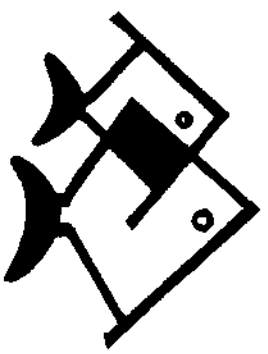
INDIAN FISHERIES

1947 – 1977



ISSUED ON THE OCCASION OF THE FIFTH SESSION OF
THE INDIAN OCEAN FISHERY COMMISSION HELD AT COCHIN FROM
19TH TO 26TH OCTOBER, 1977

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fisheries research

The fishery research activities in the country were modest prior to 1947. It was mostly species-oriented and centred around the studies on the taxonomy of fish and descriptive natural history carried out by individual scientists working in isolated places. With the realisation of the importance of research for quicker development and rational management of fisheries, specialised research institutions were set up, and organised research activities on multiple aspects of fisheries got gradually established.

Fishery Research Institutes

Premier Institutes concerned with fisheries Research and Survey in the country are:

1. Central Marine Fisheries Research Institute (CMFRI), Cochin
2. Central Institute of Fisheries Technology (CIFT), Cochin
3. Central Inland Fisheries Research Institute (CIFRI), Barrackpore
4. Pelagic Fishery Project (PFP), Cochin
5. Integrated Fisheries Project (IFP), Cochin
6. Exploratory Fisheries Project (EFP), Bombay
7. National Institute of Oceanography (NIO), Panaji
8. Zoological Survey of India (ZSI), Calcutta

Besides these, several conventional Universities as well as the Departments of Fisheries of State Governments and recently certain Agricultural Universities also carry out research on topical or regional interest.

MARINE FISHERIES RESEARCH

Marine fisheries research in any organised scale in India was first carried out in the Madras Presidency

with the establishment of Marine Biological Stations at Krusadi, West Hill and Ennore. The studies carried out between 1908 and 1946 was mainly on the fishery and biology of mackerel, sardine, anchovies, sharks, soles; on the causes of fluctuations in pearl and chank fisheries and on marine biological aspects such as inshore plankton and hydrography.

After the establishment of the Central Marine Fisheries Research Institute in 1947, marine fisheries research was put on a sound footing. The basic objectives of the Institute have been to collect and consolidate all available marine fisheries resource data which provide the vital information for all development programmes of the Centre and States; to understand the biology of most of the commercially important species and to monitor their stock for proper management, judicious exploitation and conservation; to conduct exploratory surveys and map out the productive fishing grounds and locate new areas and resources; to carry out environmental studies in relation to fisheries and recently to evolve methods of augmenting natural resources through mariculture of suitable marine organisms.

CAPTURE FISHERIES

Marine fishery resources of the country comprise chiefly of:—

i) Major Pelagic resources such as oil sardine, mackerel, seerfish, tuna and other pelagic resources of regional importance such as lesser sardine, anchovies, and ribbonfishes;

ii) Demersal fishery resources such as perches, sciaenids, catfishes, polynemids, flatfishes, pomfrets, eels, sharks, skates, rays, and fishes which are mainly caught by trawls;

iii) Mid water fishery resources constituted by Bombay duck, silverbellies and horse mackerel;

iv) Crustacean fishery resources consisting of prawns, shrimps, lobsters and crabs;

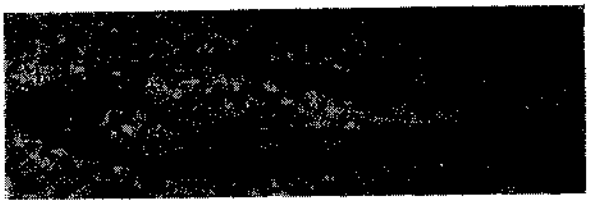
v) Molluscan fishery resources such as chank, oysters, mussels, clams, squids and cuttlefishes and

vi) Sea weed resources.

PELAGIC FISHERY RESOURCES

Oil sardine (*Sardinella longiceps*)

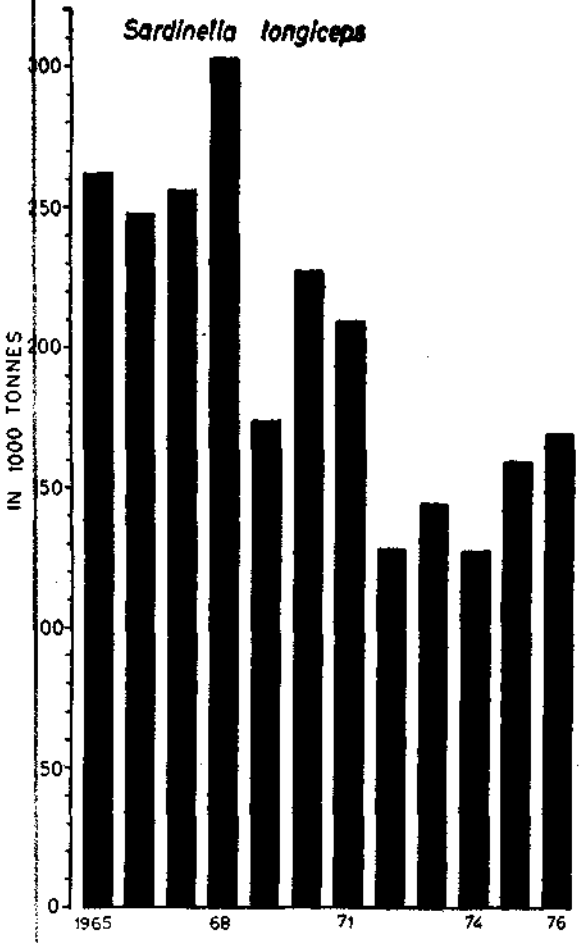
Oil sardine is the most important resource in the neritic pelagic zone off the west coast of India. The coastal areas between Quilon in Kerala and Ratnagiri in Maharashtra are the rich and traditional fishing grounds for the oil sardine; although in certain years its commercial abundance extends to other sections of the west and east coasts.



Oil Sardine *(Sardinella longiceps)*

Scientific studies made during the past three decades on the oil sardine have collected valuable information on the ecology, biology, fisheries and population characteristics, and on the resource. It is fairly clear now that the species lives in the neritic pelagic habitat and completes its life history in the area of its commercial distribution mainly off the west coast of India. Oil sardine breeds in the shelf waters off the south west coast over an extended period and area. The species has a high fecundity. The eggs are ripened and released in several batches. The main spawning, however, takes place during June-September period. Once the spawning is completed, the adult fish moves away from the inshore grounds and later appears to migrate to the southern regions. The eggs and larvae are pelagic and the eggs hatch out into larvae within a day. The larvae get transported with the prevailing current to the southern areas which form the nursery grounds. The prevailing current system in the breeding grounds thus seems to play a vital role in the spatial and temporal distribution of the oil sardine larvae. The young sardines, when they have grown to a size of 10–12 cms form into small discrete schools just prior to their migration into the inshore belt for feeding on the abundant plankton produced during the southwest monsoon period following the coastal upwelling. The food of the young and adult oil sardine consists of plankton which is abundant in the grounds. It is indicated that the areas and

periods of upwelling favour intense schooling and aggregations of oil sardine. The distribution pattern of the species appears to be similar to mackerel but with a tendency to be distributed closer to the shore.



Annual catch of oil sardine

After the monsoon, when the upwelling ceases, the oil sardine schools which are no longer restricted in their vertical distribution start to disperse and the schools move closer to the coast and become available to the shore based traditional fishery. The distribution of the stock along the coast varies, but during recent years the bulk of the biomass has been observed between 10° and 13° N.

