for a number of years, and from 1960 onwards pole and line fishing has been adopted in the other islands of Amini group with the introduction of mechanised boats. In seventies, the traditional tuna fishing boat ('odums') were replaced by mechanised boats fitted with live-bait tanks. Thus tuna fishing which plays a major role in the economy of the Lakshadweep became popular.

The total tuna catch in the Lakshadweep Is. and the all India total tuna landings during the period 1970–'84 is presented in Fig. 1. It is evident that the total catch has increased considerably from 571 tonnes in 1970 to 4,101 tonnes in 1984. Island-wise tuna catch data and the number of mechanised boats (25' and 30')

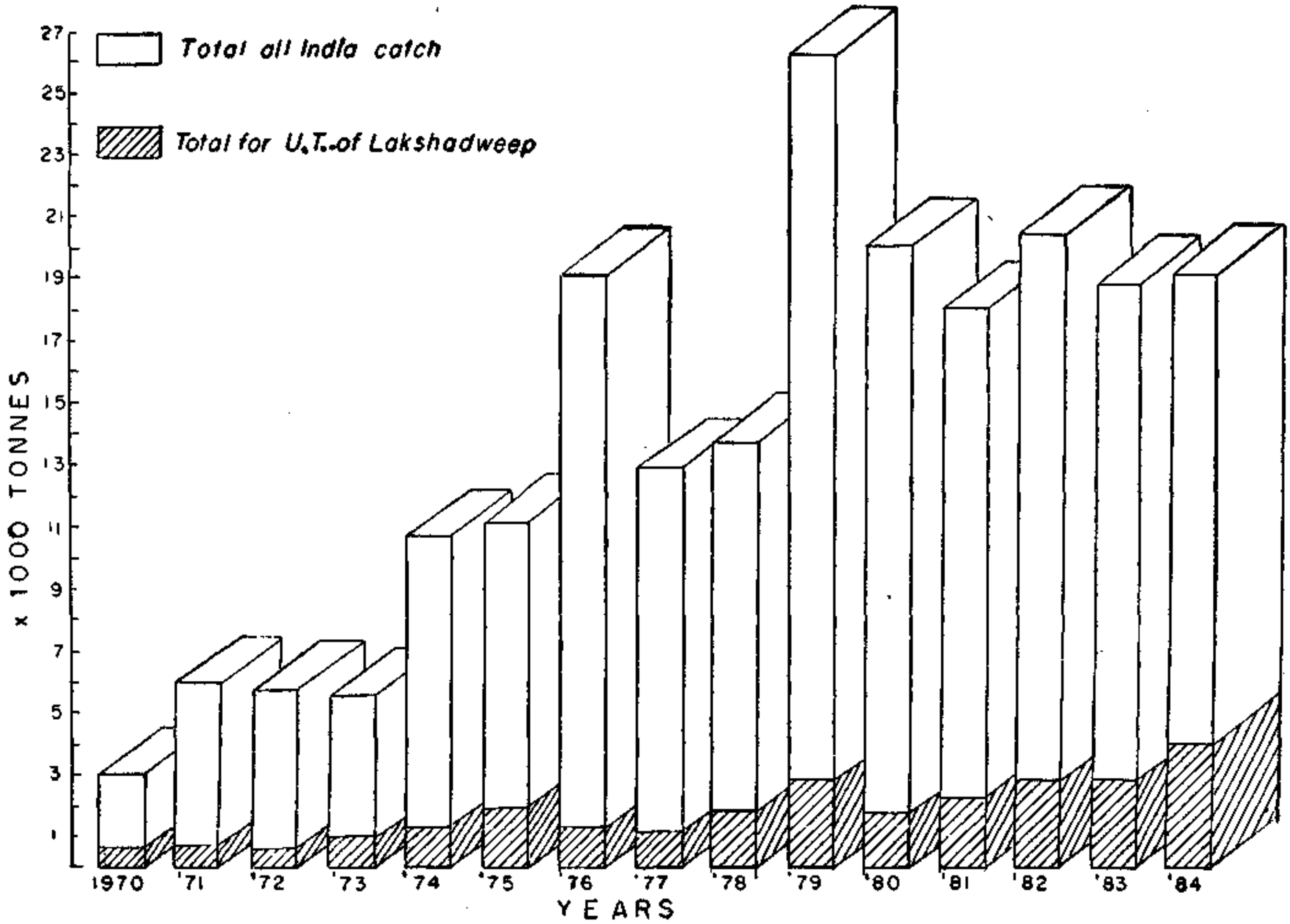

Fig. 1. Total tuna catch in the Lakshadweep and the total all India tuna landings for the years 1970-'84.

available during the period 1978-'83, are presented in Table 1. Increase in the number of mechanised boats in the tuna fishery is evident from 1978 and concomitantly catch has also increased to a considerable extend.

Detailed information on the catch, effort, species composition, biology and population dynamics of tunas are available from the Minicoy Island and hence the information presented here are based on the data collected by CMFRI from this area.

The pole and line fishery for tunas at Minicoy Island has earlier been reported by Hornell (1910), Ellis (1924), Mathew and Ramachandran (1956), Jones (1958, 1960a, 1960b, 1964a, 1964b), Jones and Kumaran (1959), Thomas (1954), Varghese (1971), Puthran & Pillai (1972), Ben-Yami (1980), Silas and Pillai (1982) and Madan Mohan *et al.* (1985). There has been a changing pattern in the pole and line fishery in this island through these years. The traditional tuna boat of Minicoy (*'Mas-odi'*) is now replaced by small mechanised boats equipped with live-bait tanks which has resulted in the improvement of the catches. This increase in catch has not created any problem for disposal due to the demand for the traditionally cured fish *'Mas min'* and also due to tuna canning factory at Minicoy.

Craft and gear

The details of pole and line boat, pole and line gear, the bait fish net and bait fish basket are described by Silas and Pillai (1982).

Operation

Fishermen start from their base by 0600 hrs for live-bait fishing in the lagoon. The number of crew range from 10 to 15. The area of the lagoon from where live-baits have to be fished and the mesh size of the bait-fish

Table 1. *Island-wise and year-wise production (in tonnes) of tuna in Lakshadweep*

Year	Agatti	Amini	Androth	Bitra	Chetlat	Kadmat	Kalpeni	Kava-ratti	Kiltan	Minicoy	Suheli	Annual total tuna landing (mt)
	Name of the Island											
1978	899	64	173	92	36	49	21	211	19	311	—	1875
1979	1314	72	303	118	116	100	62	207	86	415	—	2793
1980	490	46	179	104	33	43	27	150	54	643	—	1759
1981	820	81	196	126	38	37	41	395	24	485	—	2236
1982	550	77	243	345	148	38	63	150	102	427	823	2966
1983	731	53	283	166	96	36	59	164	55	273	1121	3037
Annual Average	801	66	230	159	78	50	45	213	57	426	972	3097
No. of Mechanised fishing boats (25' and 30')												
1978	29	14	16	6	9	12	7	16	9	27	—	145
1979	31	17	21	8	12	14	11	21	12	29	—	177
1980	35	18	24	9	13	14	12	25	13	30	—	194
1981	35	18	24	9	13	14	12	25	13	31	—	223
1982	40	22	29	10	15	14	13	30	16	31	—	223
1983	49	29	33	10	17	16	14	37	22	36	—	263

net to be operated depend on the species of live bait available at that time. Normally by about 0900 hrs sufficient quantity of live bait will be collected. Then they go out of the lagoon scouting for tuna shoals. Once a shoal is sighted it is approached, chummed and fished. If the live-bait fishing, scouting and chumming are quick, they return to the shore by noon with good catch. Then they unload the catch and again go for bait fishing for a second trip. On the other hand, if the fishing is not successful scouting for tuna shoals may continue till dusk and they return to the shore. The remaining live-bait fish will be stored in the bait baskets floated in the lagoon.

Production

The catch of tunas, standard effort and catch per standard effort during 1976–'85 are given in Table 2.

The catch per standard effort was high during the period 1970–'80, and during the subsequent years it fluctuated between 242 to 334 kg. From Table 2 it is evident that the effort has also increased from 1,060 to 2,422, but the C/SE has not indicated any increasing trend.

Table 2. *Catch, SE and catch per standard effort of tunas at Minicoy* 1976 *to* 1984–'85

Year	Catch (tonnes)	SE	C/SE (kg)
1976	312	1603	194
1977	355	1060	335
1978	539	1317	409
1979	509	1145	445
1980	687	1338	514
1981	327	1176	278
1981–'82	321	1241	258
1982–'83	371	1112	334
1983–'84	343	1370	250
1984–'85	569	2422	•235

Biology

Species composition of tuna

Data on pole and line catches indicate that skipjack tuna, *Katsuwonus pelamis* contributed bulk of the tuna catches, while in the troll line catches, always yellowfin tuna, *Thunnus albacares* dominated. During 1980–'81 season *K. pelamis* contributed 78.4% of total tuna catch

followed by 21.31% of yellowfin tuna and stray catches of *Auxis rochei* and *Euthynus affinis* (0.25%). During 1982-'83 season skipjack tuna formed 91.4% followed by yellowfin tuna (8.54%) and *A. rochei* and *E. affinis* (0.06%). In 1983-'84 season skipjack dominated the catch by contributing 84.9% followed by yellowfin tuna (15.0%) and *E. affinis* and *A. rochei* (0.1%). During 1984-'85 season the most abundant tuna was skipjack (93.7%) followed by yellowfin tuna (6.2%), *A. rochei* and *E. affinis* (0.1%).

Size composition of tunas

Studies on the size composition showed that during 1981-'82 season, fork length of the skipjack tuna ranged from 270-669 mm with size group 470 mm to 530 mm dominating in the pole and line catch. For yellowfin tuna the length of fish ranged from 300-1,380 mm while the size group 460-540 mm dominated the catch. During 1982-'83 season the length of *K. pelamis* ranged from 280 - 680 mm while the size group 460 - 570 mm dominated in the catches. For *T. albacares* the length ranged from 250-1,120 mm and the size group 400-550 mm were predominant in the catches. During 1983-'84 season the length of *K. pelamis* ranged from 242 - 680 mm while the size group 460-580 mm dominated. For *T. albacares* the length ranged from 230-1,150 mm while the size group 500-600 mm dominated. During 1984-'85 season the skipjack tuna were taken over a wide range of size from 300-720 mm and the dominant group was at 530-630 mm. For yellowfin tuna the size ranged from 310-1,009 mm and bulk of the catches consisted of fish in the length range of 560-600 mm.

Length-weight relationship of K. pelamis *and* T. albacares

440 specimens of skipjack and 134 specimens of yellowfin tunas were collected from Minicoy fish landing centre and data obtained were analysed. Regression equations for both the species were calculated for males and females separately. Testing for significance difference between regression equations of both the sexes were performed for both species. In both species regression lines for males and females were found coincidental. Therefore data for males and females were pooled together for both species and common regression equations were derived.

For skipjack tuna

$$\text{Log } W = -5.80855 + 3.39301 \text{ Log } L$$

For yellowfin tuna

$$\text{Log } W = -11.036032 + 3.001012 \text{ Log } L$$

Age and growth studies of K. pelamis *and* T. albacares

For skipjack tuna, based on the monthly length-frequency analysis and monthly progression of modes, lengths of 1, 2 and 3 years old skipjack were estimated as 360 mm, 564 mm and 682 mm respectively. By applying Von Bertalanffy's Growth Equation for the one year old skipjack the size observed was 367 mm, for two years old 573 mm, for three years old 690 mm and for four years old 777 mm. The monthly growth rates for four years were as 30.58 mm, 17.16 mm, 9.75 mm and 7.25 mm respectively.

Based on monthly length-frequency analysis the progression of modes length of one and two years old yellowfin were estimated as 500 mm and 780 mm. By applying Von Bertalanffy's Growth Equation, length upto seven years was 506, 769, 952, 1,088, 1,187, 1,259 and 1,311 mm respectively with monthly growth rate for seven years as 42.16 mm, 21.91 mm, 15.25 mm, 11.33 mm, 8.25 mm, 6.00 mm and 4.53 mm respectively.

Spawning biology

One of the important technical approaches to investigate the resource characteristics of oceanic skipjack tuna, *Katsuwonus pelamis* which forms 70 to 90% of the tuna catches of Minicoy, was to study the phases of its life history. The main aspects covered were maturity, sex ratio, spawning season and frequency of spawning and fecundity.

Maturity: For this study data collected during the calendar year 1981 and 1982 were analysed. Data revealed that fishes of all seven stages of maturity were available in the catches at Minicoy. Development of ova to maturity was traced for all the seven stages. The frequency distribution of ova diameter measurements from ripe and spawning ovaries of skipjack revealed that this species spawned more than once in a year at Minicoy.

Sex ratio: Ratio of males to females was found as 1:1.18 for the year 1981 and 1:0.98 for the year 1982. For both the years together, females dominated over males but not very significantly. Monthly variations in sex ratio was observed during both the years.

Spawning: Data on the maturity of skipjack over two successive years were analysed which revealed that fishes of various maturity stages were present in any month of the year. When female fishes were divided into three major categories i.e. immature, maturing and

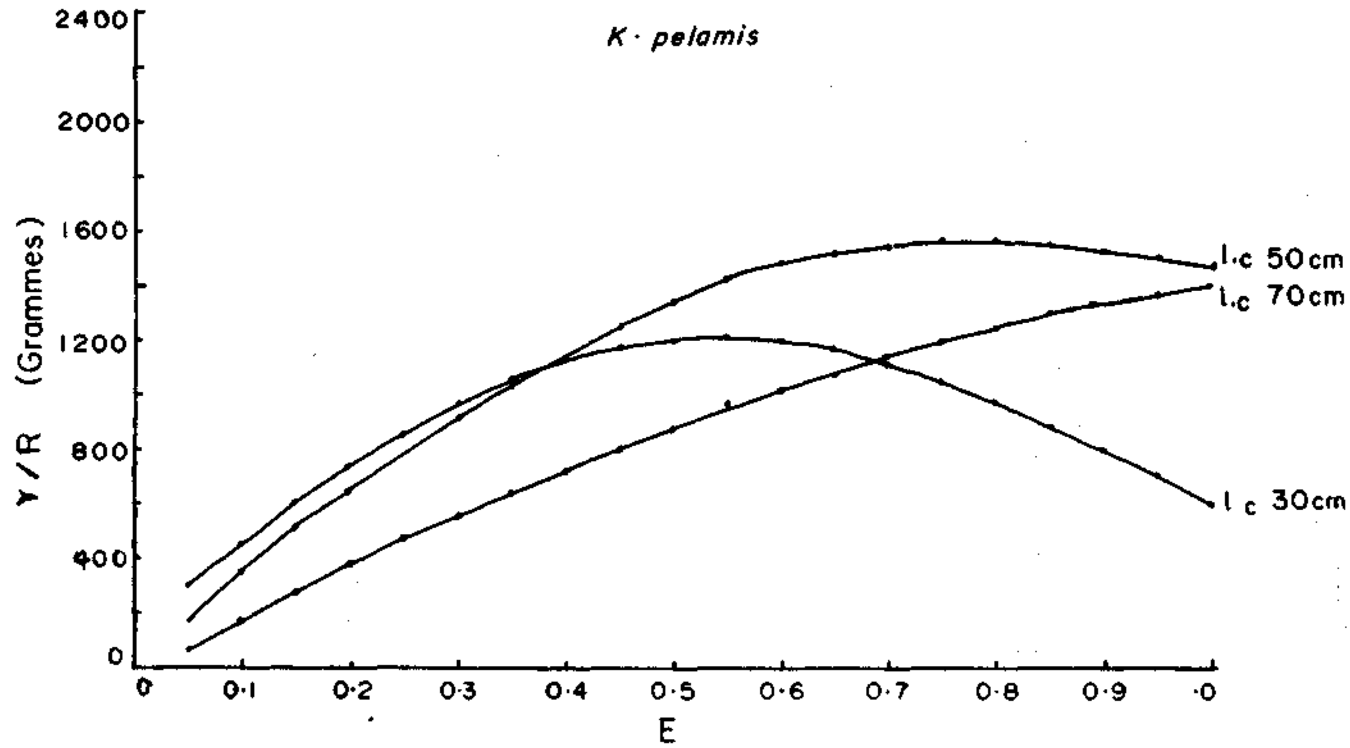

Fig. 2. Yield per recruit of *Katsuwonus pelamis*

as mature, it was seen that mature fish occurred almost throughout the pole and line fishing period. During 1981 peak occurrence of mature fish was from January to May but in 1982 mature fish dominated during all the months except October.

Therefore the occurrence of mature females throughout the pole and line fishing season and the presence of young fishes of about 30 cm during this period, clearly indicates that the skipjack tuna spawns throughout the year in the Minicoy waters.

Fecundity: A total of 23 mature ovaries were examined. Number of mature ova in an ovary ranged from 170,555 to 682,899 when length of the fish ranged from 465 mm to 660 mm. Each fish can produce about one lakh mature ova per kilogram of its body weight. Fecundity of the fish increased with the length and weight of the fish.

Population dynamics of tunas

The values of the different parameters of Von Bertalanffy's Growth Equation for skipjack and yellowfin tunas calculated for age and growth estimations based on the data collected during 1981 and 1982 were used to estimate mortality rates, yield per recruit and present rate of exploitation of both species. For skipjack tuna yield per recruit and present rate of exploitation were calculated as below.

Yield per recruit

Katsuwonus pelamis

The values of different parameters were as below:

W = 16,372 g		M = 0.75
lc = 54 cm		M/K = 1.54
lr = 30 cm		$e^{M(tr - to)}$ = 1.861

For skipjack tuna, calculating Z (Annual mortality rate) as 2.555 and other parameters as given above, the present exploitation ratio calculated was 0.71 based on the equation

$$F/Z = \frac{Z - M}{Z} = \frac{2.555 - 0.75}{2.555}$$

This indicates that the present level of exploitation of skipjack tuna at Minicoy Island is not affecting this species' stock and the capture of this species in the area has not reached the maximum sustainable yield.

E	Y/R	Ep
0.05	179.1	
0.10	349.4	
0.15	510.6	**0.71**
0.20	662.1	
0.25	803.8	
0.30	934.9	
0.35	1055.3	
0.40	1164.4	
0.45	1261.8	
0.50	1347.1	
0.55	1419.9	
0.60	1480.0	
0.65	1526.9	
0.70	1560.6	
0.75	1581.0	
0.80	1588.2	
0.85	1582.6	
0.90	1565.0	
0.95	1536.0	
1.00	1498.5	

Y/R=Yield per recruit, Ep=Present exploitation rate.