The oil sardine during its early life grows very fast and has a longevity of 4 years. The species breeds at a size of 14-15 cm when it has completed one year's growth.

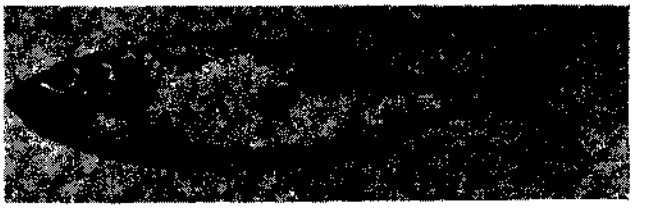
The traditional fishery is supported mainly by the fish of length range 10–16 cm comprising mostly 0-year and 1 year olds. The fishery starts immediately after the southwest monsoon and lasts from August to March with a peak during September - December period. Large shoals first appear in the southern area and strike the coast gradually in succession in the northern areas and disappear towards the end of the season in the reverse order. The fishery is restricted to a narrow coastal belt and is considered to be based on a unit stock.

The average standing stock of the oil sardine in the fishing grounds is estimated to be of the order of 400,000 tonnes. The mortality rate of the population in the fishing grounds is found to be about 80% (M = 1.12) per year, and the exploited resource forms only about 30% (F = 0.54) of the stock. Further, hardly a fraction of the spawning stock is taken by the traditional fishery. A part of the stock that is found beyond the present fishing grounds, is known to consist mainly of larger adult fish. These situations point out that considerable increase in the catches is possible by stepping up fishing pressure in the offshore grounds, employing efficient fishing methods such as pelagic trawl and purse-seining.

Large scale fluctuations in the fishery are due to fishery independent factors and the variations in the numerical strength of newly recruited year class to the fishery.

Mackerel (*Rastrelliger kanagurta*)

Rastrelliger kanagurta popularly known as the Indian mackerel, contribute to a fishery of very high magnitude in the country. Its average annual landing during 1950–76 was 69,818 tonnes varying largely

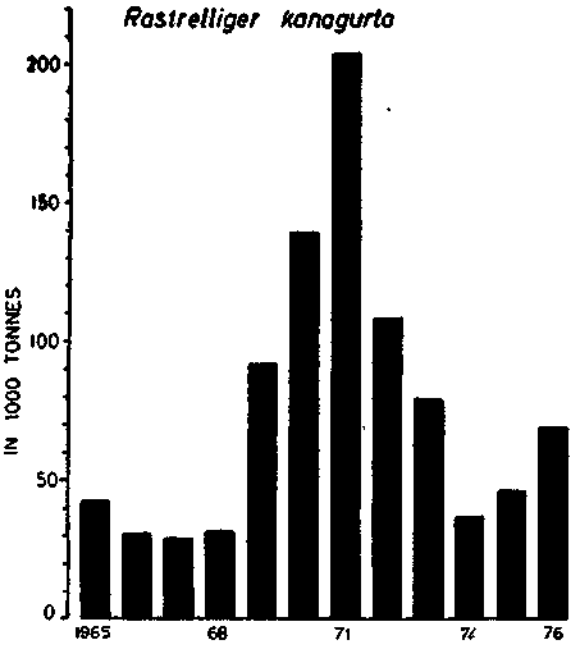


Indian Mackerel *(Rastrelliger kanagurta)*

from year to year from 16,431 tonnes in 1956 to 204,575 tonnes in 1971. On an average it accounts for about 8% of the country's marine fish landings.

Mackerel is widely distributed along the Indian coasts including Andamans. However, about 90% of the total catch is landed in the regions between Quilon and Ratnagiri along the west coast. The yield from Kerala is as high as 35%. But the fishery is of great importance in Karnataka and Goa, where it accounts for 28% and 50% respectively of the total marine fish production of these regions. The species supports a minor fishery in Tamil Nadu, Pondicherry and Andhra Pradesh along the east coast. The Indian mackerel along with the short-bodied *Rastrelliger brachysoma* forms a fishery of local importance in Andamans. A third species *Rastrelliger faughni*, is recently reported to occur off the Madras Coast.

The fish spawns in the shelf waters in the areas of its distribution, for extended periods. The individual fish releases eggs in batches. Major spawning is noticed around and during the southwest monsoon season in the west coast and during the northeast monsoon period along the east coast. Recently,



Annual catch of mackerel

the larval and post-larval stages of the mackerel have been identified and their distribution and relative abundance along the southwest coast have been charted out. The larvae and juveniles are most frequently observed between 9° and 13° N. around 30 metres depth zone. Information on the fecundity of the fish at present is very scanty.

The fish feeds mainly on zooplankton. Studies on the food and feeding habits have suggested a broad correlation between the abundance of food in the sea and availability of the shoals in the fishing grounds during the post-monsoon months.

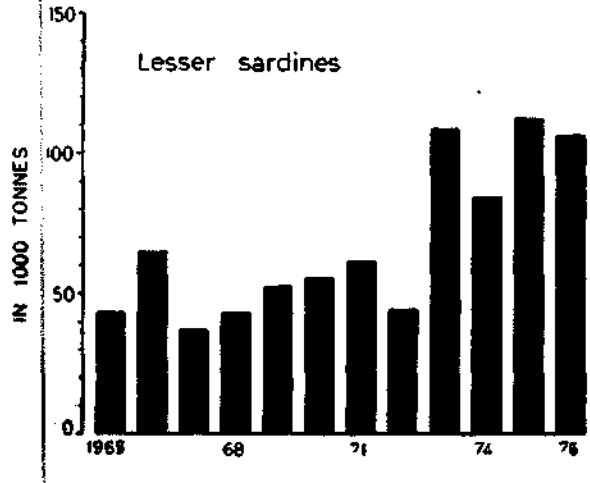
The fishing season on the west coast begins in July-August and ends by April, the peak season being November-December. It starts early in the south and lasts longer than in the north where it commences late and closes early. The fishery is sustained by immature fish, mostly 16 to 20 cm in size believed to be mostly of 0-year class fish. As the stock consists mainly of a single year class it is susceptible to large variations in recruitment and mortality. This explains to a great extent the wide annual fluctuations in the stock size.

The aerial and acoustic surveys carried out along the southwest coast have indicated an average stock size of about 280,000 tonnes and confirmed their offshore occurrence particularly between 24 and 72 metres. A considerable portion of the stock, particularly the juveniles, migrate to inshore waters after the southwest monsoon while much of the adults remain offshore. The total mortality of the stock in the fishing grounds is found to be about 90%. Studies on the exploited fishery resources indicate that the scope for further increase of production in the coastal grounds employing traditional non-mechanised fishing operations during the conventional season is just marginal. But the offshore resource at present is almost unexploited. The stray catches of larger size mackerel from the deeper waters along the Maharashtra Coast points to the availability of mackerel resource in a wide area in the sea. Further, the mackerel resource in the Andamans also remains at present underexploited. Information on the resource potential of the oceanic species, *Rastrelliger faughni* is scanty. Thus, there is great scope for intensive research on resources aspects of mackerels and their exploitation in the offshore areas by employing suitable fishing techniques such as purse-seining.

Lesser sardines

Lesser sardine (*Sardinella* spp.) catches come almost entirely from Andhra Pradesh (20%), Tamil

Nadu (28%) and Kerala (36%). The annual yield varies between 50 and 90 thousand tonnes forming about 6% of the total marine fish catch. *Sardinella gibbosa, S. fimbriata, S. albella* and *S. sirm* are the commercially important species. The other species are *S. dayi, S. clupeoides, S. sindensis* and *S. melanura. S. gibbosa* occurs singly or along with *S. albella* or *S. fimbriata*. Similarly, *S. sirm* usually occurs along with *S. clupeoides*. The lesser sardine fishery, which is restricted to the inshore waters, within 25 km from the



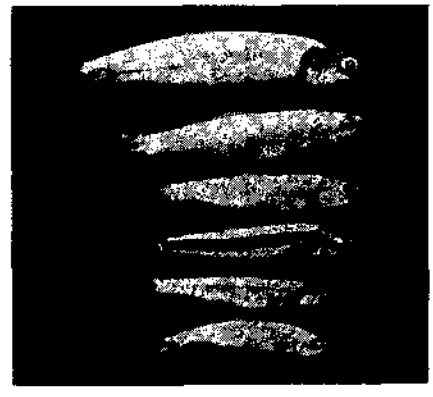
Annual catch of lesser sardines

shore, is mainly supported by o-year class fish. The fishery lasts from October to April. The catchs are usually heavy during the dark phase of the moon. *S. gibbosa, S. albella* and *S. fimbriata* have more or less the same rate of growth reaching about 120-130 mm total length at the end of one year of life, and also have a similar length of about 110 mm at the time of attaining sexual maturity. Though the overall spawning period of each species appears to extend from December to August, it is relatively brief in the different sections of the coast. March-June is the main spawning period for the foregoing three species. Each individual fish spawns once during a season. *S. sirm* on the other hand, attains 170 - 180 mm length at the end of first year of life and has the spawning season spread almost throughout the year. An individual fish seems to spawn more than once during a season in the nishore waters. Gulf of Mannar has been found to be a good spawning ground. Early life history of *S. gibbosa* and *S. sirm* has been described. The lesser sardines have similar food preferences, zooplankton (copepods) being the most dominant food item.

Some aspects of the biology of the sardine, *Herklotsichthys punctatus*, an important clupeoid around Andamans and of the white sardine, *Escaulosa thoracata* have also been investigated.

Anchovies

Species of *Stolephorus, Thryssa, Thryssina, Setipinna* and *Coilia* constitute the anchovy fisheries of the country. The average annual catch of anchovies is about 48,000 tonnes. *Stolephorus* spp. popularly known as white-baits, are the most important among them with annual average catch of 34,000 tonnes and accounts for 70% of the total anchovy catch. At present, the catch of this fish is obtained almost entirely from Andhra Pradesh (18%) Tamil Nadu (32%) and Kerala (44%). *Stolephorus heterolobus, S. devisi* and *S. bataviensis* form the bulk of white-bait catch. They occur in the catches either singly or together. *S. buccaneeri* and *S. indicus* are the two next important species occasionally contributing to very good catches. *S. andhraensis, S. macrops, S. commersonii* and *S. tri* are also recorded in the catches.

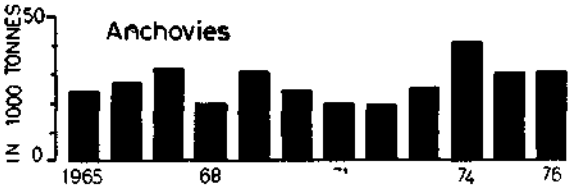


Anchovies

The present trend of exploitation indicates that over 70% of the white-bait catch along the southern half of the west coast comes from the region between Cape Comorin and Quilon. The white-bait stock north of Quilon is usually located between 8 - 32 km from the shore, while in the south, they are frequently found quite near the coast. White-baits exhibit typical diurnal vertical migrations, and occur mostly in areas with bottom depths between 20 and 50 m. They also exhibit seasonal movements along the west coast. Moving southward around April/May, they accumulate in the Gulf of Mannar during August/

September, after which they disperse along the southwest coast. Highest proportion of their stock is found in the area between Quilon and Mangalore during November/December.

The fishery seasons are during June-July and October-November along the southwest coast, from May to November along Tamil Nadu and November to April along the Andhra Coast.



Annual catch of anchovies

The fishery is constituted mainly by 0-year class fish, the mean age being 0.5 year. They also spawn at this age. White-baits are multiple spawners and have an extended period of spawning lasting from November to July. They spawn over a wide area on the inner continental shelf. White-baits feed mainly on zooplankton. The distribution of the white-baits schools generally coincide with the high density areas of plankton.

The average annual standing stock of anchovies may be around 376,000 tonnes. Estimates as high as 809,000 tonnes are also on record. In fact, white bait stock has been estimated to contribute to about 35% of the total fish biomass along the southwest coast extending upto Ratnagiri.

The bionomics of other anchovies such as *Thrissina baelama, Thryssa hamiltonii, T. purava, T. mystax, Coilia dussumieri, C. ramacarti, Setipinna phasa*, and *S. taty* which account for about 1% of the annual marine fish catch have also been studied.

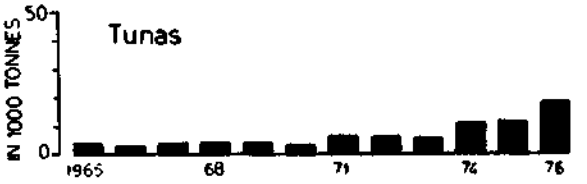
Other clupeoids

Among the other clupeoid fishes, the bionomics of *Hilsa ilisha* have been studied in great detail. Recently, success has been achieved in the artificial fecundation of this species. Hatchings thus produced and reared in tanks lived for more than 2 years exhibiting normal growth.

The bionomics of the rainbow sardine, (*Dussumieria acuta*) and of the two species of wolf-herrings of the Palk Bay and the Gulf of Mannar have been studied. Contrary to what has been believed earlier, the wolf herring fishery of the Palk Bay and the Gulf of Mannar is supported mainly by *Chirocentrus nudus* Swainson; the other well-known species *C. dorab* (Forskal) accounting for only 20% of the catches. The gulf of Mannar area has been found to be the spawning ground for both the species.

Tunas and billfishes

The average annual catch of tunas in India has been 4,000 tonnes during 1960's, but in the recent past the catches have shown signs of improvement. In 1976, the tuna landing of the country has been estimated at 20,000 tonnes. Excepting in Lakshadweep islands where the oceanic skipjack (*Katsuwonus pelamis*) and the yellowfin tuna, *Thunnus albacares* are fished in considerable quantities, there is no organised tuna fishery in India. The species such as the frigate mackerel (*Auxis thazard* and *A. rochei*), the bonito (*Sarda orientalis*), the little tunny (*Euthynnus affinis*), and the northern bluefin (*Thunnus tonggol*) are obtained from coastal waters in gears operated for other species. Kerala accounts for about 50% of tuna catches in India.



Annual catch of tunas

The tuna and tuna live bait fishery in the Minicoy, have been surveyed. Accounts of eggs, larvae and juveniles of tunas and related groups from Indian Seas have been given. The food and feeding and other aspects of biology of *E. affinis* have been studied. A comprehensive review of the helminth and copepod parasites of scombroid fishes has been carried out. Oceanographic parameters such as thermocline, areas of seasonal upwelling, convergence and divergence zones of the southwest coast and the southeast of Minicoy, primary and secondary production relating to tuna ecology have been studied.