Yield per recruit

Thunnus albacares

The values of different parameters were as below:

W_∞	= 49,478 g	M	= 0.49
lc	= 45 cm	M/K	= 1.54
lr	= 30 cm	$e^{M\ (tr - to)}$	= 1.426

Adults of yellowfin tuna are highly migratory and deep dwelling and hence only young ones of about one year age are caught at Minicoy by the pole and line fishing. By calculating Z (Annual mortality rate) as 3.488 and other parameters as above the present exploitation ratio for yellowfin tuna was estimated as 0.86. Expanding the fishing operations to areas beyond the present zone of exploitation would widen the scope for realising higher yields.

Observations on the tuna shoals associated with flotsam in the offshore waters off Minicoy

Types of flotsam objects observed: On most of the occasions flotsam objects were wooden material drifting with sea currents towards Minicoy. Other objects found floating along with tuna shoals were nylon nets, rubber pieces, nylon ropes and plastic pieces.

E	Y/R	Ep
0.05	485.9	
0.10	927.2	
0.15	1323.0	
0.20	1671.9	**0.86**
0.25	1972.7	
0.30	2224.0	
0.35	2425.9	
0.40	2577.3	
0.45	2678.2	
0.50	2728.7	
0.55	2729.7	
0.60	2683.2	
0.65	2590.7	
0.70	2456.6	
0.75	2285.9	
0.80	2085.0	
0.85	1863.3	
0.90	1631.3	
0.95	1401.7	
1.00	1188.9	

Y/R=Yield per recruit, Ep=Present exploitation rate.

Most of the flotsam had some attached algal material and very rarely a few ascidians. Though very few small fishes were found around flotsams, they disappeared from the sight when tuna fishing commenced around flotsam.

Live-bait fishes used: *Chromis* spp. were the main species used as live-bait followed by *Spratelloides delicatulus*. These were used to chum tunas from floating objects to tuna fishing boats. Out of the 75 fishing boats observed during these studies the quantity of live-bait used by only 28 boats could be recorded which was 57.5 kg.

Always more than one fishing boat approach a floating object. The first boat use livet-bait to chum tuna and on most of the occasions it is not necessary for other boats to throw bait since tuna shoals would be already feeding on live-bait thrown by the first boat.

Tuna catches: Totally 26 number of flotsams were observed from September, 1982 to May, 1983. 75 tuna fishing boats approached these shoals and caught 40,886 kg of fishes around them. The maximum catch was recorded from six floatsams during October when 14 fishing boats could catch 13,371.6 kg of fishes.

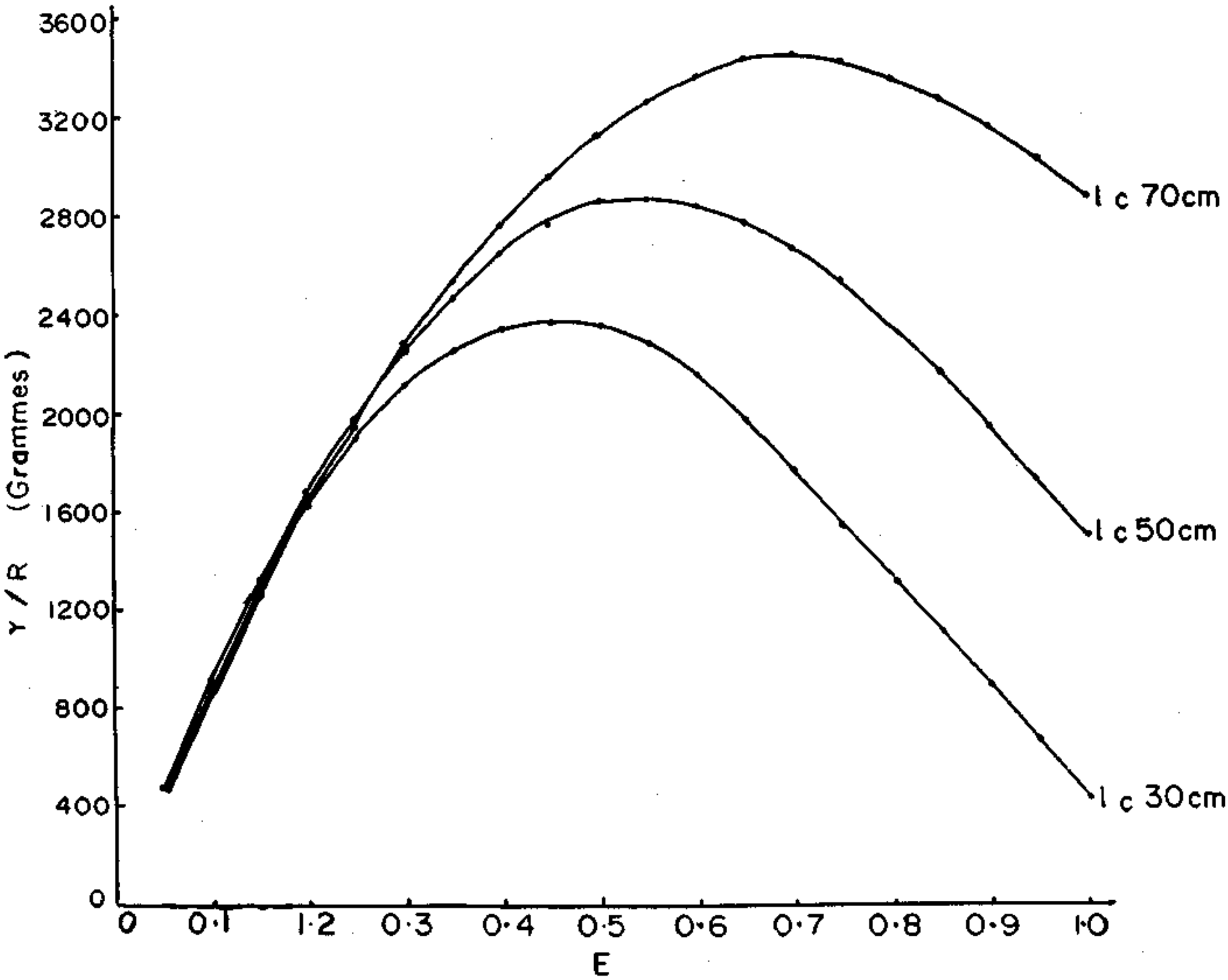

Fig. 3. Yield per recruit of *Thunnus albacares*

Species composition: Speciesewise, the yellowfin tuna *(Thunnus albacares)* dominated the catches and accounted for 18,875.5 kg (46.17%) of the total catches. It was followed by skipjack *(Katsuwonus pelamis)* 11,106.3 kg (27.16%), sharks 7,558 kg (18.48%), *Elagatis bipinnulatus* 2677.8 kg and others.

Catch per unit effort: Average catch per unit of effort for the season as a whole from floatsam associated catches was 908.58 kg. The maximum catch per unit effort was recorded during October, being 1,593.05 kg and was followed by December (1,150.5 kg), September (1,040.33kg), April (780.44kg), May (722.83 kg), November(624.70kg) and the lowest of 507.67kg during January.

It is interesting to note here that average CPUE from floatsam catches was about three times higher than average CPUE for pole and line catches during 1982–'83 tuna fishing season. The reason is the availability of fishes in good concentrations around these floating objects.

Catch per floatsam object: The maximum catch of 3,451.5 kg per float was recorded during December followed by September (3,121 kg), October (2,228.6 kg), April (1,592.10 kg), May (1,445.67 kg), November (890.91 kg) and January (761.50 kg). The average catch per floatsam object for the season as a whole was 1,572.54 kg.

During 1984–'85 season tuna fishing associated with flotsam was noted to be five times, and wooden pieces mostly constituted the flotsam. It was observed that both *K. pelamis* and *T. albacares* along with *Coryphaena* sp.

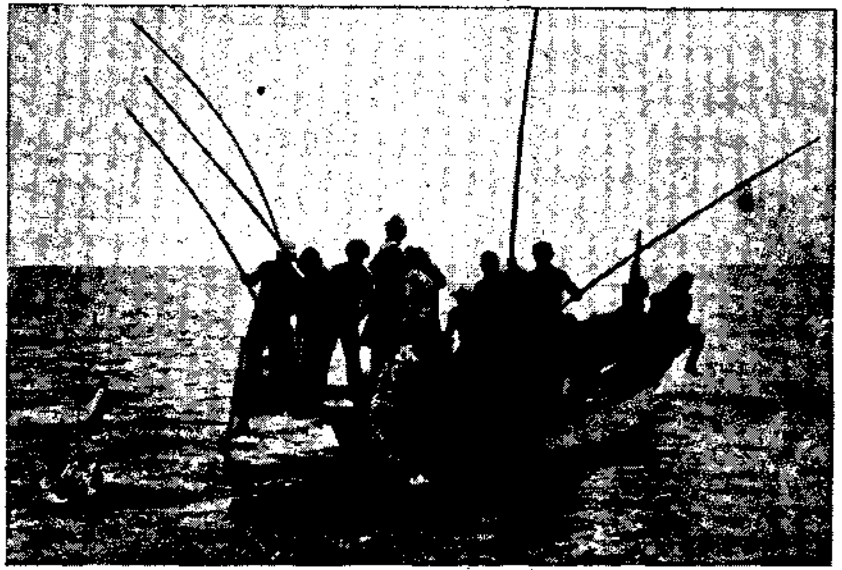

Fig. 4. Pole and line fishing for tunas around Minicoy.

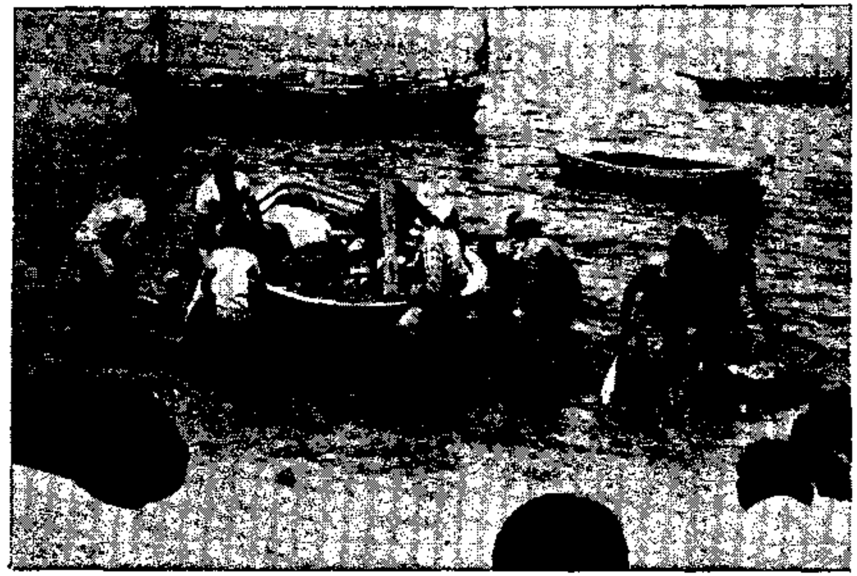

Fig. 5. Tuna landings.

Fig. 6. A catch of skipjack being taken ashore.

Fig. 7. Regular biological studies are needed for proper management of fishery.


Fig. 8. Tunas being gutted at the landing centre.

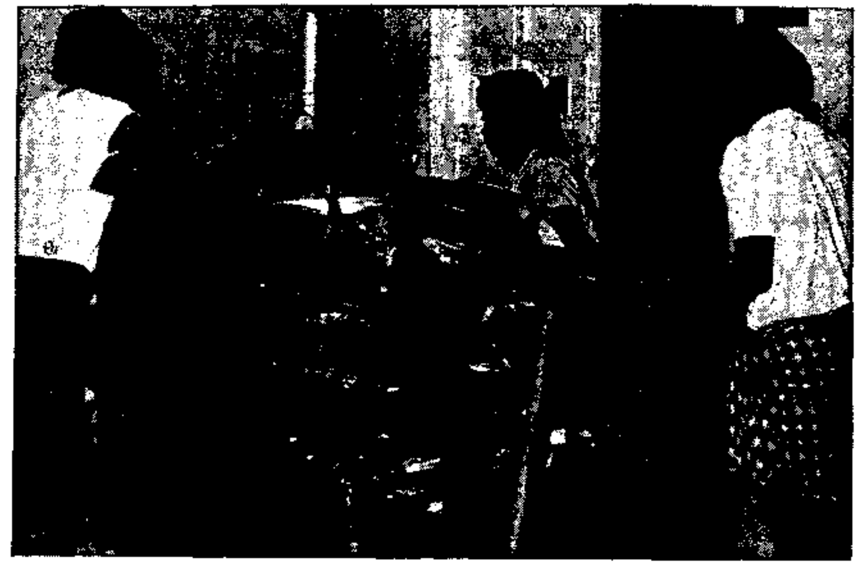
Fig. 9. Tunas are taken for processing in the factory


Fig. 10. Tuna processing in progress.


Fig. 11. Canning tunas at a factory.

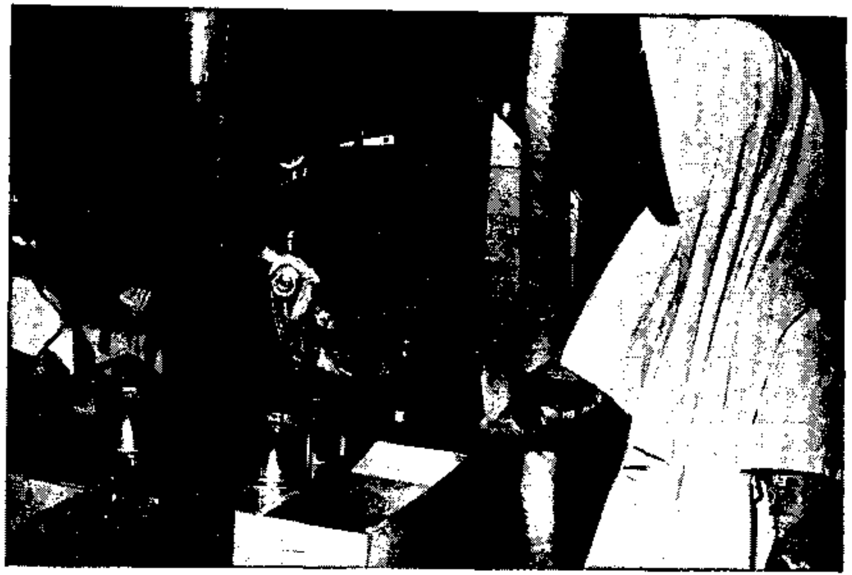

Fig. 12. Mechanical brine filling unit in operation.

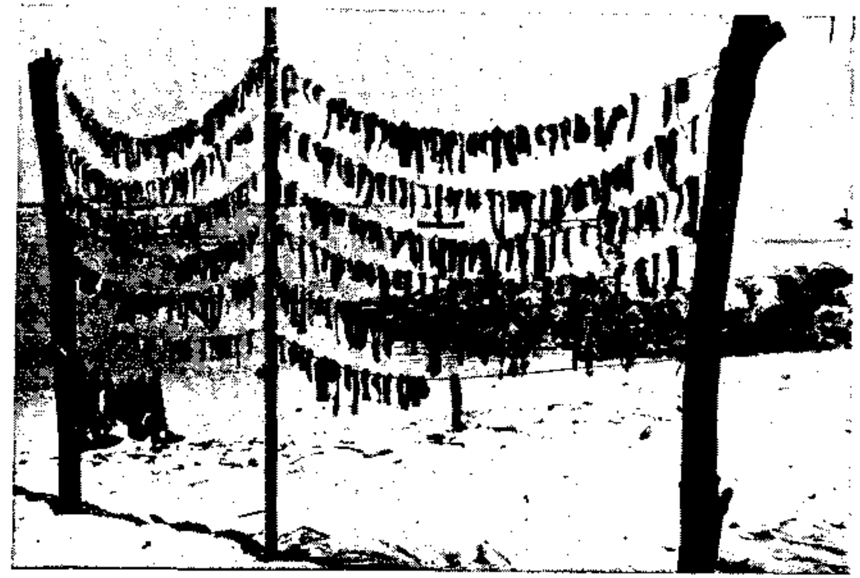

Fig. 13. Tuna being dried in the open air.

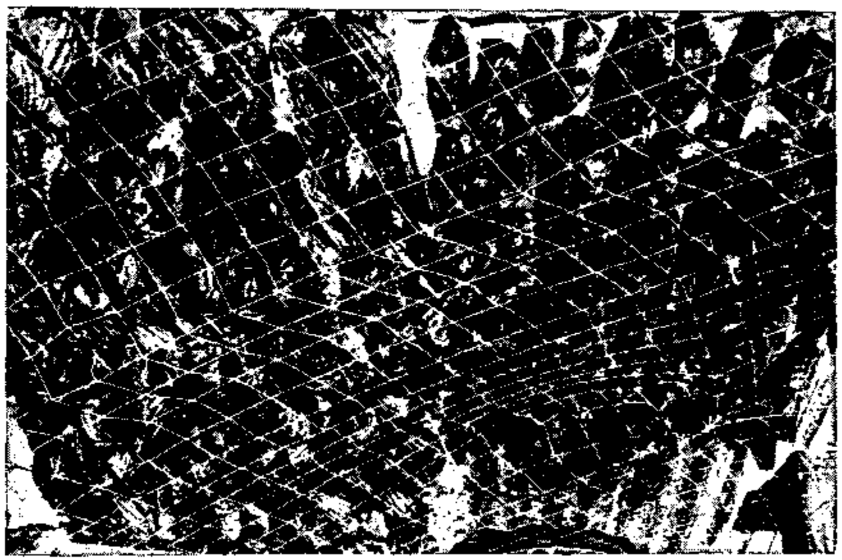

Fig. 14. *'Masmin'* – the cured and dried product of tuna.