Seerfishes

The average annual catch of seer fishes is about 15,000 tonnes which represent about 1% of the total marine fish landings of the country. Three species, namely, *Scomberomorus commerson, S. guttatus* and

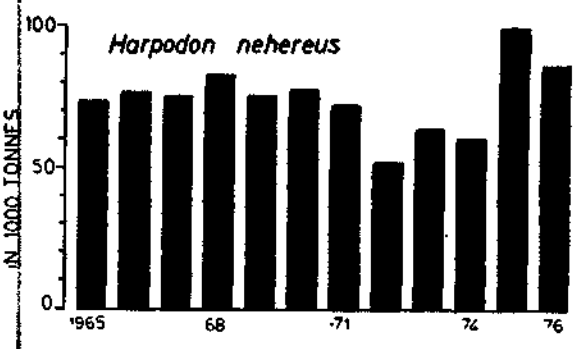
Annual catch of Seerfishes

S. lineolatus contribute to the fishery. The fishing season extends from October to March. The seer fishes are mainly caught in drift nets and by hooks and lines. *S. commerson* attains a length of one metre or more.

Mid Water Fishery Resources

Bombay duck

The Bombay duck, popularly known as "Bombil" is supported by a single species, *Harpodon nehereus* (Ham). It has a wide but discontinuous distribution along the east coast of Africa, the Indian subcontinent, Malaya, Indonesia and China. Saurashtra Coast in Gujarat and the Konkan Coast of Maharashtra, account for about 90% of the Bombay duck landings. The remaining 10% is caught in Andhra, Orissa and Bengal.



Annual catch of Bombay duck

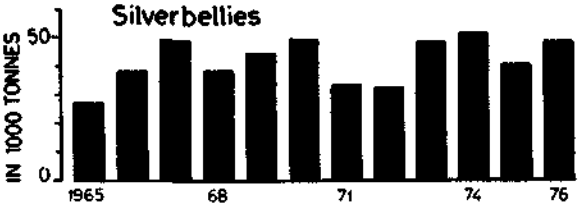
The fishing methods are as varied as its distribution. On the Maharashtra and Saurashtra Coasts it is exclusively caught in the bag net ("Dol"). The fishing operations are carried up to a depth of 40 m. In Bengal and Orissa also bag nets are in vogue, while in Andhra, seines are the principal gears.

The catch of the Bombay duck fluctuated from about 15,000 tonnes in 1950 to about 100,000 tonnes in 1955. The catch touched a new high in 1960 with a landing of about 108,000 tonnes. It is showing a declining trend since then.

H. nehereus attains maturity at about 210 mm when it is at the end of the first year of its life. It spawns almost throughout the year with two peaks in October-November and March-April. The commercial fishery is mainly supported by the 0-year class. The declining trend of catch, catch per unit of effort, average size of the fish and capture of high percentage of juveniles during the last fifteen years indicate overfishing of the Bombay duck along the north-west coast.

Silverbellies

Silver bellies belonging to the genera *Leiognathus* and *Gazza* contribute to 4 to 5% of the total annual marine fish catches. These small fishes form good

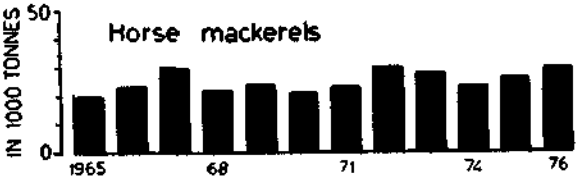


Annual catch of Silverbellies

raw material for the fish meal plants, fish protein concentrate and other fish products. They are generally included in the category of 'trash fish'. The catches comprise mostly of fish less than one year old (0-group); their life span seems to be less than two years.

Horse mackerels

This group of fishes include mainly *Megalaspis cordyla* and few other carangids and they occur all

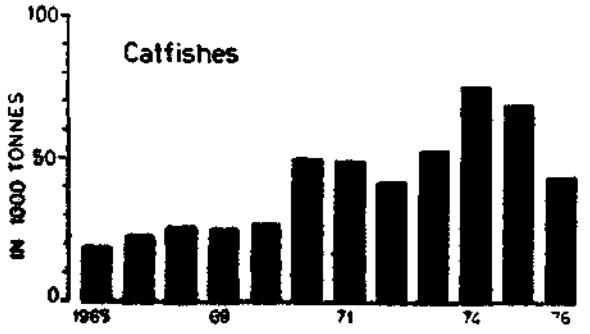


Annual catch of Horse mackerels

along the Indian Coast, forming annually about 2% of the total marine fish landings. They seem to breed almost throughout the year.

Demersal Fisheries

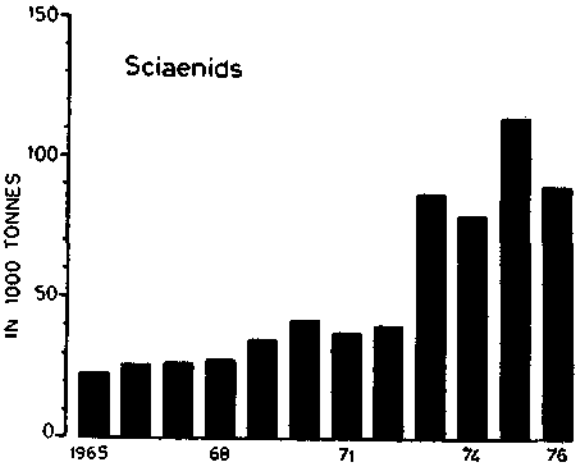
Though the traditional fishing in the country employed some indigenous gear that took in coastal demersal fishes, exploitation of demersal resources in a significant way is relatively recent. Attempts at trawling the offshore regions were first made by the turn of the century with fishing vessels like 'Golden Crown' (1908–11) in the northern Bay of Bengal, 'William Carrick' (1921–22) in Bombay waters, 'Violet' (1907), 'Lilla' (1920–23) and 'Nautilus' (1924–30) in the Wadge Bank area, and 'Lady Goschen' (1927–30) along the southwest and southeast coasts. The operation of these, and a few other vessels in the early decades were intermittant and systematic trawling of offshore grounds started only by the late forties by the exploratory fishing vessels belonging to the Government of India Organisations.



Annual catch of Catfishes

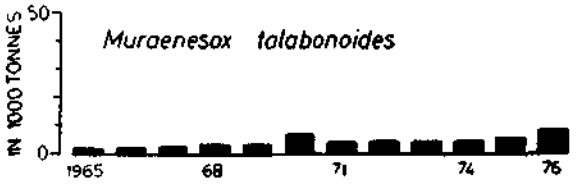
As a result of the above surveys, the demersal fishes and their resource in the grounds upto about 50 m depth have been fairly well studied and documented. The northwest region, consisting of the Bombay, Cambay, Veraval, Porbunder,Dwaraka and Kutch areas, has the most extensive shelf area (about 200,000 km²) and an abundance of such quality fish as Ghol, (*Pseudosciaena diacanthus*), Dara (*Polydactylus indicus*), Koth (*Otolithoides brunneus*), Karkara (*Pomadaysis hasta*) and a fair abundance of prawns in some areas. The yield and catch rates are high almost throughout the year, except for the third quarter when effort is low on account of the monsoon. Generally, better ghol grounds were found off Kutch, Porbunder, and Dwaraka; Dara and Koth off Dwaraka and Kutch; Karkara off Kutch, Dwaraka and Porbunder; eel in Cambay and off Veraval; garfish off Kutch and Porbunder and Prawns in Cambay and off Bombay.

In the southwest region the narrowness of shelf (about 43,000 km²) restricts trawling operations as compared to the north-west region. The existence of good fishing grounds in the Wadge Bank area is traditionally known to the fishermen of Kerala, Tamil



Annual catch of Sciaenids

Nadu and Sri Lanka. Rich prawn grounds are also located in this area in the inshore region. Recent exploratory surveys have indicated potentially rich fishing grounds for deep-sea prawns and deep-sea lobsters beyond the continental shelf edge, and for

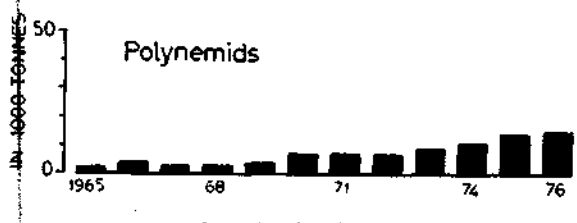


Annual catch of eel 'wam'

'Kalava' (*Epinephelus spp.* and *Pristipomoides* spp.) in the rocky areas of the shelf at 70–100 m depth off Kerala. Depth-wise, the littoral prawns occur mainly upto 30 m and decline thereafter, while fish are least upto about 15 m and increase beyond. Nemipterids form a significant resource in the 40–100 m areas.

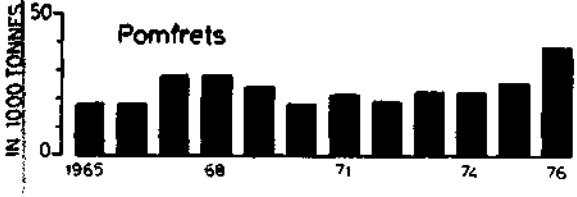
On the east coast, the trawling grounds are in general less extensive and quality fish too are less abundant. In the southeast region (about 64000 km²) the Pedro Bank area in the Palk Bay has been the traditional fishing grounds for fishermen from the

Tanjore Coast. Good trawling grounds have been indicated at Point Calimere, Nagapatnam, Tranquebar, Porto Novo, Cuddalore, Pondicherry and Madras; potentially good shark fishing grounds off Point



Annual catch of Polynemids

Calimere to Cuddalore: perch grounds from Point Calimere to Pondicherry and horse-mackerel from Pondicherry to Madras. The Palk Bay - Gulf of Manpar region has been found to be very productive for low quality fish like silver bellies which are dried



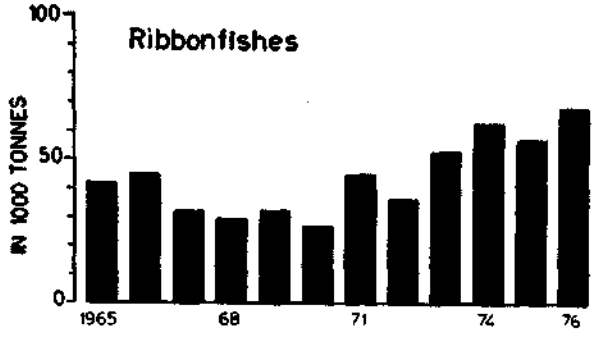
Annual catch of Pomfrets

or utilised for manufacture of fish meal. Recent explorations off Andhra Coast have given encouraging results particularly for the exploitation of prawns. In this region generally, fish catches give higher yield

Ribbon fish

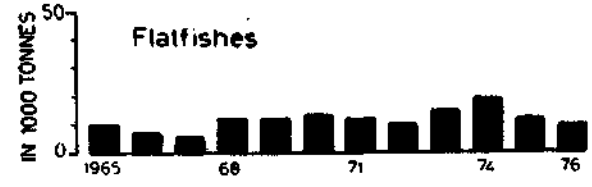
rates from the shallow (less than 50 m) areas in April-June and October-December, and from deeper areas in July-September.

In the northeast region off Orissa and West Bengal (46,000 sq. km) fishing was traditionally done in areas of tidal influence and the shelf was mostly unexploited.



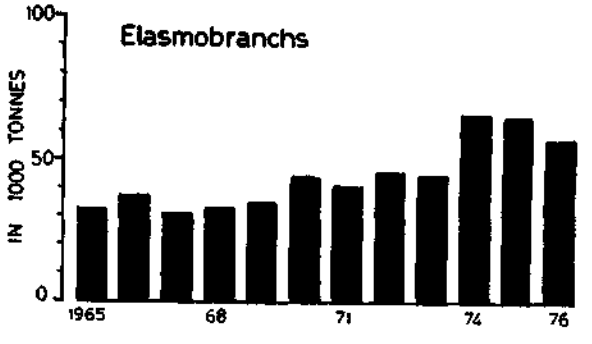
Annual catch of Ribbonfishes

The exploratory surveys have, however, revealed important grounds located off western and eastern channels, Sand Heads, Tiger Point, Baitarani, Debi, and Prachi River mouths, Black Pogada, Puri, Chilka



Annual catch of flatfishes

and Gopalpur. The "Swatch of no grounds" has been found to be good for quality fish. Areas off Chilka Lake and Kalingapatnam and some areas in the north Bay of Bengal have been found to be relatively rich grounds for commercial trawling. Quality fish

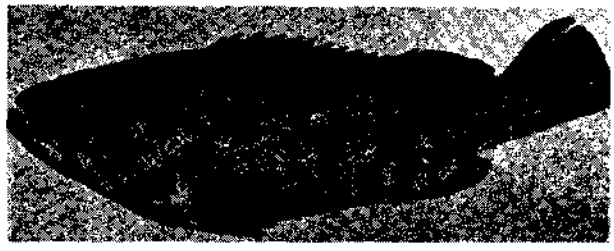


Annual catch of Elasmobranchs

like pomfrets, pomadasyds and prawns occur mainly in 10–30 m depth, others like sciaenids, clupeids,

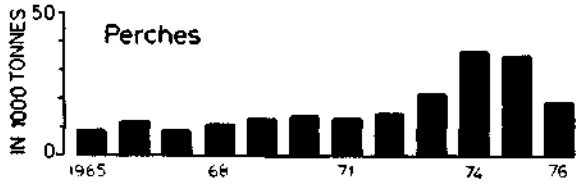
silverbellies, nemipterids, and carangids at 30–50 m and elasmobranchs, catfishes, etc. at 50 to 70 m depth.

Among the demersal fishes, perches contribute to 1.5 - 2%, sciaenids 4%, polynemids 0.7%, flatfishes



Perch

2%, catfishes 5%, and elasmobranchs 4% of the total marine fish catch of the country. Fishery and biology



Annual catch of perches

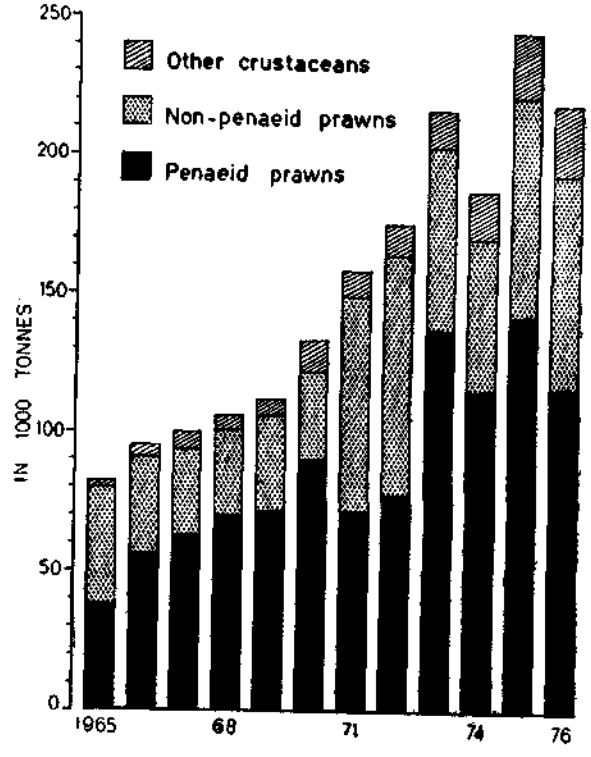
of the more important species such as *Nemipterus japonicus, Lactarius lactarius, Pomadyasis hasta, Pseudosciaena diacanthus, Polydactylus indicus, Cynoglossus macrostomus, Tachysurus thalassinus, T. tenuipinis, Pampus chinensis, P. argentius, Parastromateus niger, Muraenesox talabonoides, Scoliodon sorrakowah, Loxodon macrorhinus, Rhizoprionodon oligolinx, R. acutus* and *Himantura alcokii* have been investigated.