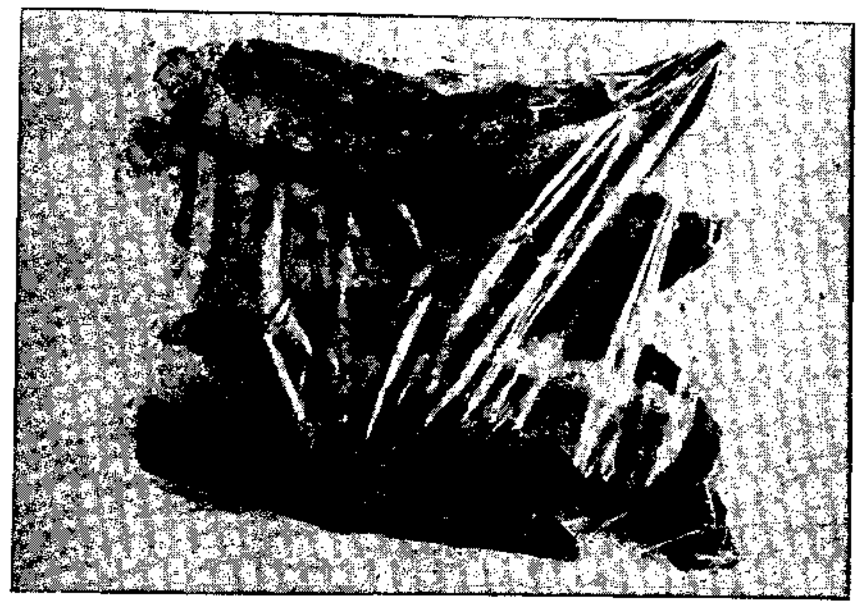

Fig. 15. *'Masmin'* – ready for marketing.

and *Elagatis bipinnulatus* were taken. The catch per boat of fishing associated with the flotsam ranged from 256.7 kg to 1,159.9 kg and averaged to 580.2 kg. An interesting aspect noted in this type of fishing was that skipjack tuna associated with floatsam ranged from 320–570 mm and yellowfin tuna 310–560 mm.

Strategies for future development

George *et al.* (1977) estimated a projected exploitation potential of 50,000 tonnes of tuna from Lakshadweep. Silas and Pillai (1985) proposed that by 2000 AD the total production of skipjack and young yellowfin tuna should achieve a commercial production target of 150,000 tonnes.

The introduction of larger pole and line boats recommended by Silas and Pillai (1982) is particularly significant to the Lakshadweep islands. The fishermen are not able to go in search of tuna shoals outside the vicinity of the islands. For undertaking prolonged fishing trips and improvements in operational techniques, navigational aids and catch storage facilities will be of great advantage and would increase tuna production. In this connection it is worth mentioning that a Radio Beacon Station (320 KHZ) and a Radar transponder Beacon (RACON) (9300 to 9500 MHZ) are working at Minicoy light house. These navigational aids can be made use of by the fishermen with the help of simple Radio Direction Finder/rader equipments.

The scarcity of live-baits is no doubt a limiting factor for the expansion of the fishery. Research inventory on live-bait fishes including the assessment of the availability and abundance of live-bait resources in space and time, along with large scale culture of suitable live-bait fishes for supplying to the fishermen deserve special attention. In this context the proper management and conservation of the coral reef habitat which sustains the bait fishes are of prime importance.

The above aspects along with adequate improvements in post-harvest technology and marketing can go a long way in the development of pole and line tuna fishery at Minicoy Island.

EXPLOITED AND POTENTIAL RESOURCES OF LIVE-BAIT FISHES OF LAKSHADWEEP

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Introduction

Jones (1958) described tuna live-bait fishery of Minicoy in detail based on firsthand information collected by him during the voyage of M. V. *KALAVA* of the erstwhile Indo-Norwegian Project. Jones (1964) described 45 species of live-bait fishes belonging to 30 genera and 19 families which included all the major bait fishes, made a key for their identification and graded them according to their survival in captivity and chumming quality. A study of the monthly fluctuations in the occurrence of major tuna live-baits of Minicoy during 1960–'61 was carried out by Thomas (1964b). Silas and Pillai (1982) described in detail the live-bait for pole and line fishery and their fishing techniques, floating receivers and transportation and culture of bait fishes. Madan Mohan and Kunhi Koya (1986c) studied the biology of live-bait fishes *Spratelloides delicatulus* and *S. japonicus*.

FLUCTUATIONS IN LIVE-BAIT FISH CATCH

Fishermen of Minicoy Island do not maintain any record of the quantity of live-bait used in a particular tuna fishing season. They generally complain about the regular decline in the live-bait fish catches. To ascertain whether really live-bait catches are declining year after year, live-bait catch data (in kg) were collected during 1981–'82, 1983–'84 and 1984–'85 fishing seasons.

Only 124 kg of live-bait fishes were caught during November, 1981 which was the lowest catch for the tuna fishing season as a whole. The maximum catch of 803 kg was recorded during March, 1982 followed by February (795 kg), April (404 kg), January (362 kg) and December, 1981 with 308.65 kg. It can be seen that there was gradual increase in live-bait catches from November to March, 1982.

During 1983–'84 tuna fishing season, lowest catches of live-bait were recorded in March, 1984; being 310.5 kg. Maximum catches of live-bait were recorded in January (833 kg) followed by December (679.5 kg), November (559.5 kg), April (476.5 kg) and February (364.4 kg). Though live-bait catches increased from November to January, it declined in February and March and recovered to some extent in April.

During 1984–'85 season, maximum catches were recorded during March (1039.5 kg). The lowest catch was recorded during May (281.5 kg). During the other months the catch fluctuated between 333.5 kg and 909.5 kg.

Fishing effort: During 1981-'82 season 885 boat trips were made for collecting live-bait. While minimum number of boat trips were recorded during November (80 trips), maximum of 260 trips were recorded during February followed by March (164 trips), December (153 trips), January (147 trips) and April (81 trips). The live-bait catches improved with the increase in effort in some months, but in other months namely March and April less number of boat trips provided good quantity of live-bait.

During 1983-'84 season a total of 1,268 boat trips were made. Minimum number of boat trips were recorded during April; being 173, while maximum of 279 were recorded in January followed by November (241 trips), December (206 trips), February (191 trips) and March (178 trips). Monthly effort showed gradual increase from November to January and then declined gradually from February to April, 1984.

SPECIES COMPOSITION OF LIVE-BAIT FISHES

Lepidozygus tapeinosoma which used to be the main live-bait fish during tuna fishing season was not available at all during the period under study. During 1981–'82 seasons *Spratelloides delicatulus* dominated among the live-bait catches, contributing to 64.16% of the total catches. This was followed by *Archamia lineolatus* 22.23%, *S. japonicus* 9.40%, *Chromis caeruleus* 2.34% and *Caesio caerulaureus* 1.87%. During all the months of the season blue sprat, *Spratelloides delicatulus* ranked highest in availability among all the live-bait fishes. *Archamia lineolatus* was available though in less quantities than blue sprat during all the months of the season. *S. japonicus* and *Chromis caeruleus* were also collected of which the former was available in good quantity during January and February.

During 1983-'84 season, catches of *Spratelloides delicatulus* declined. Though this species again dominated the live-bait catches, it contributed only 32.68% of the total catches. This was followed by *Archamia lineolatus* (30.56%), *S. japonicus* (12.28%), *Caesio chrysozona* (8.24%), *Chromis caeruleus* (6.81%), *Pranesus pinguis* (6.26%), *Gymnocaesio argenteus* (2.56%) and *Caesio pisang* (0.62%).

As is clear from the above description the live-bait catches improved a little during 1983–'84 season in comparison with that of 1981–'82 season. While 2,798.65 kg of live-bait fish were caught during 1981–'82 season, it was 3,223.5 kg during 1983–'84 season with an increase of 43.28%. Catch per unit of effort declined from 3.16 kg in former season to 2.54 kg in 1983–'84 season. During 1984–'85 season, a total of 5,595.2 kg of live-bait fishes were caught. During 1981–'82 season, *Spratelloides delicatulus* formed the bulk of the live-bait catches, contributing 64.16% of the total catches. Other species which were caught in good percentage were *Archamia lineolatus* and *S. japonicus*. But during 1983–'84 season *S. delicatulus* and *Archamia lineolatus* contributed almost equally with 32.68% and 30.56% respectively. Other species which supported live-bait fishery were *S. japonicus* (12.28%), *Caesio chrysozona* (8.24%), *Chromis caeruleus* (6.80%) and *Pranesus pinguis* (6.26%).

Caesio chrysozona, Pranesus pinguis and *Gymnocaesio argenteus* which contributed to the betterment of the live-bait catches during 1983–'84 were not caught during 1981–'82 season at all. Since major live-bait fishes were not available and could not meet the bait fish demand during 1983-'84 season, about 550 kg of *Caesio chrysozona, Pranesus pinguis* and *Gymnocaesio argenteus* together were caught and used as live-bait.

During 1984–'85 season, a total of 12 species were recorded of which *S. japonicus* constituted 36.1%, *Caesio caerulaureus* 18.5%, and *C. chrysozona* 12.2% followed by other species (Table 1).

Table 1. *Species composition of tuna live-bait at Minicoy during* 1981–'82, 1983–'84 *and* 1984–'85 *seasons (Kg)*

Species	1981–'82	1983–'84	1984–'85
1. *Spratelloides delicatulus*	1,795.65	1,053.5	2,019.0
2. *S. japonicus*	263.00	395.0	435.0
3. *Archamia lineolatus*	622.00	985.0	—
4. *Chromis caeruleus*	65.50	—	119.1
5. *C. ternatensis*			41.5
6. *Caesio caerulaureus*	52.50	219.0	1,031.9
7. *C. chrysozona*		265.5	722.1
8. *C. pisang*		20.0	
9. *Gymnocaesio argenteus*		82.5	683.9
10. *Lepidozygus tapeinosoma*			26.0
11. *Apogon sangiensis*			118.7
12. *Rhabdamia gracilis*			63.0
13. *Archamia fucata*			98.6
14. *Dussumieria hasselti*			124.0
15. *Pranesus pinguis*		202.0	

OBSERVATIONS ON THE HABITS AND HABITATS OF TUNA LIVE-BAIT FISHES

Fishermen of Minicoy fully depend for their live-bait fish requirements on the lagoon which provides them a variety of fishes. It is a well known fact that at Minicoy some of the live-bait fishes appear in the lagoon all of a sudden, remain there for some days and then disappear. Some of the live-bait fishes reside inside the lagoon, while others enter the lagoon and support the fishery during tuna fishing season. Therefore, observations were made on the different habitats at the time of their availability in the lagoon.

Sprats

Spratelloides delicatulus: This species is locally known as 'Hodeli'. It is found in scattered shoals near the inner reef area at Ragandi point in the western part of the lagoon. It can easily be found on the shoal sand and coral flats nearthe clear and moving water and in shallow water area inside the fringing reef. It enters the Minicoy lagoon during the southwest monsoon and are fished during the tuna season. Only young and immature fish are caught and used as live-bait. Mature specimens in stray numbers can be caught from the coastal area of the lagoon.

S. japonicus: This species is locally known as 'Rehi' at Minicoy. It is found in the deeper part of the lagoon north of Ragandi point and are found associated with the corals. During high tide, this species gathers on the top of the coral heads but during low tide it moves to deeper waters away from the corals.

Apogonids

These are locally known as 'Bodi'. *Archamia lineolatus* accounts for more than 90% of the *Apogon* catches at Minicoy. This species lives around coral heads, mostly forming thick layer little away from the corals. They are found motionless in the deeper waters of Minicoy lagoon but whenever they are disturbed at the time of live-bait catching, they move for shelter among coral branches. These are available in the deeper waters in the central and northern part of the lagoon.

Pomacentrids

Few years back, *Lepidozygus tapeinosoma* (locally known as 'Bureki') used to enter Minicoy lagoon from December onwards. It was the most important pomacentrid which used to rank first in availability among all the bait fishes. But from 1981–'82 tuna fishing season onwards this species was not available. *Chromis caeruleus* (locally known as 'Nelamahi') which is now the major pomacentrid caught from the lagoon, is found closely associated with the corals in the southern part of the Minicoy lagoon and also in the deeper part of the lagoon.

Some other pomacentrids are also collected from near the coral colonies of the deeper part of the lagoon. They include *Dascyllus aruanus, Pomacentrus pavo, Abudefduf biocellatus* and *Abudefduf* spp. These species are available only as stray specimens along with the major live-bait fishes.

Caesio spp.

These are locally known as 'Mugurang'. They are found in the deeper area of the northern part of Minicoy lagoon, crevices and small caves of shallow reef area. They are caught during the latter half of the tuna fishing season from the Kodi point area and outer part of the lagoon and northern side of Ragandi point. Their occurrence is very erratic and every year one or the other species occur. For example *Caesio caerulaureus* was available during 1981–'82 season in good numbers but during 1983–'84 season *Caesio chrysozona* occurred in good quantity.

Atherina spp.

These are locally known as 'Fitham'. Two species are common at present, namely *Prenesus pinguis*

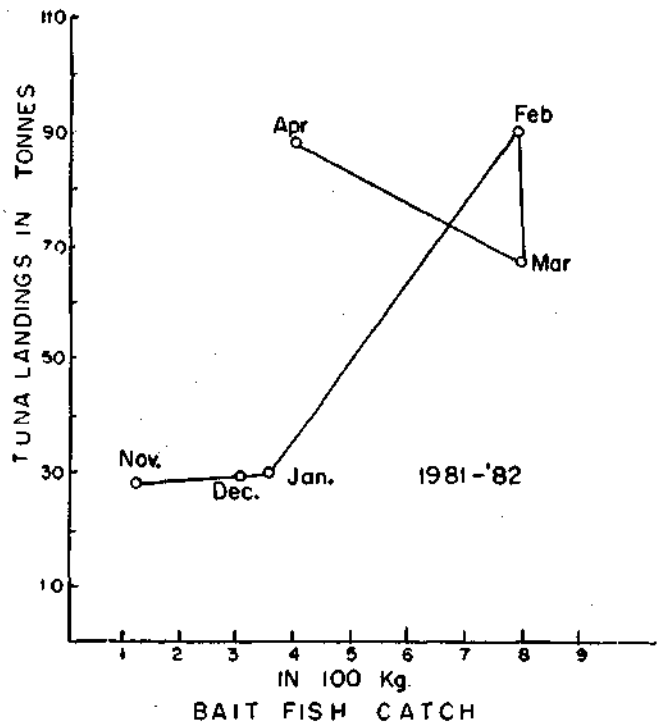

Fig. 1. Relationship between bait-fish catch and tuna landings at Minicoy, 1981-'82.

and *Stenatherina tammincki* out of which the former formed the bulk of the catch. These are found near lagoon shore area specially where algal blooms occur. These are seen swimming near the Minicoy jetty and in a little deeper part of the lagoon. *Atherina* spp. were caught in good percentage and used as live-bait during 1983–'84 season.

Other live-bait fishes

Two species of mullets, namely *Crenimugil crenilabis* and *Velamugil seheli* are found along sandy beach area. Usually *Atherina* and mullets are found together. Some of the parrot fishes like *Helichoeres* spp. juveniles of *Thalassoma* spp. are found associated with corals in shallow water area. They are caught and used as bait during the end of the tuna fishing season.

BIOLOGY OF LIVE-BAIT FISHES AT MINICOY

While collecting data on live-bait fish catches at Minicoy during 1981 to 1984, it was felt that investigation on the biology of major live-bait fishes is of prime importance. Biological studies on the length-frequency, age and growth, sex and maturity, and feeding were carried out on *Spratelloides delicatulus*, *S. japonicus* and *Pranesus pinguis*.

Spratelloides delicatulus: Studies on this species are based on material collected during 1981–'82. Total length of the individual fish ranged between 18 and 59 mm. Based on the length-frequency studies, the length of the one year old fish was estimated to be 46 mm. Since bigger specimens of more than 59 mm long were not available during the year as a whole, it can be stated that fish are available upto 1 + year age.

Specimens with six stages of maturity were recorded during the studies. Spent specimens were not available. Ripe group of ova ranged in diameter from 0.47 mm to 0.71 mm with mode at 0.56 mm. The species spawn during southwest monsoon season which may extend upto December and because of this young fishes are available from October to April. Sex ratio of males to females was found to be 1:0.79. The fish spawn more than once in a spawning season. Number of mature ova in an ovary ranged from 286 to 1,005 when 15 ripe ovaries were examined.

The food of this species was composed mainly of crustaceans which were represented by post larvae of decapods, copepods mainly herpacticoides and calanoides, mysids, gammarids, fish eggs and algal filaments.

S. japonicus: Since this species is available usually for a few months only during the tuna fishing season

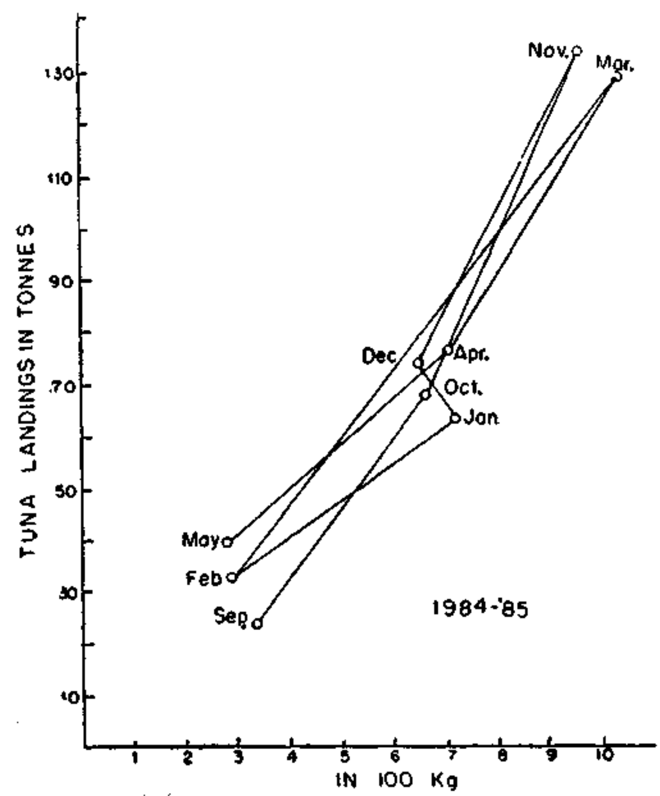

Fig. 2. Relationship between bait-fish catch and tuna landings at Minicoy, 1984–'85.

at Minicoy, a few samples from December, 1981 to March, 1982 were collected and studied.

Total length of the individual fish ranged between 35 and 60 mm. The length data are available for a few months only. But since they resemble *S. delicatulus,* in growth pattern, it is estimated that *S. japonicus* also will be about 46 mm long when it becomes one year old.

Six maturity stages in males and females were identified. Spent specimens were not available. Ripe ova ranged in diameter between 0.38 mm to 0.56 mm with mode at 0.42 mm. Since mature ovary contains three types of ova namely immature, maturing and mature, it can be stated that fish may spawn more than once in a spawning season. Number of mature ova in a mature ovary ranged from 381 to 1,181. Ratio of males to females was found to be 1:0.71.

Pranesus pinguis: This species is used as live-bait generally towards the end of the tuna fishing season. It was collected from the shore area of lagoon for biological investigations. A total of about 1,325 specimens were collected and biological parameters studied.

Total length of the individual fish ranged between 12 mm to 102 mm. Young fishes of about 40 mm in length were available in the samples throughout the year.

Fishes of seven stages of maturity were available; sometimes in one sample itself. During both the years indeterminates made bulk of the specimens examined. Since mature fishes are available along with spent specimens and indeterminate young fishes throughout the year, it can be concluded that *Pranesus pinguis* spawns throughout the year in the Minicoy lagoon itself.

This species is very hardy during transportation and is supposed to be the second best live-bait in Hawaiian islands in Pacific Ocean. But at Minicoy this is used as live-bait when other major live-bait fish are not available. During 1983–'84 season a good amount of this species was used as live-bait.

STUDIES ON THE COMPARATIVE EFFICIENCY OF LIVE-BAIT FISHES

Different fish species associated with corals are used as live-bait at Minicoy. Whichever species is available in good numbers are made use of as live-bait. But only a few of them are considered superior for pole and line operations. A live-bait fish can be more successful on one occasion in a particular area than at others. Therefore based on species-wise live-bait catch and tuna catch data, relative effectiveness of major live-bait fishes was studied during 1981–'82 and 1984–'85 seasons.

Since *Spratelloides delicatulus* formed bulk of the live-bait fish catches with reasonably good average tuna catch per unit of live-bait for the season, it was taken as standard bait to work out the relative effectiveness of other live-bait fishes. Average CPUB of other individual species was divided by the average CPUB of *Spratelloides delicatulus* for this purpose. Relative efficiency of *Archamia lineolatus* was calculated as 1.38, *S. japonicus* 1.53, *Chromis caeruleus* 0.49 and for *Caesio caerulaureus* 0.85.

For *Spratelloides delicatulus* CPUB ranged from 39 kg to 76.4 kg with an average of 62.53 kg for two seasons. For *Archamia lineolatus* CPUB varied from 55 kg to 239 kg with an average of 86.3 kg for the two seasons. For *S. japonicus* it ranged from 41 kg to 400 kg with an average of 95.57 kg. For *Chromis caeruleus* it ranged from 23 kg to 116 kg with average of 31 kg. For *Caesio caerulaureus* CPUB ranged from 14 kg to 64 kg with an average of 53.10 kg.

But there are some factors which can effect tuna catch per unit of bait such as size and species of tuna caught, number of men fishing, size and number of fish per one kilogram of live-bait, relative abundance of tunas and above all response of tunas to live-bait fishes.

Though *Spratelloides japonicus* proved to be the most efficienct live-bait fish during 1981–'82 season followed by *Archamia lineolatus*, the former species contributed only 9.40% to the total live-bait fish catches and latter 22.23%. *Spratelloides delicatulus* with CPUB of the 62.53 kg also proved good in efficiency and it contributed 64.16% of the total live-bait catches and was available to tuna fishing boats during all the months of 1981–'82 season.

STUDIES ON CORRELATION AMONG LUNAR CYCLE, LIVE-BAIT AND TUNA CATCHES AT MINICOY

It is believed at Minicoy by the local fishermen that some live-bait fishes appear in the lagoon during certain phases of the moon and after that live-bait catches generally show decreasing trend. There was no record of

Fig. 3. *Spratelloides delicatulus*

Fig. 4. *Rhabdamia gracilis*

Fig. 5. *Apogon sangiensis*

Fig. 6. *Gymnocaesio argenteus*

live-bait fish landings at Minicoy prior to 1981. This study was undertaken during 1983–'84 season to see whether moon phases are really playing an important role in the availability of live-bait fishes in sufficient quantities at Minicoy.

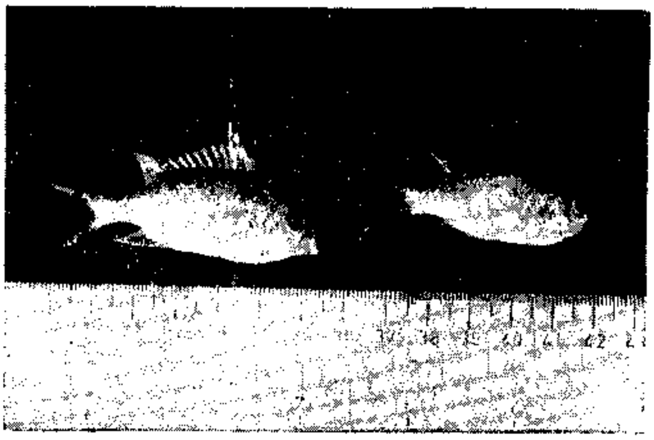

Fig. 7. *Chromis caeruleus*

By this study, the dependence of live-bait fish and tuna catches on the four phases of moon namely new moon, first quarter, full moon and last quarter during 1983–'84 tuna fishing season has been demonstrated. Out of the six months of fishing season, live-bait fish catches were higher during new moon phase in four months but when considered for the whole season, the live-bait catches and tuna catches were greatest during new moon phase and lowest in last quarter. Tuna catches per kilogram of bait fish were found highest during the last quarter and lowest during new moon phase. Effort for live-bait fishing and tuna fishing, and catch per unit of effort of live-bait fishes and tunas were highest during new moon phase and lowest in the last quarter.

LIVE-BAIT FISH REARING EXPERIMENTS

At Minicoy, specimens of *Chromis caeruleus* were collected from the southern part of the lagoon and were brought to Research Centre laboratory for rearing experiments. They were kept in plastic aquarium tanks and were reared for about three months by providing them supplementary food. They were fed by crab body parts, fish flesh and occasionally zooplankton.

Since the catch of *Chromis* sp. is diminishing year after year, there is an urgent need to protect this bait fish resource by their large scale production. The survival of this species in captivity has opened up the way for the planning of its large scale rearing.

The relationship between tuna catch and live-bait fish landings during the period 1981–'82 and 1984–'85 are presented in figures 1 and 2. It is very clear from the figures that a positive relationship exists between the total landings of tunas and live-bait fish catch.

PRESENT STATUS OF LIVE-BAIT FISHERY IN MINICOY

Pillai (1983 and 1985) described in detail the ecological crisis in the Minicoy lagoon.

There is a general feeling among the fishermen of Minicoy that the live-baits are not as plenty at present as they used to be in the past. The condition at the other islands is not fully realised. To obtain the views of a few well experienced fishermen, the CMFRI interviewed them and their opinions were taken into consideration, as a prelude to an attempt to find a scientific interpretation of the problem.

It is rather difficult at this stage to find, figure-wise, any decline in the live-bait catches at Minicoy or at other islands in the recent past due to non-availability of much needed quantitative data over the span of many years. Such data collected by the CMFRI at Minicoy during the fishing season 1981–'82, 1983–'84 and 1984–'85 show that the catches of live-baits were in the order of 2,799 kg, 3,224 kg and 4,270 kg respectively. These catches were mainly sustained by *Spratelloides delicatulus* (64.2%), *S. japonicus* (9.4%), *Archamia lineolatus* (22.2%) and *Chromis caeruleus* (2.3%) in 1981–'82 season; by *S. delicatulus* (32.7%), *A. lineolatus* (30.6%), *S. japonicus* (12.3%) *Caesio chrysozona*

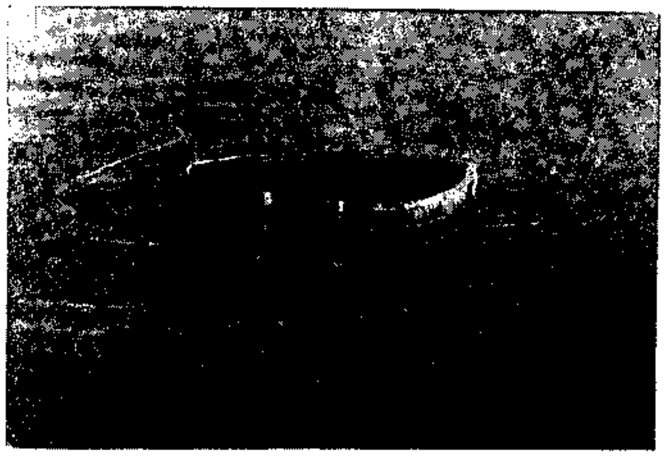

Fig. 8. Floating basket for tuna live-baits

(8.2%), *Caesio caerulaureus* (6.8%), *Pranesus pinguis* (6.3%) and *Gymnocaesio argenteus* (2.6%) in 1983–'84 season and by *S. delicatulus* (36.1%), *C. caerulaureus* (18.5%), *C. chrysozona* (12.9%), *G. argenteus* (12.2%) and *S. japonicus* (7.8%) in 1984–'85 season. However,

Fig. 9. Tuna live bait basket

the fact remains that the demand for live-baits now-a-days exceeds the fishable stock in the atoll regions. At least, three major reasons can probably be attributed to this shortage.

(a) *Environmental deterioration:* This has been dealt with in detail in another article in this issue by C. S. Gopinadha Pillai and Madan Mohan (P. 33).

(b) *Fluctuations in the seasonal recruitment of migrant bait fishes:* The recruitment of live-bait fishes to a small geographic area like Minicoy and other islands as well involves an element of chance mostly controlled by the meteorological conditions. For the last three or four years some of the important live-baits such as *Lepidozygus tapeinosoma* which was considered as much prefered and abundant live-bait in the earlier period (Jones, 1964 a and Thomas, 1964 b), have not entered the lagoon in any appreciable quantities. This, along with the seasonal fluctuations in the recruitment of the other migrant species belonging to *Spratelloides* and *Caesio* as evident from the catches of the bait fishes, form another reason for the recent probable paucity of live-baits. The migratory forms have exerted much pressure on the available stocks of resident forms. It is also probable that the deterioration of the habitat is not conducive for the proper survival of the new recruits of the resident species.

(c) *Demand exceeds available stock:* A third reason which is of much significance on the reported dwindling of live-baits seems to be over exploitation of the resources consequent on the introduction of mechanised vessels in pole and line tuna fishery in most of the inhabited islands of Lakshadweep. This fleet which consisted of nine boats in 1963 has increased to 94 boats in 1973 and to 263 in 1983. This has resulted in the increase in the production of tuna by the pole and line fishery from about 566 tonnes in 1963 to 1,020 tonnes in 1973 and to a record production of 3,037 tonnes in 1983. There is, thus, certainly a greater demand for the live-baits than in the past; and the fishermen exploit the available resident species to the possible level. This is very clearly observed in the case of *Chromis caeruleus,* a species which was very dominant throughout the lagoon of Minicoy till the beginning of 1980 started dwindling thereafter. Similar situation probably prevails at Agatti, Androth, Bitra, Kavaratti and Suheli as could be judged by the increased tuna production by the mechanised pole and line fishery.

The cumulative effect of these, is an apparent shortage of live-baits not only at Minicoy but probably also at the other islands of Lakshadweep. It is to be watched whether the situation will improve by the increased recruitment of the non-resident migratory species. The chances of resident species showing improvement appear to be very little, because of the deterioration of the environment caused by human interference.

Errata based on subsequent communication

1. Page 27, Table 1. The species name *Archamia lineolatus* may be deleted.
2. In the same Table the catch details given against *Archamia lineolatus* are referable to *Archamia fucata.*
3. Page 27, column 1, para. 2, line 2. 'Hodeli' may be read as 'Hondeli'.
4. Page 28, column 1, line 1, *Stenatherina tammincki* may be read as *Stenatherina temmincki.*
5. Throughout the article *Archamia lineolatus* may be read as *Archamia fucata.*

ECOLOGICAL STRESS IN MINICOY LAGOON AND IT'S IMPACT ON TUNA LIVE-BAITS

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Central Marine Fisheries Research Institute, Cochin

Introduction

Pioneering works on the faunal composition and exploitation of tuna live-baits of Lakshadweep, especially of Minicoy Island are those of Jones (1958, 1960a, 1960b, 1964a) Jones and Kumaran (1980) and Thomas (1964b). subsequently Pillai (1971a, 1971b, 1983 and 1985) and Nair and Pillai (1972) have described the microhabitats, distribution of corals, ecological stress and primary production in the Minicoy lagoon, a major habitat for live-baits. Though, Jones (1964) listed 45 species of reef associated fishes divided among 18 families from Lakshadweep which are used as live-baits, only about 10 species are of common use (Thomas, 1964b). Inspite of all these earlier works, many aspects of the ecology and biology of reef fishes from Lakshadweep remained unknown. In the present communication the authors make an attempt to throw more light on the above aspects especially on the impact of ecological stress in the Minicoy Lagoon on the tuna live-baits.

Major reef fish habitats in Minicoy

The major habitats for reef fishes in Minicoy include the reef flat, reef front, inner lagoon reef, lagoon shoals and sand flat. The reef fronts of Minicoy or any other atoll of Lakshadweep provide rich ground for both small and large fishes. The littoral reef flats have been recently studied for their fin fish and shell fish resources (Pillai *et al.*, 1984). The microhabitats on both windward and leeward reef flats include dead coral boulders with or without algal coating and live corals. The upper and midlittoral reef flats present significant variation in the structure and composition of resident fishes. The rock pools form the primary settling sites for many reef fishes during November to April. Both herbivorous and carnivorous fishes make diurnal migration over the reef flat along with the tide. These fishes move to the upper littoral flats at high tide and feed on the rich source of food items and return along with the receding tide. The live corals on the reef flats also harbour many resident reef fishes as in the lagoon. A relative paucity of fish fauna on the windward reef flat was also observed during the present observation. Pillai *et al.*, 1984 explained this as due to relative absence of living habitats by way of dens and crevices at the protected side.

The lagoon possesses two ecologically distinct habitats, viz, coral shoals and sand flats (Pillai, 1971). The former provides habitat for many important live-baits belonging to the families Pomacentridae and Apogonidae and form the traditional site of live-bait fishery. The southern half of the lagoon has a vast sand flat with smaller shoals and live coral isolate. The arborescent corals of the genus *Acropora* once dominated in this area. Except for *Spratelloides* the area is not important as a site of fishery.

Live-baits and their microhabitats in lagoon

The lagoon fishes in general can be classified into either resident or migrants. Those that are found on coral heads are resident, while those that sporadically appear in the lagoon waters are migrants.

Fig. 1. A Reef flat in Minicoy. Beneath the waves there is a profusion of fish life.

Live coral associates

The association between coral reef fishes and corals is more or less specific. The growth-form of corals

seems to be a controlling factor. Inherent and physiological factors may also be involved. Only important live-baits and their specific habitats are considered herein:

a) **Corymbose, pedicellate corals with reticulately coalescent branches**

The common species with this growth-form belong to the genus *Acropora* and include *A. corymbosa, A. hyacinthus A. efflorescens* and *A. granulosa.* The following are the common live-baits found in these corals.

Family: Apogonidae

The genera *Apogon, Pristiapogon* and *Archamia* constitute the largely exploited fishes. Yet another species that is found along with them is *Spratelloides japonicus.*

Archamia fucata (Local name 'Rybodi'): The species is found either hiding among the coral colonies or swimming close to them. Probably their settlement on corals along with other apogonids takes place soon after the monsoon. Exploited stock during January to April include post-larvae and juveniles.

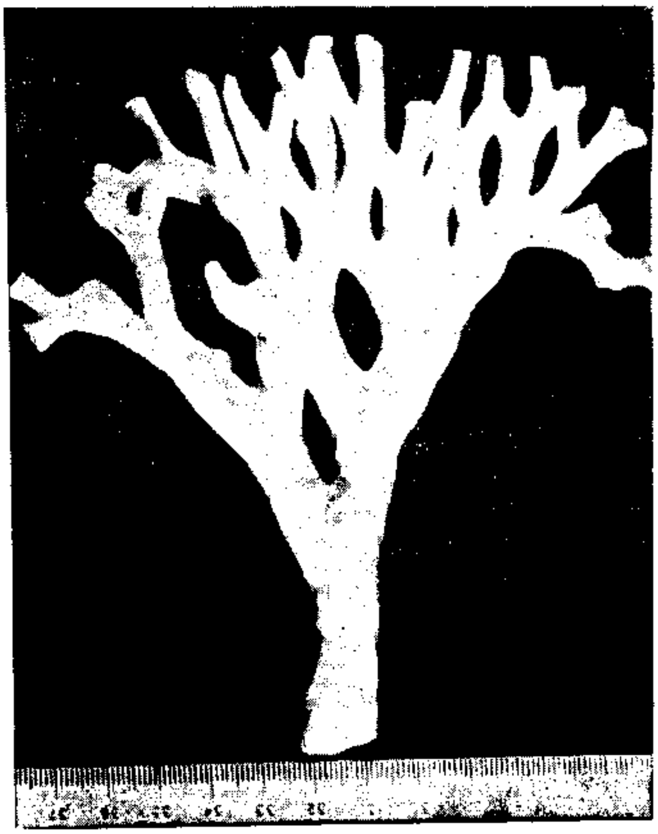

Fig. 2. Millipora – a hydroid coral.

Apogon sangiensis and *A. leptacanthus* (Local name: 'Rybodi'): Though both the species are found along with *Archemia,* of recent these are found on live massive corals also. Whether this is an adaptation in response to deteriorating primary habitat is yet to be assertained. It is known that for example, *Dascyllus aruanus,* may

Fig. 3. *Heliopora caerulea* a very dominant coral.

opt for dead corals in the absence of live corals. Both the species are planktivorous and exploited stock constitutes juveniles.

Pristiapogon fraenatus (Local name 'Murakibodi') and *P. synderi* (Local name: 'Bodu bodi'): The habit and habitat of these two species is almost similar to that of *Apogon* spp.

b) **Ramose arborescent and flabellate corals**

The dominant species of corals with the above growthform include, *Acropora formosa, A. teres, A. aspera, A. palifera, A. humilis, Stylophora pistillata, Pocillopora damicornis, Porites andrewsi, P. minicoiensis* and *Heliopora caerulea.* The blue coral *H. caerulea* is essentially an inner lagoon reef form while the rest thrive in the south and central part of the atoll often forming large thickets. The important associated fishes of this habitat belong to the family pomacentridae.

Family: Pomacentridae

Chromis caeruleus (Local name 'Nilamahi') and *Dascyllus aruanus* lead a co-existing life on ramose arborescent corals (Pillai *et al.*, in press). While the former serve a steady supply of live-baits in Minicoy, the latter is not of any value. *Pomacentrus pavo* is yet another species found along with *C. caeruleus* especially in the central part of the lagoon. This is also fished along with *C. caeruleus,* a strictly resident species with a pelagic post-larval life.

c) The surface waters of the lagoon

A few species of small fishes enter the lagoon at sporadic intervals as juveniles and are caught if and when available. None the less, they form a major component of the live-baits of Lakshadweep though their appearance is unpredictable and there is a lot of inconsistence in their recruitment to the fishery. Often their massive recruitment is coupled with a bumper catch of tunas. It is likely that tunas follow this group of fishes along with the oceanic current. Though tunas never enter the lagoon, the live-baits make their way into the calm lagoon waters along with the water current. The following are the major species listed under this category.