Crustacean Fisheries

Several species of prawns, shrimps, lobsters and crabs inhabiting different ecosystems such as seas, estuaries brackish-waters, creeks, lakes, rivers and canals contribute to the Crustacean fisheries of India.

Prawns and shrimps

Among the crustaceans, prawns and shrimps are the more important as they command a high price and have a great demand in the export market. About 52 species of prawns and shrimps that are either commercially exploited at present or have great commercial potentialities occur in the Indian waters. These belong to the families Sergestidae, Penaeidae, Palaemonidae, Oplophoridae Hippolytidae, Pandalidae and Atyidae. By intensive taxonomic studies, the identity and synonyms of these species have been well established and adequate background information for future studies has been made available. Most of the species exhibit wide geographical distribution in our waters as well as in the entire Indo-Pacific region. Bathymetrically, most of the prawns supporting the commercial fishery in the marine region are largely confined to the inner half of the continental shelf. However, depending on the productivity of the fishing grounds, physico-chemical changes in the ecosystem and movement of prawns, the abundance within this depth zone is found to vary in space and time.



Annual catch of crustaceans

The biological investigations carried out so far relate to age and growth, food and feeding habits, maturation and spawning, larval biology, mortality rate and some aspects of movements of the important commercial penaeid prawns (*Penaeus indicus*, H. Milne Edwards, *P. monodon* Fabricius, *P. semisulcatus* de Haan, *P. merguiensis* de Man, *Metapenaeus dobsoni*

(Miers), *M. monoceros* (Fabricius), *M. affinis* (H. Milne Edwards), *M. brevicornis* (H. Milne Edwards), *M. kutchensis* George, George and Rao, *Parapenaeopsis stylifera* (H. Milne Edwards), *P. sculptilis* (Heller), *P. hardwickii* (Miers) and *Solenocera crassicornis* (H. Milne Edwards) and some palaemonid prawns *Palaemon styliferus* (H. Milne Edwards), *P. tenuipes* (Henderson), *Hippolysmata ensirostris* Kemp, *Macrobrachium rosenbergii* (de Man), and *M. malcolmsonii* (H. Milne Edwards). A review of these studies shows that the littoral penaeid prawns of the Indian Coast have many similarities in their life history. This is particularly evident in species like *M. dobsoni, M. monoceros, M. affinis* and *P. indicus* that breed and spend their adulthood in the sea and juvenile stages in the coastal estuarine regions. *P. stylifera,* however, spends its entire life cycle in the marine habitat. All these prawns usually breed at some distance from the shore, but the peak spawning seasons vary from place to place. The early larval development also takes place in the sea. The distribution of larval stages in the inshore waters normally depends on the prevailing coastal currents to which they are subjected in the open seas. The location of spawning of adults and their inshore and offshore movements also affect the larval distribution. As the larvae develop they start moving towards the shore and on attaining the postlarval stage they reach the shallow coastal waters and estuarine nursery grounds where they assume a demersal existence.

After settling down to the bottom habitat, they grow fast feeding on plant materials, small animals and detritus available in the nursery grounds. They remain in this ecosystem for some time which varies from species to species. During this period of growth, they attain all the adult features including the secondary sexual characters, but do not breed there. This biological trait explains the return migration of prawns into the sea. In the sea, the prawns grow at a relatively slower rate and this retardation of growth rate is due to reproductive stress. From the observed growth rate, it is estimated that the species like *M. dobsoni, P. stylifera* and *P. indicus* live for two years, while the other species, *M. monoceros* and *M. affinis* have a slightly longer life span. Thus, while each of the species has its own biological characteristics, features such as their capacity to produce large number of eggs, protracted breeding season, spawning in the less exploited offshore areas, faster growth, short life span and the ability to withstand wide variations in the environmental conditions play an important role in maintaining their population and in the continued success of the prawn fishery of the country.

Some aspects of the physiology of the penaeid prawns, such as the rate of metabolism of *P. indicus;* osmoregulatory ability and food conversion efficiency of *M. monoceros* have been studied.

As regards the biology of the fresh water prawns, information on breeding grounds and seasons, nursery grounds, age and growth, food and feeding habits, reproduction and larval development is available in some detail, particularly for *M. rosenbergii* and *M. malcolmsonii.*

In India, prawns and shrimps are commercially exploited from all the three major aquatic environments, namely sea, estuary and fresh water. In the marine realm, they are caught all along the coast from the inshore waters by the indigenous as well as mechanised fishing vessels. The extensive estuarine systems of rivers like the Ganga, Mahanadi, Godavary, Krishna and Cauvery, and the brackish water areas like Chilka, Pulicat and the Vembanad lake support rich fishery for juvenile prawns. Fresh water prawn fisheries exist mainly in the peninsular rivers flowing into the Bay of Bengal, rivers of Maharashtra and the Pampa river system in Kerala.

The average annual marine prawn production of the country during the past ten year period (1966-1975) has been of the order of 1,35,242 tonnes, forming 13% of the total marine fish production. Penaeid prawns contribute to about 62% of the total prawn landings. The fishery is supported by multiple species that co-exist in the fishing grounds and is characterised by wide seasonal and annual fluctuations in abundance. Most of the commercial penaeid prawns are subjected to exploitation in the juvenile phase in the sea. The State of Maharashtra ranks first (47.5%) in prawn production followed by Kerala (30.7%), Andhra Pradesh (5.5%), Tamil Nadu (4.6%), Gujarat (4.1%), Karnataka (3.8%), West Bengal and Orissa (3.1%). However, the prawn catch of Maharashtra is chiefly composed of non-penaeid prawns. The highest catch of penaeid prawns is obtained from Kerala. In recent years, there has been significant increase in the penaeid prawn landings in all the east coast States.

In the All-India prawn landings, *P. indicus* contributes to about 8%, *P. monodon* 1%, *M. dobsoni* 28%, *M. affinis* 11%, *M. monoceros* 3%, *M. brevicornis* 2.5%, *P. stylifera* 28%, *P. sculptilis* 1.3%, *P. hardwickii* 2.5%, *S. crassicornis* 0.9%, *P. tenuipes* 3%, *P. styliferus* 0.6%, *H. ensirostris* 0.9%, *Acetes* spp. 3% and other miscellaneous prawns 6.3%.

Recent exploratory surveys carried out along the continental shelf edge and slope of the southwest and southeast coasts have located potentially rich fishing grounds for deepwater prawns. These grounds on the southwest coast are about 5000 km² in extent and the potential prawn resources of the area is estimated to be about 5300 tonnes per year. The average catch rate recorded is 120.3 kg/hr. Commercially important species encountered in the catches are *Aristeus semidentatus, Solenocera hextii, Penaeopsis rectacuta, Metapenaeopsis andamanensis, M. philippi, Parapandalus spinipes, Plesionika martia, Heterocarpus woodmasoni* and *H. gibbosus.* Certain aspects of the biology and fishery of these prawns have been studied.