Family: Emmelichthyidae

Dipterygonotus leucogrammicus (Local name: 'Dandimugurang') is the most common species of this family. Some observations on the habit and habitat of this species were already made by Thomas (1964b.) and Jones and Kumaran (1980). This fish enter the lagoon between December and April. The first recruits are juveniles or post larvae. The adult habitat around Lakshadweep needs further investigation.

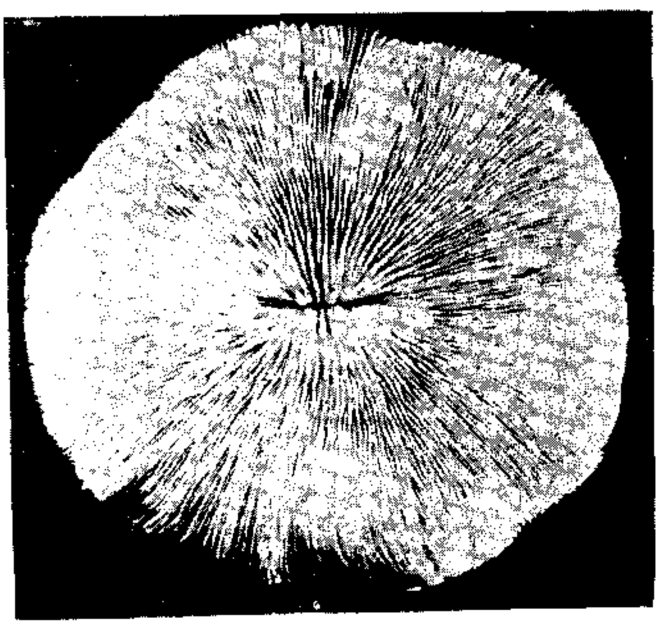

Fig. 4. *Fungia fungites,* a solitary coral-oral view

Family: Caesiodidae

Caesio chrysozona and *C. caerulaureus* (Local name: 'Furrua') are among the important caesiodids that enter the lagoon as juveniles and fished as live-baits.

Family: Pomacentridae

While *Chromis caeruleus* of this family is a strictly resident form, *Lepidozygus tapeinosoma* (Local name: 'Bureki') is almost a pelagic migrant soon after the monsoon season. There was a paucity of this species at Minicoy during 1981-'84 period.

The statement in early literature that most of these pelagic forms disappear from the lagoon after April needs confirmation. Generally, the lagoon remains choppy after May, and till end of November there is no fishing activity in the lagoon. Hitherto no effort has been made to survey the lagoon all through the year. Madan Mohan was able to collect some fully matured spratelloids from the near shore area during the monsoon which indicates that these pelagic forms of live-baits also may not altogether disappear from the lagoon soon after the tuna season or at the onset of monsoon.

d) Sand flat - lagoon bottom

Spratelloides delicatulus (Local name: 'Hondeli') of the family Dussumieriidae lives on the sandy bottom of the lagoon. Some times they swim to the surface and when scared make gliding movements in the air. The species is a planktivorous one and form an important source of live-bait. There is a preponderance of this species near Boaz Point (Ragandi Is.) and Viringili Island.

Ecological stress and its impact on live-baits

The lagoon environment of Minicoy has undergone visible changes in the last decade due to both natural and artificial factors (Pillai, 1983, 1985). The current prevailing feeling among the fishermen is that the live-baits are on a declining trend and the available stock is insufficient to meet the local demand. There are several factors responsible for this crisis of which the visible changes brought about in the environment are of prime importance.

Environmental deterioration

At present the lagoon of Minicoy is a modified ecosystem compared to that of a decade ago. Corals

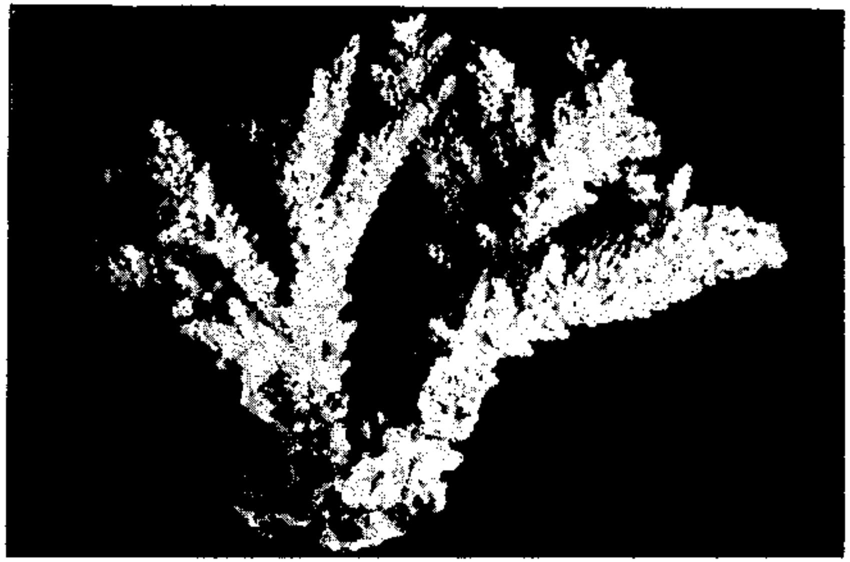

Fig. 5. *Acropora abrotanoides* an arborescent coral predominant in the lagoon.

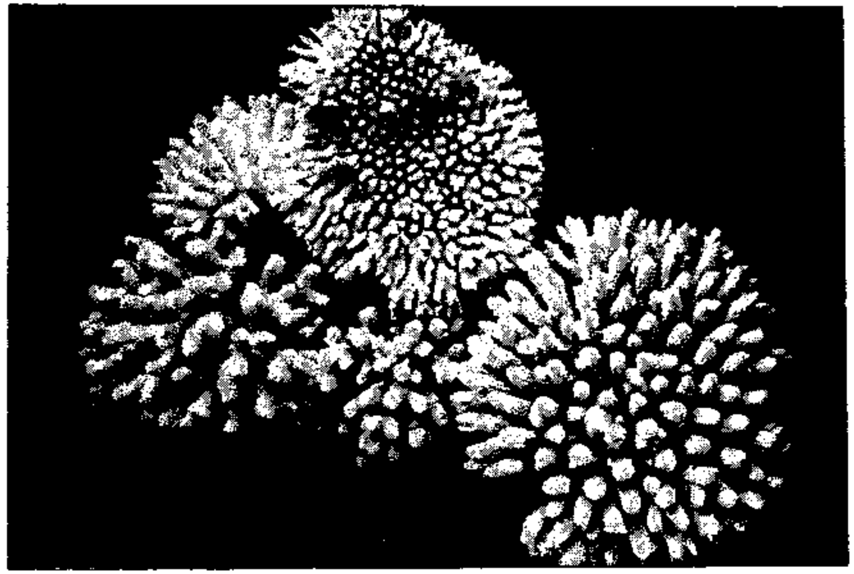

Fig. 6. A few common *Acropora* spp. corals from Lakshadweep that form the microhabitat for the resident reef fishes including the live-baits.

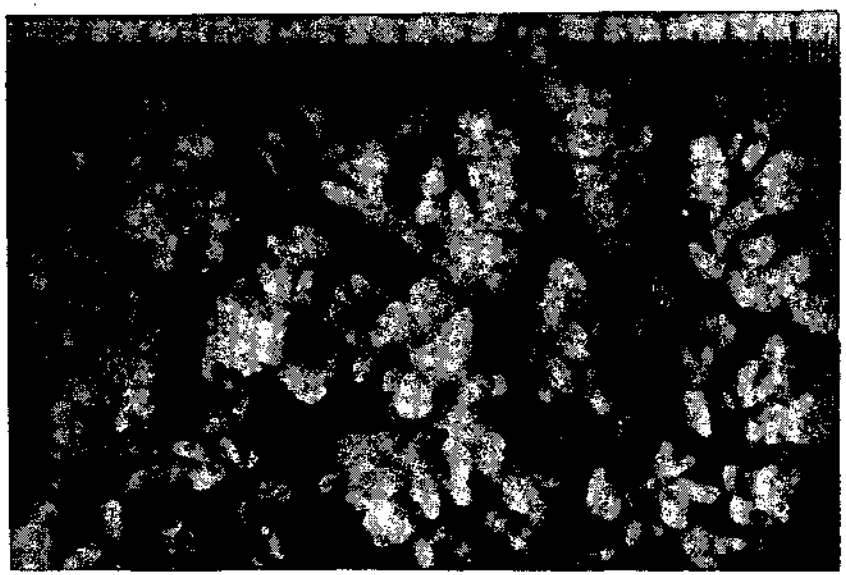

Fig. 7. *Pocillopora damicornis* – the most common Indo-Pacific coral that thrives both on reef flat and lagoon.

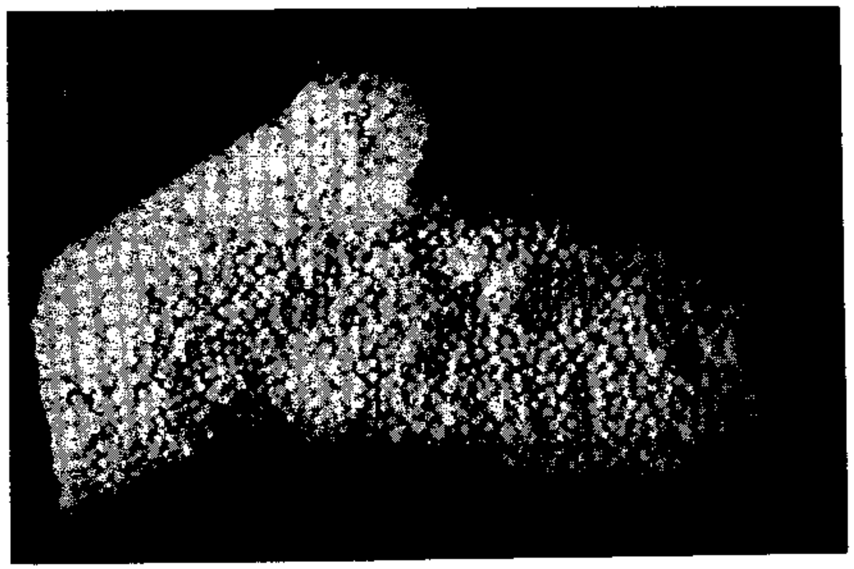

Fig. 8. *Acropora palifera*. Once this species dominated in the lagoon but now mostly dead due to siltation.

of all genera and species have suffered mass mortality during the last five or six years (Pillai, 1983). The large number of *Acropora* thickets that formed the habitat of many reef fishes including live-baits are all dead and are getting disintegrated. The lagoon bottom is strewn with dead branches and is slowly getting covered by sand. The major reason for this mass mortality of corals is undoubtedly excessive siltation. The blasting

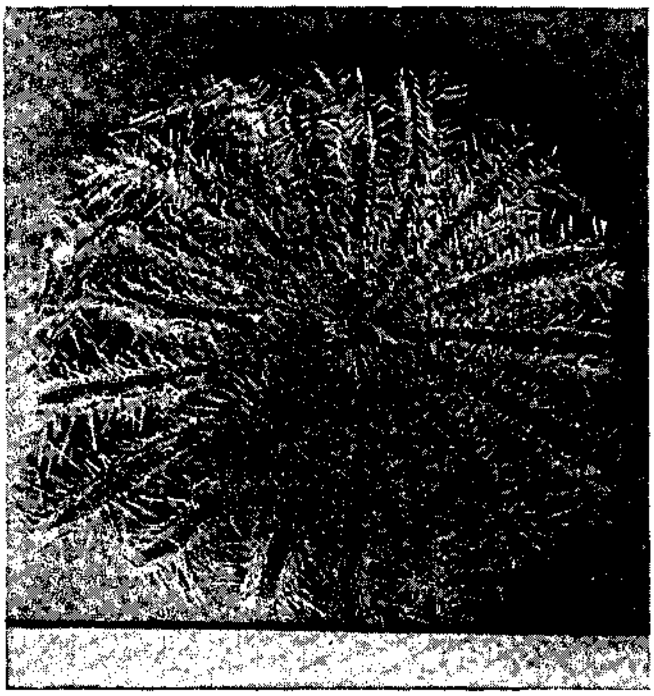

Fig. 9. *Acanthaster planci* — a star fish which feeds on the polyps of corals and destroys them (Photo courtesy: D. B. James)

of the reef and lagoon shoals as well as dredging the lagoon to deepen the boat channel have caused stirring up of sand and its transportation towards the southern half of the lagoon from the north along with the water current. At the southern half of the lagoon at least there is fresh deposit of 50 cm thick sand as estimated from the height of *Acropora palifera* colonies measured in 1968 which are at present buried intact.

Sea erosion is rampant and the blasting of the reef and deepening of the lagoon bottom at the northern entrance has certainly permitted greater influx of water into the lagoon. A greater degree of accretion is evident near the Light House area. The lagoon at the southern half is getting filled up rapidly. The dead ramose corals are efficient sediment trappers which aid the filling up of the lagoon. Small polyped corals like *Acropora* are very sensitive to the smothering effect of sediments and are easily killed (Pillai, 1971b).

In 1980, *Acanthaster planci* was also recorded in fair numbers among the *Acropora* thickets and several patches of freshly killed corals were observed (Murty *et al.*, 1980). The mass mortality of corals has adversely affected the resident ichthyofauna. The dominant resident species such as *Chromis caeruleus, Pomacentrus pavo* and *Dascyllus aruanus* have deplorably dwindled in the lagoon and the present lagoon looks depopulated when compared to a decade ago.

Habitats and recruitment of pelagic species

Fluctuation in the rate of recruitment of reef fishes to specific habitat is an established phenomenon. The settlement of fish larvae on their specific microhabitat depends on many factors such as breeding season, lunar periodicity in spawning, survival of larvae, species composition of the adult fish assemblage, force and direction of water current and natural tendency for precise microhabitat selection of the species (Sale *et al.*, 1984). At least some of these factors along with the conditions of the habitat are in operation in the Minicoy Atoll.

Except for a single known species of reef fish viz. *Acanthochromis polyacanthus* all reef fishes are believed to have a pelagic larval life (Sale, 1980). The pelagic life varies from two weeks to three months depending on the species and at the end of the pelagic phase they should settle on the specific microhabitat. Some species may be able to prolong their post larval pelagic life and undergo sexual maturity as in the case of *Ctenochaetus strigosus* when failed to get foothold on the reef (Pillai *et al.*, 1984b)

In resident species such as *Chromis caeruleus, Dascyllus aruanus, Apogon* and *Pristiapogon* spp. the major ecological constraint is the dwindling of living space due to mass mortality of corals (Pillai, 1983). Even if the larvae of these resident species enter the lagoon, their precise microhabitat requirement is a major controlling factor in their settlement and growth. Sale *et al.* (1984) have recently shown how some of the pomacentrids settle more profusely on wider live coral coverage than on area with sparse coral coverage. This indicates that intensity of coral growth is a factor that determines the settlement of coral reef fishes including tuna live-baits in many cases.

STATUS OF CORAL REEFS IN LAKSHADWEEP

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Historical

The Lakshadweep still remains to be one of the least studied group of islands in the Indian Ocean for its coral reefs and reef resources. The area is biologically significant in view of its isolation from major continental coastline as well as for its rich and varied marine life. The early studies on the reefs of Lakshadweep are those of Gardiner (1903, 1906) from Minicoy which include detailed descriptions of the reef and some reef corals. Alcock (1902) the surgeon naturalist visited several islands in the Laccadives (Lakshadweep) at the end of the last century. Though his visits to the islands were of short duration he left short but graphic description of many atolls mostly based on Admirality Charts. The islands were re-surveyed by Lt. Comm. C.G. Francis from the survey ship *Sutlej* (Charts by Indian Naval Hydrographic Office, Dehradun). A consolidated report on the icthyofauna by Jones and Kumaran (1980) is the most significant contribution from this area. Pillai (1971a, 1971b, 1982, 1983) Pillai *et al.* (1984) and Nair and Pillai (1972) furthered our knowledge of the various aspects of the reefs of Minicoy in the last more than one decade. A team of scientists from Central Marine Fisheries Research Institute made a detailed study of the fauna and flora of Kiltan Atoll in 1974 in connection with a major oil spill. The above resume of work on the reefs of Lakshadweep indicates that except for some useful information from Minicoy and Kiltan, ie. the extreme south and north of the archipelago, the area remains largely unknown for its reefs and reef resources.

THE REEFS OF LAKSHADWEEP

Morphology: The Lakshadweep has twelve atolls, three reefs and five submerged banks with a total of 27 islands. The total land area is 32 km² and the total extent of lagoon is about 420 km² (Mannadiar, 1977). Most of the islands are located on the windward reef flat at the eastern side. Raised reefs as far as known are found in Kiltan Atoll indicating a relative change in the level of land with sea in this area in the geological past. The surface morphology of Minicoy finds a place in Gardiner's (1903) extensive work, on the fauna and geography of Maldives and Laccadives. Silas *et al.*, (unpub.) have studied the surface morphology of the reefs of Kiltan Atoll (Long. 73°E, Lat. 11°29′N). The windward reef flats of both these islands have well developed algal ridges and spur and grove system. The supralittoral and littoral fringes are mostly devoid of any live corals though the rock pools may harbour isolated coral colonies. The windward reef flats are studded with huge lime stone masses which are under different stages of erosion. This should represent the remnants of elevated reef flat which were later subjected to heavy wave action.

Formation: According to Alcock (1902) "All Laccadive islands appear to be the remains of eroded atolls, raised only a few feet above the sea level and formed entirely of coral rock and coral sand. They rise quite abruptly from the sea that within half a mile of the shore often close upon 1000 fathoms deep." According to Gardiner (1903) the Maldives and Laccadives were formed on a large bank which was part of an ancient land that completely sunk. He also felt that some of the islands are remnants of mountains that existed in the sunken land. The two archipelagoes are located at the northern end of the north-south alinged submarine Laccadive – Chagos ridge. Lakshadweep is located on a large linear aseismic ridge which is made of massive coral capping on massive volcanoes. This volcanism

Fig. 1. A closer view of dead corals lying at the lagoon bottom. Also note dead *insitu* specimens of giant clam *Tridacna maxima*.

is probably Paleozoic -Eocene in age (Stoddart, 1973), No deep drilling has been hitherto made on the Lakshadweep reefs proper to estimate the thickness of coral capping. However, based on geophysical data the thickness in western Indian Ocean including Saya de Malha and Amirantes and Great Chagos Bank is estimated to be between 0.6 to 1.7 km (Glennie, 1936). In general confirmity with the geological history of

Fig. 2. Sea erosion is a major factor for siltation in the lagoon.

the Indian Ocean reefs, it may be stated that the reefs of Lakshadweep were also built in Tertiary and Quartenery eras on volcanic structures and the present day surface features of the reefs are the results of erosional and depositional consequences of Pleistocene and Holocene sea-level changes (Stoddart, 1973).

The structure of the coral fauna

Composition of the coral fauna: To the date there exists no comprehensive account of the coral fauna of Lakshadweep. Our knowledge of the fauna is based only on Minicoy at the south and Kiltan at the north. A total of 28 genera comprising of 73 species of stony corals are hitherto recorded (Pillai, 1971, 1972) (Table 1). The octocorals are represented by *Heliopora coerulea* which form a very conspicuous element in the inner lagoon reefs throughout Lakshadweep. The gorgonids are not found in shallow waters. The hydrozoans are represented by *Millipora* with three species known. The affinities of the fauna of Minicoy with adjacent Indian Ocean areas were discussed by Pillai (1971a). Both ramose and massive corals dominate. The genus *Acropora* is the richest as is the case with all the Indian Ocean reefs, and form about 25% of the total species known from Minicoy. A notable feature of the coral fauna of Lakshadweep is the absence of foliaceous forms such as *Montipora foliosa* and *Echinopora lamellosa*. *Montipora* a very common genus in Indian Ocean reefs is rare and only one encrusting species is hitherto recorded. The massive species of corals are mainly those of *Porites lutea* and *P. solida*. *Diploastrea* was very common till recently in Minicoy though there is a dwindling of this coral at present. Ramose *Porites* is essentially a component of the lagoon both in Kiltan, Minicoy and Kavaratti atolls.

Coral sociology

Based on the major assemblage of dominant genera more or less three distinct coral communities can be defined in the various habitats of reefs and lagoons of Lakshadweep as follows.

Porites *community:* The *Porites* community is dominated by *P. lutea* and *P. solida* and is essentially an inner lagoon reef community. Faviids such as *Favia, Favites, Platygyra* and *Goniastrea* are found mixed with. *Pocillopora* spp. and *Acropora* spp. are also found at the sides and top of large *Porites* colonies.

Acropora *community* The *Acropora* community is predominantly of various species of *Acropora* in the lagoon. Both arborescent and corymbose species thrived in the lagoon till recently. *A. formosa, A. aspera, A. teres, A. corymbosa, A. hyacinthus* and *A. humilis* are the common species. This community forms the most ideal habitat for many reef fishes including important live-baits.

Heliopora *community: Holiopora* forms a very dominant coral both in lagoon reef and open reef flat, especially at the former habitat. Among the *Heliopora* colonies many fungiids and some faviids are found. There is a comparative paucity of reef fishes among the *Heliopora* compared to *Acropora* community.

Coral genera of Lakshadweep

The following is a list of coral genera hithereto recorded from Lakshadweep based on information obained from Minicoy and Kiltan (Table 1). Other islands need further study. It is likely that many more common Indo-Pacific genera may occur in Lakshadweep. A total of 73 species and 28 genera is certainly very low for an area like Lakshadweep, and future investigations are bound to bring forth many more unrecorded species and genera.

Table 1. *Coral species occurring in Minicoy and Kiltan atolls*

	Genera	No. of species recorded	
		Minicoy	Kiltan
	Scleractinian corlas		
1.	*Psammocora*	3	3
2.	*Stylophora*	1	1
3.	*Pocillopora*	4	5
4.	*Acropora*	20	11
5.	*Montipora*	1	1
6.	*Pavona*	2	2
7.	*Cycloseris*	1	1
8.	*Fungia*	3	1
9.	*Gardineroseris*	1	1
10.	*Podabacia*	1	—
11.	*Goniopora*	2	—
12.	*Porites*	6	4
	Porites (Synaraea)	1	—
13.	*Plesiastrea*	1	—
14.	*Favia*	3	2
15.	*Favites*	5	1
16.	*Goniastrea*	2	1
17.	*Platygyra*	1	1
18.	*Leptoria*	1	—
19.	*Hydnophora*	1	—
20.	*Diploastrea*	1	—
21.	*Leptastrea*	3	2
22.	*Galaxea*	2	1
23.	*Merulina*	1	—
24.	*Acanthastrea*	1	—
25.	*Symphyllia*	2	—
26.	*Lobophyllia*	1	—
27.	*Euphyllia*	1	—
28.	*Turbinaria*	—	1
	Non-scleractinian corals		
1.	*Heliopora*	1	1
2.	*Millipora*	3	3

Ecological impact on coral reefs

Climate: All islands in the archipelago are subjected to cyclones which may do mechanical damage to coral growth. Both northeast and southwest monsoons bring rains to the islands but the runoff to the reef flat seems to be negligible. There are no fresh water streams. The surface current during the monsoons is a major factor that influences the recruitment of many reef organisms in this area including lobsters (Pillai *et al.*, 1984). Total annual rain-fall range from 1,500 to 1,600 mm.

Primary production: The annual net production in Minicoy lagoon from a reef was estimated to be 3,000 $gC/m^2/day$ (Nair and Pillai, 1972). This is comparable to many reefs in Indo-Pacific that show high rates of production. The Minicoy reefs were also shown to be autotrophic. Future estimations are likely to show a retarding trend due to mass mortality of corals that occurred recently, resulting in a cyclic change of community structure.

Predators: The occurrence of *Acanthaster planci* was recorded both at Kavaratti (Sivadas, 1977) and Minicoy (Murty *et al.*, 1980). These starfishes were

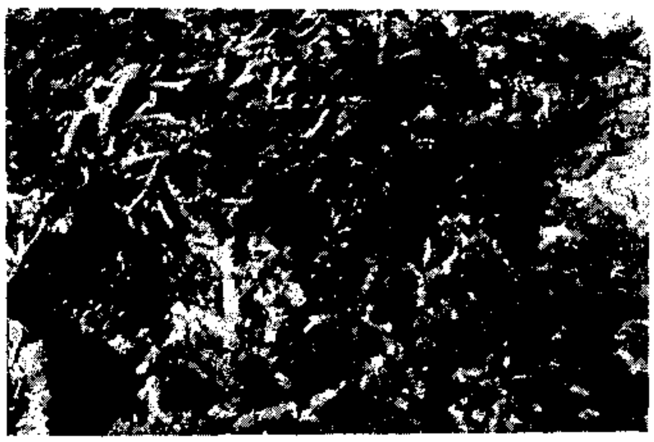

Fig. 3. Dead branches of *Acropora* spp. in lagoon bottom.

observed to leave white patches on live *acropora* thickets in the lagoon of Minicoy thus causing death to corals. However, they were not found in the lagoon from 1981 probably due to many reasons. They might have played a role in the recent mass mortality of corals seen in the lagoon.

Siltation: The interference from silt smother the corals and kills them. The rate of siltation in the lagoons of Minicoy and other islands would have increased due to sea erosion and disturbances to the lagoon (Pillai, 1983). Further, human interferences have also increased siltation rate in the lagoon which brought out large scale death of corals in all the atolls of Lakshadweep. No detailed study on the rate of siltation in Lakshadweep is available. But it is stated that some of the northern islands have a greater degree of silting and the lagoon are fast getting filled up as in Kiltan.

Human interferences: A comprehensive account of the various aspects of human interference on the atolls of Lakshadweep was presented by the author in an earlier communication (Pillai, 1983). Since human settlement started in these atolls, both their terrestrial and marine habitats were subjected to environmental stress. Removal of corals from the shore and reefs, pitting the ground, removal of surface soil, mining of sand stone as in Kiltan for construction work were all being done. The postindependent developmental activities have further deteriorated the ecosystems. Construction of concrete buildings, cutting of natural vegetation, introduction of exotic plants, introduction of cattle and goats, excessive application of pesticides on agricultural crops are all having adverse impact on the natural ecosystems of the atolls. Blasting of reefs and dredging of lagoon to deepen the boat channels have done irreparable damage to lagoon habitat and has almost killed the entire lagoon coral fauna. Any amount of arguments from any quarters will not justify the unwise decision taken to dredge the channels. Infact, it has not served any purpose except killing all the corals in the lagoon which has effected a drastic dwindling of the resident tuna live-baits.

Resources: The major resources of the Lakshadweep still need further survey and proper assessment. The deep water molluscs, lobsters algae and gorgonids need survey and documentation. A proposal is in vogue in this direction from the Central Marine Fisheries Research Institute to carry out a detailed survey of the northern islands in the immediate future.

Conservation: In view of the deteriorating environmental conditions of this archipelago, effective measures of conservation need to be implemented. The present ban on dredging of reef habitats and collecting of corals should continue. The actions taken to prevent sea erosion by the local Administration should serve a long way in conserving one of our most valuable natural resources.

POTENTIAL RESOURCES OF FISHES OTHER THAN TUNA IN LAKSHADWEEP

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Introduction

The tuna fishery of the Lakshadweep in the south-eastern Arabian Sea is often overemphasised to the extent to create an impression that there is no other exploitable resources of fishes other than tunas, especially the skipjack, *Katsuwonus pelamis*. At present, fishing in an organised manner exists only for tunas in the islands (Jones and Kumaran, 1959). There is a well-established traditional system for the capture of tunas in Minicoy and some other islands with indigenous craft and gear and mechanised boats. The highly productive waters around the islands (numbering twenty seven), the submerged banks and the crevices of coral boulders and reefs offer ideal habitats for a large number of economically important groups of fishes (Jones and Kumaran, 1980) which offers scope for extensive fishing by simple crafts and gears. Most of the other fish resources are now caught either as a by-catch of pole and line tuna fishery or as incidental catches in surface trolling.

The people of Lakshadweep are traditionally dependant on coconut and fish for subsistence for centuries, and avenues for other occupations are limited. Any developmental programme for improving the economy of Lakshadweep and to provide employment to the increasing population has to be mainly oriented towards

Table 1. *Composition of marine fish landings other than tunas and bill-fishes in Lakshadweep during* 1971–'84 (figures *in tonnes*)

Category	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Average ('82–'84)	Percentage*
Elasmobranchs	120	157	171	253	325	354	296	198	364	284	211	240	332	287	286	25.6
Catfish	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Half beaks & Belonids	9	19	99	27	29	33	58	144	101	99	113	87	103	62	84	7.5
Flying fish	14	17	42	43	30	41	30	33	16	29	16	25	25	15	22	2.0
Perches	43	83	130	159	186	193	211	163	203	376	315	230	252	205	229	20.5
Goat fishes	8	12	36	32	34	58	29	27	27	27	25	27	32	24	28	2.5
Carangids	20	30	63	61	61	94	65	60	58	80	105	214	147	45	135	12.1
Seer fish	48	51	29	91	66	87	41	41	24	21	50	99	59	59	72	6.4
Barracuda	7	8	11	18	17	20	15	18	11	14	12	10	19	14	14	1.2
Sciaenids	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—
Silver bellies	—	—	—	—	5	—	—	—	—	—	—	—	—	—	—	—
Miscellaneous	134	172	232	279	224	361	281	201	233	206	203	239	237	265	248	22.2
Total (excluding tuna)	403	549	813	963	980	1241	1026	885	1037	1136	1050	1171	1206	976	1118	(24.0)
Tuna	774	514	1020	1254	1932	1291	1166	1875	2794	1760	2236	2966	3303	4313	3527	(76.0)
Grand Total	1177	1063	1833	2217	2912	2532	2192	2760	3831	2896	3286	4137	4509	5289	4645	

* Percentage to the Total (excluding tuna)
Percentage indicated in the brackets refer to percentage to Grand Total

the fishing industry. In this context, the diversification of fishing effort for the exploitation of fishery resources other than tuna and evolving cheaper preservation methods and effective marketing become essential for the futurological development in the fisheries sector of these islands.

Present status of the fishery resources other than tunas

The indigenous fishing craft employed for the capture of other fish resources in the islands vary from five to seven metres in length. In recent years, a few of the dug-out canoes have been fitted with 'Yamaha' outboard engines. Traditional drag nets of varying dimensions and cast nets are in use for the capture of other fishes, mostly from the lagoons. Harpoons are used for capturing sharks, rays and other big fishes from the open sea. 'Chilla' with spikes are used for catching half beaks, belonids and flying fishes. In the open sea, drift netting is carried out on a limited scale by mechanised boats introduced since the early sixties. Occasionally, trolling is done from mechanised boats for catching wahoo, sailfish etc. and long lines are employed for catching sharks and other large fishes. The method of capture is surface trolling with one troll line on either side of the boat. Considerable improvement in the fish landings in the islands have been observed in recent years. However, the increase in the landings of fishes other than tuna consequent on the introduction of mechanised boats is of a lesser magnitude than that of tuna.

The group-wise annual catch, average catch, and the percentage contribution of each group in the landings of other fishes for the years 1971 to 1984 are given in Table-1. The average contribution (average of 1982–'84) of the fishery resources other than tunas to the total fish production of the islands is 24.0%. However, it varies from island to island and is inversely related to the development of pole-and-line fishery for tuna of different islands. The average tuna landings in the islands was 3,527 tonnes and other fishes 1,118 tonnes. The landings of other fish resources excluding tuna was the lowest in 1971 (403 tonnes) and the highest in 1976 (1,241 tonnes).

It could be seen from Table-1 that the commercially important resources other than tunas in the Lakshadweep in the order of abundance are: sharks and rays (25.6%), perches (20.5%), carangids (12.1%), half beaks and belonids (7.5%), seer fishes (6.4%), flying fishes (2%) and goat fishes (2.5%). Devil rays *(Manta birostris)* and sail fish are caught in good numbers by the islanders except in Minicoy. Wahoo, *Acanthocybium solandri* is abundant all round the islands and are fished by trolling lines and harpooning. Sharks, rays, seer fish, snappers, rock cods, rabbit fishes *(Siganus* spp.) and surgeon fishes *(Acanthurus* spp.) are caught in good quantities from submerged banks and reefs when tuna fishing is poor. Flying fishes are caught in good numbers by torch fishing in most of the islands.

Fig. 1. *Abudefduf glaucus* a very common reef-flat fish.

Since fishing effort is concentrated mainly for tuna in most of the islands, the catch of other fishes generally vary according to the fluctuations in the availability of tuna shoals around the islands. When the tuna catch became poor in a particular season, the effort expended for other groups of fishes was increased and consequently the landings of other resources also increased. This indicates that if the effort is diversified, the catches of other resources could be enhanced.

The status of other fishery resources of Minicoy Island

Minicoy Island, where the traditional pole-and line fishery for tunas is in vogue, the fishing effort for other fish resources is mainly during the latter half of the year when the pole and line boats fail to chum tuna shoals. The other fish resources constitute less than 2% of the total fish landing of Minicoy as the fishermen of Minicoy are averse to capture fishes other than tunas. This is not representative of the fishery in the rest of the islands where the proportion of other fishes in the landings is much higher.

The month-wise landings of the various other resources for 1984 and 1985 at Minicoy are given in Tables two and three. The annual average landings of other fishes is about 10.4 tonnes. The major constituents of other resources are wahoo *(Acanthocybium solandri)*, rainbow runner *(Elagatis bipinnulatus)*, carangids, dolphin fish (Coryphaena hippurus), barracudas *(Sphyraena* spp.), perches and sharks. *Acanthocybium solandri* caught mainly by troll lines constitutes the bulk of other fish landings at Minicoy, in both the years (22.8% and 38.7% respectively). The size of *A. solandri* which is a good quality fish ranged from 80–200 cm with a mode at 100 cm. The next most abundant in the landings is *Elagatis bipinnulatus* and *Coryphaena hippurus* which are mostly obtained as by-catch of pole and line fishing. The size of *E. bipinnulatus* in the landings ranged from 40–70 cm. Sharks are obtained in surface trolling and occasionally a by-catch of pole and line fishing for tuna. Eventhough there appears to be a great potential for carangids and perches around Minicoy, no special effort is taken for the exploitation of the resource.

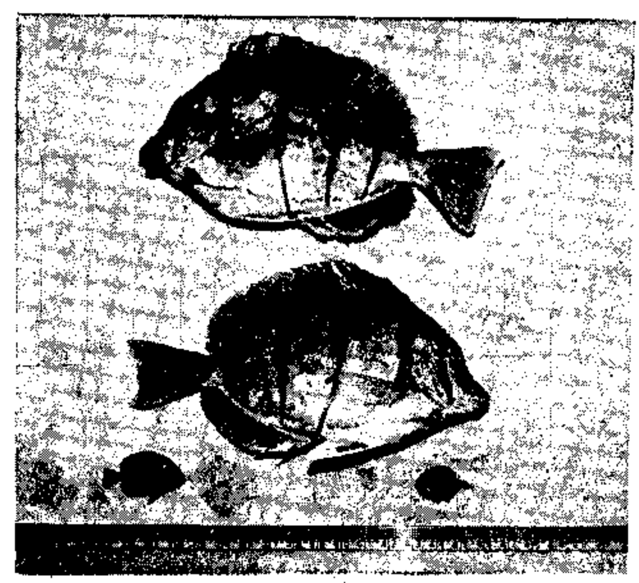

Fig. 2. *Acanthurus triostegus triostegus* the most common herbivorus fish of food value.