Prawn and prawn products form the most important commodity in the export trade of marine products from the country. With progressive increase over the years, the export of this commodity in 1976 reached a figure of 48,090 tonnes valued at 1610.8 millions rupees which represent 77% of the total export of marine products in weight and 89.6% in terms of value. A variety of products like frozen prawns, canned prawns, dried prawns, prawn powder, prawn pickle, etc are exported to over 50 countries in the world.

Lobsters

The lobster fauna of India includes species belonging to the families Eryonidae, Nephropsidae, Scyllaridae and Palinuridae. Eighteen species representing nine genera in family Palinuridae have been reported from the Indian Ocean region. Among Scyllaridae 20 species comprising five genera also occur in the same region. The families of Nephropsidae and Eryonidae are represented by about 7 and 10 species respectively.

The lobster fishery of India is supported by 6 specie of shallow water spiny rock lobsters belonging to the genus *Panulirus,* namely, *P. homarus, P. polyphagus, P. ornatus, P. penicillatus, P. versicolor* and *P. longipes,* and one species, *Thenus orientalis,* belonging to the family scyllaridae. Of these, three species (*P. homarus, P. polyphagus* and *P. ornatus*) are commercially exploited. The annual catch of lobsters in 1976 was 6,233 tonnes realised mainly from Gujarat, Maharashtra and Tamil Nadu. The export of frozen lobster tails during the same year was of the order of 513 tonnes valued at 31.8 million rupees.

Some aspects of the biology and fishery of *P. homarus* have been studied. The species breeds during November-December in Kanyakumari District where the fishery for the species is most prevalent. Tagging experiments conducted with suture tags have shown that the movement of the species in the fishing grounds is of a restricted nature and it grows very fast attaining the commercial size by the end of first year after the puerulus stage settles down in the fishing grounds. The size attained at successive ages has been estimated and the commercial fishery is largely supported by one and two years old lobsters.

Extensive studies on the phyllosoma larvae occurring in the Indian Ocean region and their distribution pattern have been carried out. Detailed description of the anatomy and the organ systems and information on chemical constituents, ash content, trace elements, natural radio active nucleids and amino-acids of *P. polyphagus* are available. Some data on the prephenolosidase properties of *P. homarus* are also available.

Recently, the exploratory trawling conducted along the continental shelf edge and slope off the southwest coast and Gulf of Mannar has revealed large concentrations of the deep-sea spiny lobster, *Puerulus sewelli,* at depths between 160–360 m. Another deep-sea lobster, *Palinustus mossambicus* was also caught in fairly good numbers from certain localities along the southwest coast. Distribution and seasonal abundance of *P. sewelli* in the fishing grounds on the continental slope of the southwest coast have been studied. From 1969 onwards the species is regularly exploited by the trawlers belonging to the Government of India.

Crabs

Faunistic investigations carried out from 1890 have revealed that about 560 species of crabs occur

in the Indian region. Of these, only 8 species, namely *Portunus pelagicus, P. sanguinolentus, Scylla serrata, Charybdis (Charybdis) feriatus, C. (C). annulata, C. (C). natator, Matuta lunaris* and *Varuna littorata* support localised fishery of some importance in the marine and brackish water regions. Insignificant quantities of the fresh water crab, *Paratelphusa* spp. are also captured in some of the Inland States where it forms the food of local inhabitants.

Studies on the biology of edible crabs are restricteg to certain aspects of the growth, food and feedind, reproduction and effect of parasites, but many of the observations are inconclusive. The morphology and anatomy of *P. sanguinolentus* are well documented. Recently investigations on the physiology relating to endocrine control of pigmentation, reproduction, histological and histo-chemical aspects of reproductive organs of certain crabs have been undertaken.

Available information on various aspects of the fishery shows that the fishing is restricted to the inshore areas mostly by the operation of indigenous crafts and gears. In most of the places crabs form an ancillary catch along with other crustaceans and fishes. The annual catch which amounted to 18,177 tonnes in 1976, is subject to marked fluctuations. The catches are largely obtained from the central Maharashtra, Karnataka and southern Tamil Nadu Coasts. Estimated potential resources of crabs in the inshore waters up to 40 metres depth and in the brackish water areas is found to be about 44,000 tonnes. In addition to this, recent exploratory surveys conducted in the Indian Ocean have brought to light the existence of deep water crab, *Charybdis (Goniohellenus) edwardsi* in large quantities.

Molluscan Fisheries

The molluscs form one of the less exploited resources of our waters. Researches carried out on this group mainly relate to the study of the specific identity of commercially important molluscs and identification of the areas of abundance; investigations on the fish and fisheries in selected centres; observations on the biology, reproduction and development of some important species and preliminary observations on the potentialities of certain areas and water masses. The species involved in detailed biological and fisheries studies are *Meretrix casta, M. meretrix, M. casta ovum, Villorita cyprinoides, Paphia malabarica, Katelysia opima, Donax cuneatus, D. faba, Solen kempi,* (all clams); *Crassostrea madrasensis, C. gryphoides, C. discoidea, C. cucullata* (all edible oysters); and *Perna viridis P.* sp. (green and brown mussel); *Sepia aculeata, Sepioteuthi sarctipinnis, Loligo duvauceli* (all cephalopods) and *Pinctada fucata* (pearl oyster), *Xancus pyrum* (chank). Extensive explorations of the molluscan grounds in the Gulf of Mannar have been carried out by aqua lung diving operations. Considerable information on the wood boring molluscs which are of industrial significance is also collected. The shell fisheries of Andaman and the Lakshadweep have been investigated. Although reliable statistics on the landings of molluscs from the country are not available.

Ecology of mangrove swamps

In India extensive mangrove forests and swamps occur in deltas of various rivers, estuaries, bays, islands and other sheltered areas. Virtually unexplored mangrove forests occur among Coromandel Coast, Sunderbans, Gulf of Cambay, north Kanara and Kerala Coasts. In recent years ecology of mangrove swamps in selected areas have been studied. Mangrove vegetation, resident and migratory fauna have been surveyed. Mangrove areas are very productive and offer shelter to juveniles of many species of fishes, prawns, crabs and other fauna. Investigations on mangrove swamps are of importance as they could be utilised for culture of edible oysters, prawns and certain fishes. Mangrove areas serve also as barriers against coastal erosion.

Ancillary Resources

Sponges

About 305 species of marine sponges have been recorded from India. Of these, the species *Spongia officianalis* var *ceylonensis* Dendy is commercially important. It is widely distributed in the shallow waters of the Gulf of Mannar, Palk Bay and the Arabian Sea and grows to a size of 30 cm in diametre generally a hemispherical shape. Its size, shape, colour, resistence, absorptiveness, durability, etc. are similar to those of other commercial species of sponges. Preliminary experiments conducted on the culture of this species have indicated the possibility of their culture on a large scale. A detailed study on the taxonomy and distribution of sponges has been undertaken.

Corals

Corals form one of the important organisms of considerable commercial value. In the seas around India, coral formations are found in the Gulf of Kutch, in Andaman Nicobar islands, Palk Bay and Gulf of Mannar (fringing reefs) in the Laccadive Archipelago (atolls) and in scattered areas along the continental shelf. Extensive investigations on the corals of the Palk Bay and Gulf of Mannar have been undertaken. Studies are also carried out on the ecosystem of the coral reef and productivity of the coral reefs and atolls.