From the foregoing, it is evident that the islands have a resource potential for at least four major groups of fishes other than tunas viz., *Acanthocybium solandri,*

Table 2. *Monthly landings of fishes other than tunas and bill-fishes at Minicoy during* 1984 *(in kg)*

Month	*Acantho-cybium solandri*	Caran-gids	*Elagatis bipinnu-latus*	*Corypha-ena hippurus*	*Sphyraena* spp.	Perches	Sharks	Total
January	25.0	—	54.5	—	—	—	75.0	154.5
February	10.0	61.0	114.0	—	—	—	50.0	235.0
March	—	—	399.5	—	—	—	1,012.0	1,411.5
April	35.0	—	80.5	—	—	—	270.0	385.5
May	164.0	68.0	—	—	—	307.0	348.0	887.0
June	27.0	82.5	28.0	4.5	—	249.0	—	391.0
July	45.0	2.0	23.0	—	132.5	378.5	20.0	601.0
August	90.0	1,175.5	96.0	11.0	521.5	1,589.5	435.0	3,918.5
September	1,202.0	52.5	31.5	143.0	128.0	55.0	507.0	2,119.0
October	517.0	5.0	273.5	30.0	6.0	—	143.0	974.5
November	471.0	—	817.5	—	—	—	—	1,288.5
December	471.0	2.0	499.0	5.0	4.5	13.0	25.0	1,019.5
Total	3,057.0	1,448.5	2,417.0	193.5	792.5	2,592.0	2,885.0	13,385.5
%	22.8	10.8	18.1	1.4	5.9	19.4	21.6	

Table 3. *Monthly landings of fishes other than tunas and bill-fishes at Minicoy during* 1985 *(in kg)*

Month	*Acantho-cybium solandri*	Caran-gids	*Elagatis bipinnu-latus*	*Corypheena hippurus*	*Sphyraena* spp.	Perches	Sharks	Total
January	248.0	16.0	213.0	19.0	4.0	20.0	—	520.0
February	137.0	5.0	154.0	9.0	2.0	—	410.0	717.0
March	99.0	27.0	212.0	199.0	—	—	190.0	727.0
April	169.0	5.0	235.5	61.0	1.0	—	140.0	611.5
May	29.0	42.0	118.5	6.0	2.0	—	—	197.5
June	20.0	166.0	1.0	12.0	2.0	—	136.0	337.0
July	437.0	74.0	71.5	35.0	21.0	—	297.5	936.0
August	377.0	106.0	41.5	—	1.0	—	20.0	545.5
September	396.0	155.0	45.0	—	—	—	—	596.0
October	371.0	4.0	123.0	74.0	—	—	125	697.0
November	354.0	—	466.5	10.5	12.0	—	—	843.0
December	189.0	29.0	360.5	3.5	—	—	—	582.0
Total	2,826.0	629.0	2,042.0	429.0	45.0	20.0	1,318.5	7,309.5
%	38.7	8.6	27.9	5.9	0.6	0.3	18.0	

carangids, perches and sharks. The other two species i.e., *Elagatis bipinnulatus* and *Coryphaena hippurus* are landed mainly as a by-catch of pole and line fishery.

Strategies for future development

For the rational exploitation of the other fish resources available, attention has to be paid for the balanced development of indigenous and mechanised sector simultaneously.

1) *Development in the small-scale sector*

The small-scale sector remains under developed as the local people are practicing only the age-old methods for fishing to meet the local requirements and this sector

is also not organised. The traditional methods of fishing has not undergone any appreciable change in the islands over the years. Consequently the production of other fishes by traditional fishing operations has not increased significantly when compared to increasing trend in the operations of mechanised boats for tuna fishery.

Diversification of fishing effort, effecting improvements in the existing crafts and gears and providing financial support to develop traditional practices by artisanal fishermen employing indigenous crafts and gears are of prime importance for the development of small-scale sector aimed at the exploitation of resources other than tunas. This is labour intensive and can bring about economic uplift and generate employment to the increasing population.

2) *Large-scale development*

Although the use of mechanised boats for pole and line fishing was introduced two decades ago, there has not been any proportionate increase in the landings of other fish species. The main reason for this is the use of unsophisticated methods of fishing and inadequate marketing facilities. With the realisation of great potentials for increasing the fish landings, it is inevitable to extend the area of fishing operations by adopting improved technology. Sub-surface long lining with modifications suitable for local conditions when introduced will not only increase the exploitation of tunas, but also other resources such as sharks, carangids and perches. The methodologies practiced elsewhere may not be suitable to the conditions prevailing in Lakshadweep and in this context, the prevailing socio-economic level of the people also have to be seriously considered. A survey of the seas around the islands by drift gill netting and long lining have to be carried out to locate and chart productive areas for the different fish resources of economic importance and to evaluate the economics of operations and suitability of different gears.

Post-harvest technology and marketing

Simultaneous with the increased exploitation, facilities for processing and marketing the products have to be provided. At present, tuna is the only fish much sought after by the islanders. The traditionally cured product '*mas min*' is in good demand on the mainland. The other fishes are regarded as second rate by the islanders and hence the problem of disposal of the catch arises while developing other fishery resources. Effective preservation and processing techniques have to be adopted so that the surplus fish is brought to the mainland for marketing.

In order to improve the socio-economic conditions of the fishermen population, it is imperative to implement welfare programmes to provide technical and financial assistance for taking up fishing as an employment by the local population.

As avenues for other occupations are limited, a good percentage of the population remains idle for a substantial part of the year. The problem of unemployment and inadequate returns can be solved by diversification of employment through judicious exploitation of the fisheries resources around the islands. Provision of credit facilities by financial institutions, adoption of suitable preservation techniques and development of marketing facilities in the mainland to fetch higher prices are essential for the all-round development of the fisheries sector.

ANCILLARY LIVING MARINE RESOURCES OF LAKSHADWEEP

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Introduction

Till recently the Lakshadweep archipelago was not investigated upon seriously from a resource point of view. In the latter half of the 19th century attempts have been made by some British naturalists to study the fauna and flora of the Lakshadweep and Maldive Archipelagoes. (Alcock, 1895 - 1900, 1902; Borradaile, 1903; Betts, 1930 and Burton, 1940). Observations of a general nature on fish and fisheries of the islands were subsequently made by Ayyangar (1922), Mathew and Ramachandran (1956) and Balan (1958). However, published information on the marine living resources of the Lakshadweep, other than those of tunas and corals are rather scattered and scanty.

While the major commercially important resources like the corals, tunas and other fish resources of the archipelago are dealt with elsewhere in this volume, here the potential ancillary resources are touched upon.

Sea weeds, crustaceans, molluscs, sponges, echinoderms, reptiles such as turtles, birds etc, are treated here as ancillary resources. There are few others like the beautiful coral reef fishes which are of potential value as an export item for marine aquaria all over the world. Of the above, only the marine algae have been systematically surveyed from a resource assessment angle (Anon, 1979), by the Central Salt and Marine Chemicals Research Institute. Information on the others are based on faunistic observations conducted now and then by different workers.

Algae

Ten islands (Kavaratti, Agatti, Bangaram, Amini, Kadmat, Chetlat, Kiltan, Androth, Kalpeni and Minicoy) were surveyed for the marine algal resources during the 1977-'79 period and estimates of the standing crops were made. Marine algal distribution was generally sparce and heterogenous. All islands except Bangaram supported the growth of marine algae.

The biomass estimates (wet) of the standing crop for all Lakshadweep islands covering an area of 1,334ha was estimated to be within 4,940–10,110 tonnes consisting of 980–2, 100 tonnes of agarophytes, 10–16 tonnes alginophytes and 3,950–7,980 tonnes of others.

The major agarophytes observed were *Gelidiella acerosa, Gracilaria edulis, Gelidium rigidum* and *Gelidiopsis repens*. Alginate resources were meagre represented by *Turbinaria* and *Sargassum*, observed in Kalpeni, Androth and Minicoy. Among the sea weeds categoried as 'others' *Halimeda, Dictyota, Laurencia, Jania, Tolypiocladia, Caulerpa* and *Chondrococcus* constitute more than 75% and are potentially useful sea weeds. Altogether 82 species of sea weeds were collected during the survey, of which only 60 species are found in estimable quantities.

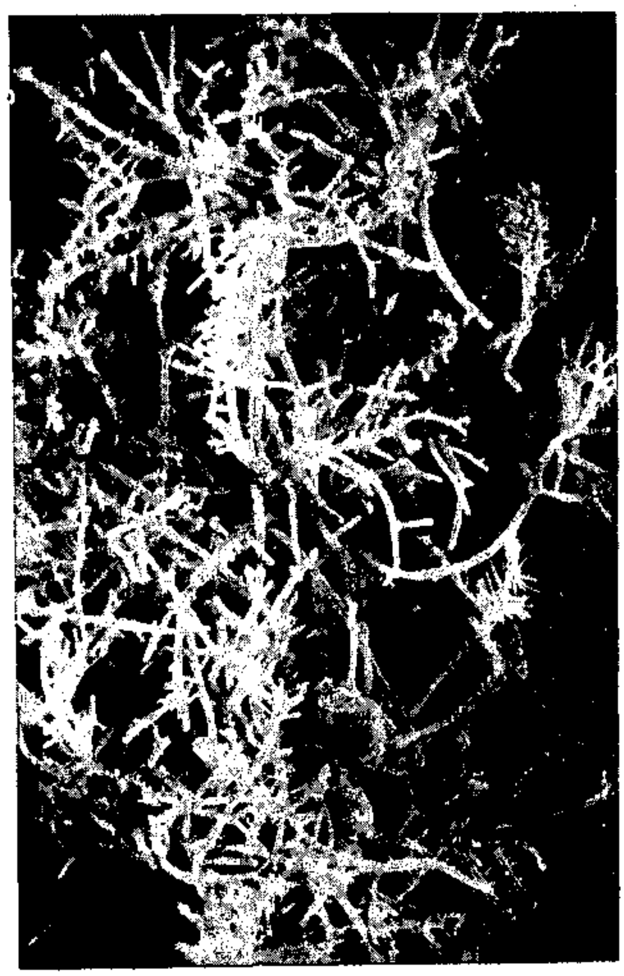

Fig. 1. *Gelidiella acerosa* one of the very common sea weed resource in the Lakshadweep.

Halimedia gracilis was the most abundant form occurring in lagoon and reef areas. *Gelidiella acerosa* occurred in all islands except Chetlat and Kiltan.

It is reported that the agarophyte resource with a preponderance of *Gelidiella acerosa* offer an immediately exploitable resource for establishing an *Agar agar* production unit. Kalpeni, Kavaratti, Agatti and Kadmat islands have more agarophytes around them. *Caulerpa, Dictyota* and *Laurencia* can be used as food in different forms.

Regulated harvest of the sea weeds up to 50% level of the resources is recommended in the report (Anon, 1979).

Crustacea

The prawns and crabs are not fished in Lakshadweep. The brachyuran crabs and lobsters of Lakshadweep have been studied by Alcock (1895, 1896, 1898, 1899 & 1900) and Borradaile (1903 & 1906). Alcock reported 41 species of crabs and Borradaile 52 species of crabs and two species of lobsters. Sankarankutty (1961) recorded 36 species of crabs from the Lakshadweep out of these 27 were from Minicoy, and the rest from Kavaratti, Aminidivi and Bitra islands. The species include representatives of the familes Portunidae, Grapsidae, Ocypodidae, Xanthidae, Maiedae, Parthenopidae and Calappidae.

Fig. 2. *Panulirus penicillatus*, another lobster found in Lakshadweep.

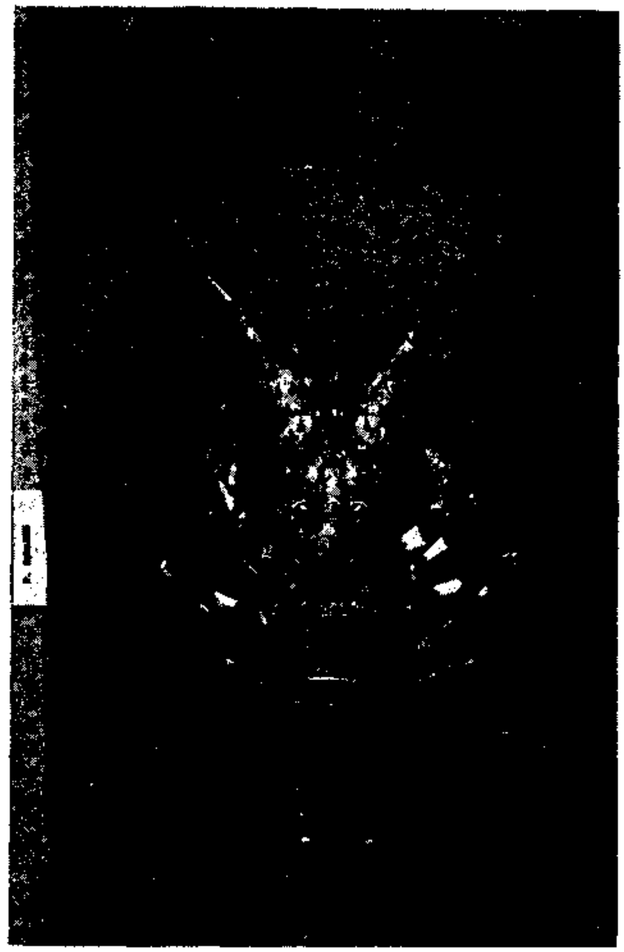

Fig. 3. *Panulirus homarus*, a common lobster of economic value in the Lakshadweep.

The significant abundance of any particular family is not stated in the above literature, since they were mainly faunistic or taxonomic studies based on one time or intermittent collections by different authors.

Kathirvel (MS) collected 28 species of brachyuran crabs and one species of Panulirid lobster from Kiltan atoll. Meiyappan and Kathirvel (1978) published records of the brachyuran crab *Grapsus albolineatus, Cardiosoma carnifex* and the lobsters *Parribacus antarcticus* and *Panulirus homarus* from Minicoy. Pillai, *et al.* (1985)

recorded *P. versicolor* mostly during November–January period in Minicoy. *P. versicolor* is found to be the most common. The distribution pattern of the lobsters was found to be seasonal, more common on the

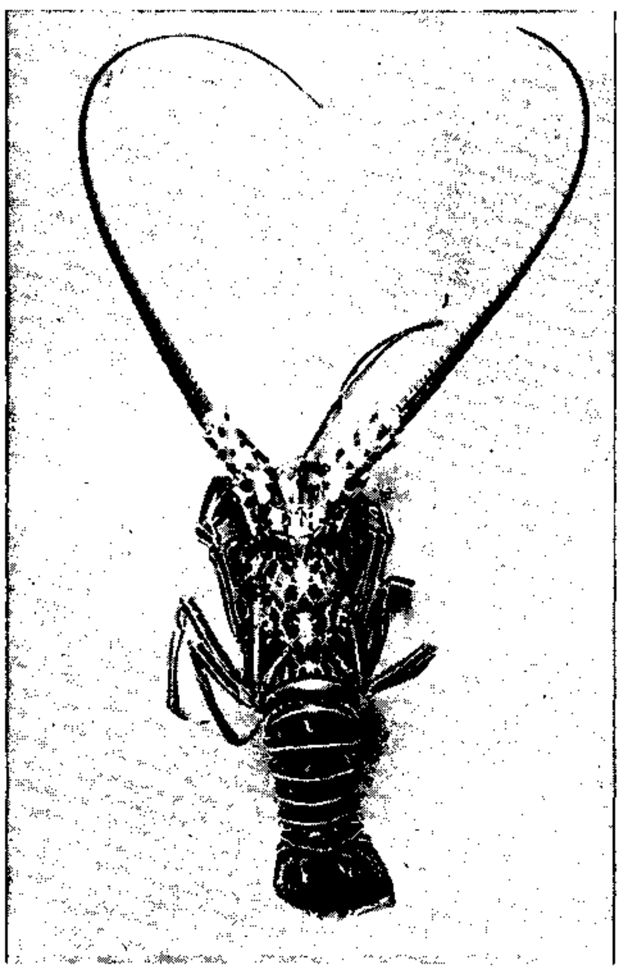

Fig. 4. Painted rock lobster *Panulirus versicolor* – a potential reef resource in the Lakshadweep.

reef flats during November–January period. Meiyappan and Kathirvel (1978) found *P. penicillatus* to be the most common lobster in Minicoy in the late seventies while Pillai *et al.* (1984) found *P. versicolor* as the the major lobster at Minicoy. This species is also recorded from Kiltan atoll (Kathirvel, MS).

Mollusca

Smith (1906) listed *Conus, Terebra, Sistrum, Purpura, Nassa, Oliva, Solarium, Trochus* and *Circe* as the common genera widely distributed in Maldives and Lakshadweep. Burton (1940) reported the common occurrence of the giant clam *Tridacna* over the reef of Chetlat Island when he visited the Lakshadweep in 1935. He recorded the shells of *Pterocera* from Bitra. Octopus was recorded from Chetlat and Bitra where they were found in plenty over the reef. In recent times on an average 20 tonnes of these are landed annually in the Lakshadweep islands. *Octopus macropus* and *O. vulgaris* are common in Minicoy, the former forming about 80% of the catch. Both species inhabit crevices in the reef-flat. The islanders use them as food and as bait for fishing.

Appukuttan (1973) observed nine species of coral boring bivalves causing destruction to the fringing reefs of the Islands. They belong to the genera *Lithophaga Botula, Petricola, Gastrochaena* and *Jeuannetia*. Appukuttan and Pillai (MS) observed that the molluscan fauna of Lakshadweep is similar to that of other islands

Fig. 5. *Tridacna* sp. the giant clam that grows to more than half a metre in length.

in the Indian Ocean. They have listed 48 gastropods and 12 bivalves and found the abundance of gastropods in number and species particularly in the littoral and eulittoral reef-flat habitats.

The important families of gastropods observed in Lakshadweep are Patellidae, Trochidae, Neritidae, Littorinidae, Planaxidae, Strombidae, Cassididae, Cypraedae, Muricidae, Buccinidae, Conidae, Vasidae, Terebridae, Ellobidae and Cerethidae. Among the bivalves Arcidae, Mytilidae, Pectinidae, Ostreidae, Chamidae, Tridacnidae, Veneridae, Mactridae, Labitinidae, Tellinidae, Teredinidae and Pholadidae are the most important groups.

Among the gastropods found in these islands, Top shells (Trochidae), Spider conch (Strombidae), Cone shells (Conidae), Cowries (Cypraedae) and Helmet shells (Cassididae) are commercially important. *Trochus radiatus, Lambis* spp., *Arabica arabica, Conus* spp., *Charonia tritonis* and *Cassis cornuta* are some of the beautiful shells available in good quantity in these islands. Giant clams *Tridacna maximum* is found in good numbers in all the islands in the lagoon. Till 1980 good population of the giant clam was observed in the lagoon of Minicoy but at present dead shells of this clam are found in large numbers along with corals. The probable reason for large scale mortality can be siltation due to the dredging operation done in the harbour area. There was also an incidence of aggregation of large spider shells *(Lambis truncata)* numbering 400–500 ranging 20–25 cm in length and weighing 1.15 kg in the lagoon during January, 1984 when water was calm. This species is not found very often in reef flat. It is understood from the older generation of fishermen of the islands that there was good settlement of green mussel *Perna viridis* in Amini Island 20 years back and was used for edible purpose by local people. At present no settlement of mussel is reported from any of the islands. *Cyprea monita* is found in plenty in the inner reef-flat and 1 kg of shell is valued at Rs. 30-40. Usually during low tide large quantities of shells are picked up by women and this has got a good market in the mainland.

Sponges

Thomas (1973, 1979 & MS) mentions 41 species of sponges from Minicoy including typical coral and shell boring species, such as *Spirastrella cuspidifera, S. inconstance* and *Cliona* spp. The common Indian bath sponge *Spongia officianalis* has been observed in Minicoy. Many sponges recorded from Minicoy are rich in Bromine and Iodine.

Echinodermata

Gardiner (1903) observed surface living holothurians very commonly, in Minicoy and mentioned about large numbers of a white variety living in sand. Burton (1940) recorded holothurians of several varieties in every

Fig. 6. *Holothuria atra* – a common sea cucumber on reef-flat and lagoon.

Fig. 7. *Thelenota ananas* – a holothurian used in the preparation of Beche-de-mer, an export product. (Photo courtesy : D. B. James)

pool in Chetlat. *Holothuria atra, H. seabra, Actinopyga mauritiana,* and *A. echinites* are the most abundant species in Minicoy. Ten species of echinoderms were recorded by James (MS) from Kiltan atoll of the northern part of the Lakshadweep. These include the

Fig. 8. *Bohadschia marmorata* - another holothurian used in preparation of Beche - de - mer. (Photo courtesy: D. B. James)

holothurians *Stichopus chloronotus, Bohadschia marmorata, Holothuria rigida, H. impatiens, H. pardalis, H. leucospilota* and *Actinopyga mauritiana.* The cake urchin *Clucila novaeguineae* and ophiuroid *Ophiocoma orinaceus* were the other echinoderms collected around Kiltan.

These information point to the possibility for a modest *Beche-de-mer* industry in a suitable location in the Lakshadweep.

Turtles

Bhaskar (1984) reports four species of turtles which occur and nest in Lakshadweep. They are the hawks-bill *(Erethmochelys imbricata),* the olive-ridley *(Lepidochelys olivacea),* the green turtle *(Chelonia mydas)* and the leather-back *(Dermochelys coriacea).* The last one is reportedly very rare.

The green turtles nest mainly during the southwest monsoon (June–September) on the Suheli Valiakara, Suheli Cheriakara, Tinnakara, Bangaram and Parali. A feeding and nesting population of green turtles are observed in Minicoy. A few hawks-bills and olive-ridleys also nest on Androth, Kadmat and Agatti islands. Trading in hawks-bill scutes through Mangalore existed in earlier years. Turtle fat especially that of the green, olive-ridley and the leather-back is used by islanders for water proofing the wooden boats.

A cautious approach to exploitation of the turtle population of Lakshadweep archipelago is necessary as their existence here with least human predation serves to conserve them in this niche. Therefore future activities of constructions, agricultural operations etc. along known nesting beaches may be carefully planned.

Birds

Alcock (1902) found the whole sand banks of Pitti island literally covered with the young of two species of terns. The only specific study on the birds of the Lakshadweep islands seems to be that of Betts (1938). Of the 44 species of birds reported by Betts there were several shore and water birds like plovers, terns, sand pipers, shear waters, teals and herons.

Marine ornamental fishes and other marine organisms

Trade in marine ornamental fishes for home aquaria in different parts of the world started some time in the mid sixties. Philippines, Indonesia, Singapore and Sri Lanka are some of the countries exporting marine ornamental fishes. Mostly marine species caught in the wild are used in this trade. Most salt water ornamental fishes come from coral reefs.

Cheap to very expensive ornamental fishes are available. Sri Lanka price for a specimen of the file fish is reportedly 50 US $. (Kvalvas Gnaes, 1982). Varieties such as *Abudefduf, Amphiprion, Apogon, Coris, Balistes, Platax* and several other beautiful coral reef fishes are available in Lakshadweep. Ornamental invertebrate such as sea anemones, crustaceans, echinoderms and sedentary tube worms are also reared in marine aquaria and hence have marketing possibilities.

Limited exploitation of these hitherto untouched resources for capturing a share of the worlds ornamental marine organisms trade is worth attempting.

PROSPECTS OF DEVELOPMENT OF MARINE FISHERIES RESOURCES IN LAKSHADWEEP

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Introduction

The Central Marine Fisheries Research Institute in the past has carried out a number of research programmes in Lakshadweep especially around Minicoy, through its research centre located there. The investigations covered studies on the survey of fauna and flora of the Lakshadweep, the biology and fishery of tunas, the biology and fishery of live-bait fishes, other ancillary resources like sea weeds, sea cucumbers, lobsters and molluscs, oceanographic phenomena affecting the fish resources and coral reef eco-system. However, in recent times, the concentration of efforts was on corals, tunas and live-bait fishes.

A good data base has already been developed by the Institute on various marine resources of the islands and related conservation problems. However, the studies have been mostly confined to the seas around the Minicoy Island. Due to acute limitations of staff, residential facilities, vessel and other infrastructural facilities, the Institute was not in a position to undertake several other important programmes of the region. The Institute has now proposed certain priority projects which will be implemented as soon as the required facilities become available.

In the present paper, the potentialities and the areas where future research and developmental activities need to be directed are briefly discussed.

Tuna resources

Stock assessment studies have shown that there is good potential of tuna resources around the islands (Silas and Pillai, 1982, 1986). Currently, exploitation is in the near shore waters through pole and line fishing. Introduction of larger pole and line boats with storage facilities and simple navigational aids would facilitate the fishermen to move beyond the traditional grounds to scout for tuna shoals and obtain better catches. Apart from pole and line fishing, other operations like gill-netting, surface-trolling and long-lining suited for local conditions could be tried and popularised for tuna fishing which incidentally would help in reducing the pressure on live-bait requirements.

It is now well established that tunas are attracted by floating objects. Trials on fish aggregating devices have been conducted by a number of countries and several methods are now available. In Lakshadweep, a beginning has already been made in the setting up of 'Payao' type of fish aggregating device off Kavaratti Island by the Fisheries Department. The aggregating tunas are caught by the traditional gears. The method with modifications if needed can be extended to the whole region for increasing tuna catches in the small-scale sector.

Live-bait resources

An important component of pole and line fishing is the availability of coral-associated bait fishes. In recent times, acute shortage of live-bait fishes for the tuna fishery has been faced. The Institute, based on the continuous observations which were made over the past years attributed the following reasons for the shortage of live-bait fishes in the Lakshadweep.

Due to heavy exploitation of the live and dead corals from the islands, the bottom of the sea has been greatly disturbed, which resulted in siltation of the reefs and consequent large scale mortality of the live corals. This has also caused some amount of erosion around the island. The periodic dredging of the lagoon also contributed to disturbances of the bottom and consequent siltation killing the live corals. Since several invertebrate and vertebrate organisms are closely associated with the coral reef ecosystem, any damage caused to the coral reef results in damage to the populations of different organisms inhabiting the coral reef. The live-bait fishes form an important component of the eco-system and hence the populations appear to have deserted the disturbed areas.

The second reason for shortage of live-bait is the lack of recruitment of the young ones of these fishes to

the populations. The live-bait fishes of Lakshadweep are broadly classified into resident and non-resident or migratory species. If continuous exploitation of the live-bait takes place without proper recruitment, there would be a decline in the total populations of live-bait fish. The recruitments may also be affected by the meteorological conditions through strong wind and currents, which drive away the eggs and larvae of live-bait fishes to regions other than the conventional lagoon waters.

The third reason in declining the live-bait fish population is the increasing demand of these fish to meet the pole and line fishery for tuna. The tuna fishery a decade or so ago was restricted only to the Minicoy Island. But in recent times, the fishery has expanded to other islands as well, bringing in a catch of about 5,000 tonnes per year. This enlarged fishery naturally required more live-bait and hence exploitation of limited resources of live-bait has led to depletion of stocks.

The catch statistics for tuna and live-bait resources are mainly taken by the Institute from the information available with the local administration. Although the staff of the Administration have been trained by the Institute, comprehensive data on these resources are still wanting to cover effectively all the islands from where tunas are captured. For a proper management of the tuna fishery and steady supply of live-bait fishes for the local tuna fishery, reliable estimates of potential and exploited stocks are necessary. Through critical analyses of data collected systematically, it would be possible to plan ways and means of augmenting the live-bait resources. Therefore, future research programmes of CMFRI would concentrate on estimation of exploited and potential resources separately of tuna and the live-bait. In addition, surveys should be conducted to identify suitable resources of live-bait in the vicinity of the islands and develop methods to transport and maintain the stock for later use in the tuna fishery. Attempts should be made to identify promising species of fishes for artificial propagation and development of stocks to be used as live-bait. Since it is suspected that natural populations of live-bait are available in regions presently not exploited by fishermen, fishing at night through lights could be experimented upon. Attempts will also be made to identify alternate species which could be used as live-baits, for which experiments could be conducted. The possibilities of using artificial bait for catching tuna could also be a part of the over-all programme on live-bait fishes.

Coral conservation

As stated earlier, coral reefs form the habitat of live-bait fishes. At present the stock of these fishes is on a declining trend which inturn affects the pole and line tuna fishery. It is essential to preserve the coral reef eco-system of the islands if the marine resources of the region are to be stabilised (Gopinadha Pillai, 1983, 1985). This programme should involve (i) declaration of a few undisturbed and undamaged areas in the region as a marine park for the protection and preservation of the marine wealth. This would have the advantage of not only preserving the nature but also providing excellent tourist attraction; (ii) conducting experiments to rejuvenate and re-grow the corals by transplanting live and suitable species of corals into regions where they thrived earlier and (iii) adoption of a cautious approach to dredging and blasting operations in the lagoons.

Conservation of the eco-system and the marine resources assumes paramount importance in any future plans for the development of Lakshadweep.

Resources other than tuna

Tuna fishing and production of *'mas min'* are traditional occupations and the islanders have little attraction for other fishes. However, even without much organised efforts, one fourth of the landings in Lakshadweep is accounted for by fishes other than tuna which include important fishes like sharks, perches, carangids, half-beaks, belonids and seer fishes. (Jones and Kumaran, 1980). It may not be possible to exploit these groups of fishes by following the traditional methods like dragnets and castnets. Diversified fishing efforts like drift/gill-netting coupled with improvements in crafts to fish in farther waters would go a long way in tapping these resources. Commercially important crustaceans like lobsters and crabs and molluscs could be developed as minor fisheries, which in addition to enhancing production, will promote exports. Diversification of fishing effort would also help in providing employment and income to the fishermen during the tuna off season.

Several coral reef fishes are considered as excellent ornamental fishes for aquaria in many parts of the world. Many countries import marine ornamental fishes. Studies have shown that there are a number of small but colourful coral reef fishes like butterfly fish, surgeon fish and parrot fish in plenty in Lakshadweep. Collection methods, packaging technologies and transportation

facilities need to be developed so as to tap those resources for export trade.

The lagoons of Lakshadweep are rich in sea-weeds which have good potential for industrial purposes. However, indiscriminate harvesting would adversely affect the stocks. The sea-weed resources will have to be monitored continuously so as to arrive at yield levels which would be sustainable and at the same time do not affect the live-bait and ornamental fisheries.

Limited experiments conducted in Bangaram lagoon for pearl oyster culture showed encouraging results. Further research will be required to study the technical feasibility and economic viability before large-scale programme can be introduced. It may also be worthwhile to undertake investigations on the feasibility of introducing aquaculture programmes for resources suitable to the island conditions.

Storage, product development and marketing

With increased production of tuna and other fishes through developmental efforts in the coming years, preservation, processing and marketing assume great importance. Suitable post-harvest technologies and the needed infrastructure will have to be provided. Even though smoked and cured *'mas min'* from tuna prepared indigenously, is the major product today, methods for improving the quality of *'mas min'* and development of new products from tunas and other fishes will have to be attempted keeping in view the market preferences. Through proper extension methods, utilization of unconventional fishes and their products can be popularised for local markets. But the bulk of the extra production will have to find markets in the main land or in other countries.

Remote sensing

The problems of Lakshadweep are varied and peculiar. For achieving rapid progress, the government has earmarked funds in VII Plan for several development projects with more emphasis on science and technology. The Institute from its side would be able to employ the latest techniques for exploration, research and management. Use of remote sensing for dilineating productive areas of the sea is one such attempt where the Institute has developed expertise in collaboration with Indian Space Research Organisation.

Quantification of biological parameters such as phytoplankton pigments, using bio-optical algorithm is possible through remote sensing techniques. These phytoplankton pigments are the prime synthesizers in the marine food chain and can serve as a link with commercially important fishes through its conversion to other levels in food chain.

By time-series maps from satellites such as IRSS, LANDSAT and NIMBUS-7 it would be possible to estimate the basic productivity in the sea around Lakshadweep so that aggregation of fish schools could be predicted. It would be also possible to evaluate the ecological changes, nature of vegetation, extent of pollution and shore-line changes using modern space technology methods.

Information base

A sound data base is a pre-requisite for planning of research and development of marine fisheries. Data will have to be collected through scientifically planned surveys. Information on physical, chemical, biological, meteorological and environmental parameters in relation to fisheries and data on fish landings, effort expended, economics of operations of various types of fishing units, marketing and socio-economics will have to be continuously gathered and studied. Shore as well as vessel-based programmes covering the entire region will have to be taken up for acquiring the requisite data. It would be possible then to estimate optimum sustainable yield of resources and inter-relationship of fishery dependent and fishery independent factors with fish abundance facilitating fishery forecasting. Such an information base would very much help not only in critically reviewing the progress of the on-going programmes, in identifying bottlenecks and arriving at remedial measures but also for planning objective development programmes for years ahead.

Need for systems approach

Knowledge of the location, density and variations of the marine living resources, developing suitable crafts and gears as means of exploitation, meeting the requirements of man-power including trained personnel, making available the credit needed and providing infrastructure facilities for fish landing, processing, transportation and marketing are some of the important aspects concerned with the development of marine fisheries. Simultaneously the problem of conservation of the environment has to be effectively tackled to prevent any short or long term deliterious effects on the marine resources.

Some of the factors governing the marine sector are complementary but some others may lead to conflicting interests. Keeping in view the prosperity of the islanders, the inter-relationships and interactions of various components will have to be correctly understood. In this context it is desirable to follow a systems approach where the various components are treated as essential parts of the system instead of dealing each problem or a group of problems in isolation at their own merits. In fact, marine fishery itself could be taken as a major component of the total system for the development of the islands. Such an approach would help in bringing to light the complexities of the problem in the correct perspective, in building up proper linkages between the different components and to ensure a fast and balanced growth of the economy of the islands.

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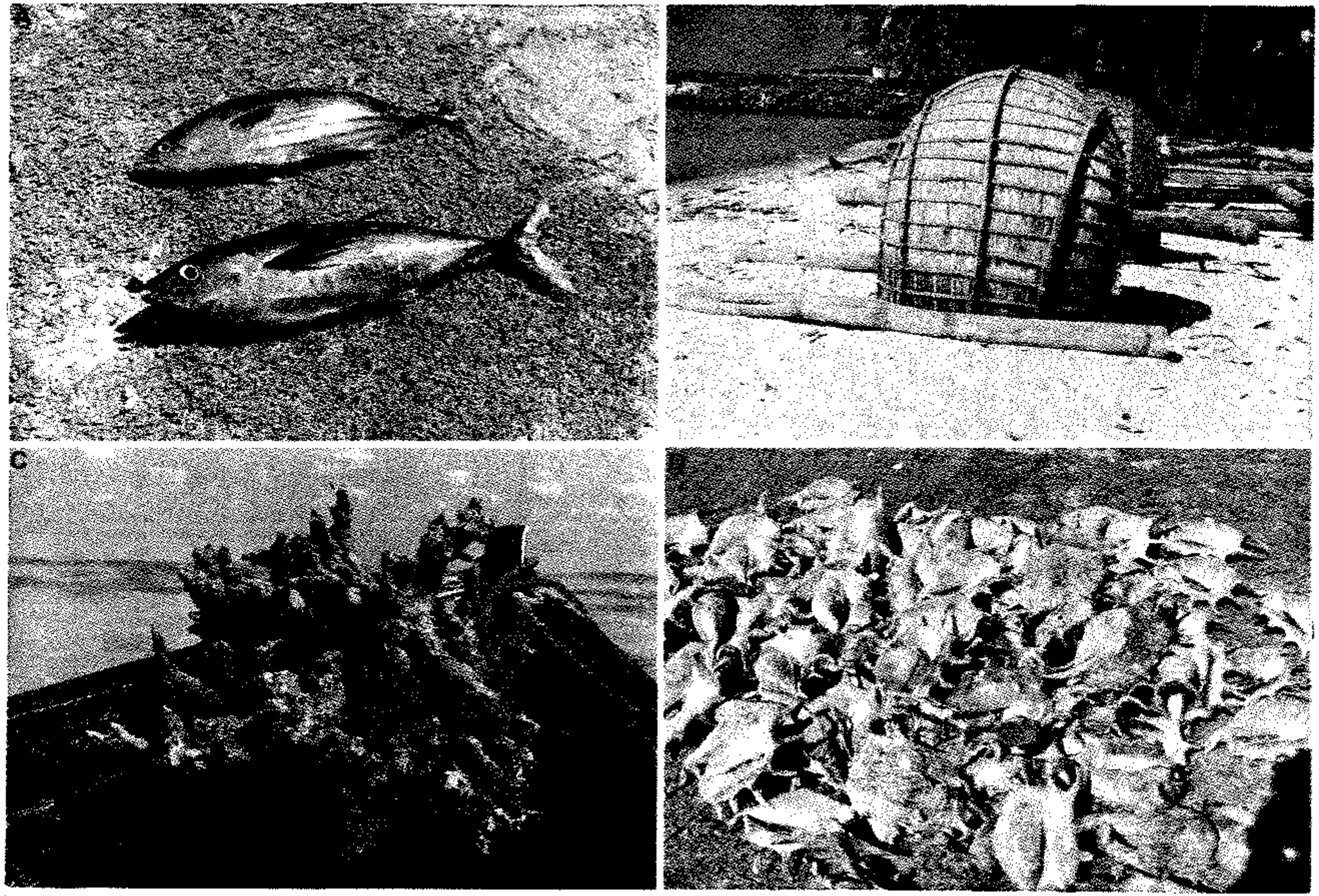

A. Two species of very common tunas in the Lakshadweep Sea. Above: skipjack (*Katsuwonus pelamis*) and below: yellowfin (*Thunnus albacares*).
B. The traditional tuna live-bait basket commonly used for keeping live-bait fish in captivity.
C. A collection of recently dead corals (*Acropora* sp.) from Minicoy lagoon.
D. A heap of shells of *Lambis truncata*, an ornamental mollusc, which made an unusual invasion into the Minicoy lagoon in 1984.