The most important commercially valuable corals of the Indian Coasts are the Scleractinias. They form a major source of calcium carbonate and are used in the preparation of Calcium carbide, lime and cement, besides as building blocks and in the constructions of roads. Other economically important corals belong to *Heliopora, Tubipora,* gorgonids and *Antipatharia.*

Large scale quarrying of corals is undertaken at present in the Gulf of Mannar and Palk Bay region. Unrestricted destruction of the coral beds is adversely affecting the general fishery of the area as well as the reef dewelling animals. In order to protect the coral reefs of the Gulf of Mannar from human interference and to save some of the endangered marine species such as dugong (*Dugon dugon*), green turtles and other marine turtles which nest in the sandy beaches, it is proposed to establish a National Marine Park in the area. The proposal when implemented would not only help to conserve the marine ecosystem of the area, but also to utilise the experience gained to extend the concept to other areas such as Andaman-Nicobar Islands and the Lakshadweep.

Echinoderms

Comprehensive investigation on the taxonomy and distribution of echinoderms of India, particularly of the southeast coast have been undertaken. Although several echinoderms have economic importance, holothurians belonging to the families Holothuridae and Stichopodidae are commercially exploited, processed and exported as *Beche-de-mer.* At present over 68,000 kg of *Beche-de-mer* is exported from India to Hong-kong, Singapore and Sri Lanka. Holothurians occur in large numbers in the Gulf of Kutch and along the southwest coast. They are collected by divers in 3–12 m depth from February to September. They are also caught in appreciable numbers in trawls. *Holothuria scabra* is the species widely used in the country for the preparation of *Beche-de-mer.*

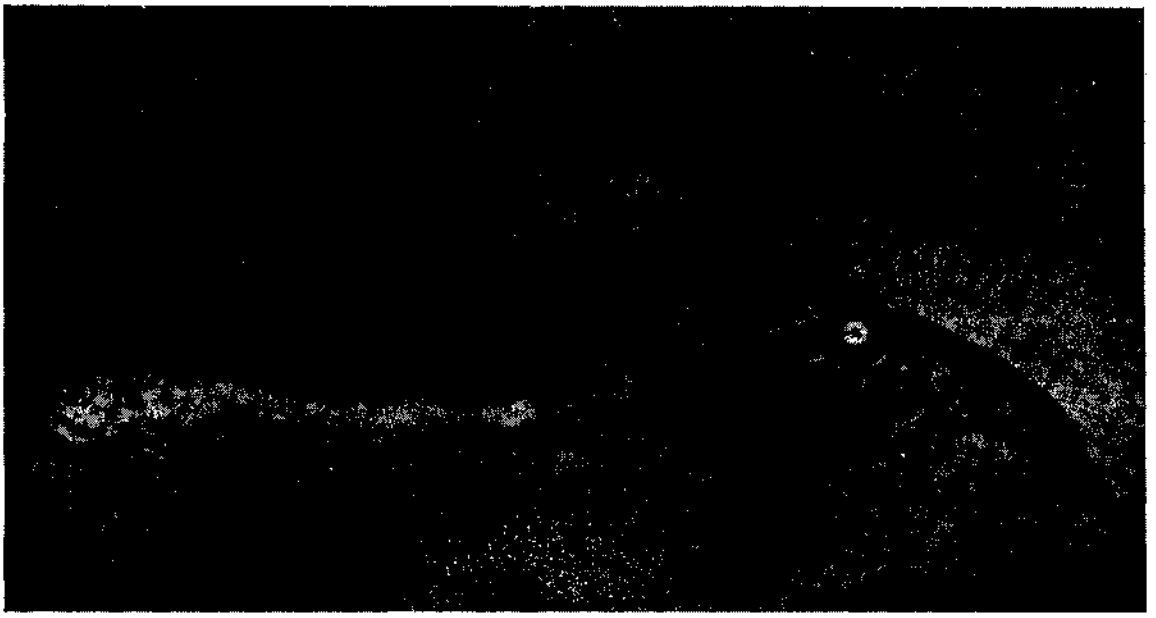
SEAWEEDS

Although there are no detailed systematic accounts for the identification of commercially valuable seaweeds, considerable work has been done on the taxonomy of the Indian marine algae during the last 40 years. Research on various aspects of commercially important seaweeds such as their identity, growth, reproduction and seasonal changes in chemical composition has been carried out in India. The distribution, rate of growth, life history, fruiting cycle, ecological conditions, mineral constituents, seasonal changes in mannitol, algin and agar contents of a number of commercially important green, brown and red algae like *Ulva* spp., *Dictyota* sp., *Padina* sp., *Sargassum* spp., *Turbinaria* spp., *Gracillaria edulis* and *Gelidiella acerosa* have been studied.

Recently as part of the programme on estimation and resources survey of the available sea weed resources in different regions, a comprehensive survey of the seaweeds of Tamil Nadu Coast has been conducted. The survey indicates that there are vast resources in the intertidal zone in the Gulf of Mannar, Palk Bay and the rocky regions between Rameswaram and Colachel. The density of distribution of the total algae is on an average 1 tonne per ha. Of these agarophytes form 10% of the total in the Gulf of Mannar and 40% in the Palk Bay. The alginophytes form the dominant component contributing 42% in the Gulf of Mannar, 51% in the islands and 34% in the Palk Bay. The most productive depth zones are between 0–1.25 m for agarophytes and 0–3 m for alginophytes. The total yield from an area of 15,000 ha has been found to be 6,000 tonnes of alginophytes and 1000 tonnes of agarophytes. Besides, rich beds are found in Gujarat (Okha, Dwaraka, etc.) Lakshadweep and Andaman and Nicobar Islands. Recent survey report from Gulf of Kutch indicates that about 4000 tonnes of fresh *Sargassum* can be harvested from this area.

A technique for the extraction of agar-agar from *Gracilaria edulis* without using either freezing or other costly equipments to purify the agar at the jel stage has

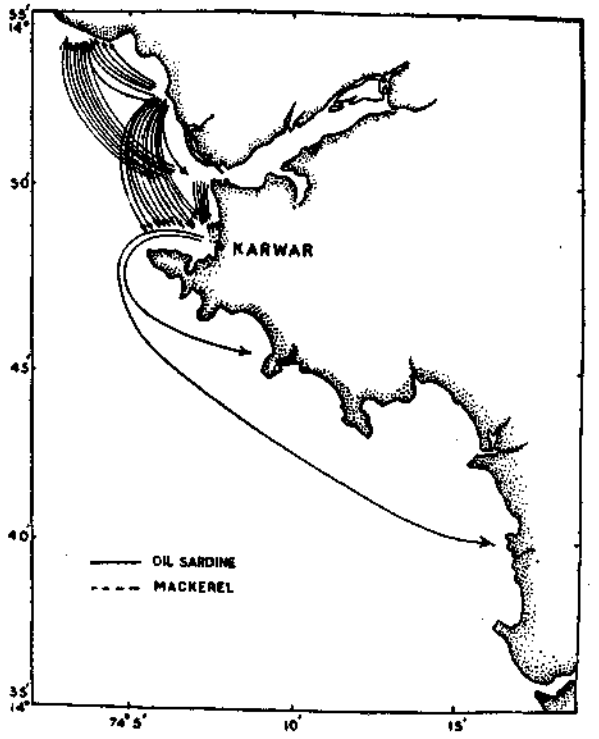
been developed. This technique can be advantageously used at the Cottage level. Large quantities of seaweeds and seagrasses such as species of *Cymodocea*, *Diplanthera* and *Halophila* can be utilised as manure directly or in the form of compost. The use of *Hypnea* compost as manure has resulted in higher yield of Bhendi, various beans, gourds, greens, lime, papaya, and drum stick and remarkable results have been obtained with protons and zinnias. Recently, a process has been worked out for the preparation of "seaweed meal" from *Gracilaria edulis*.



Tagged mackerel, oil sardine and prawn

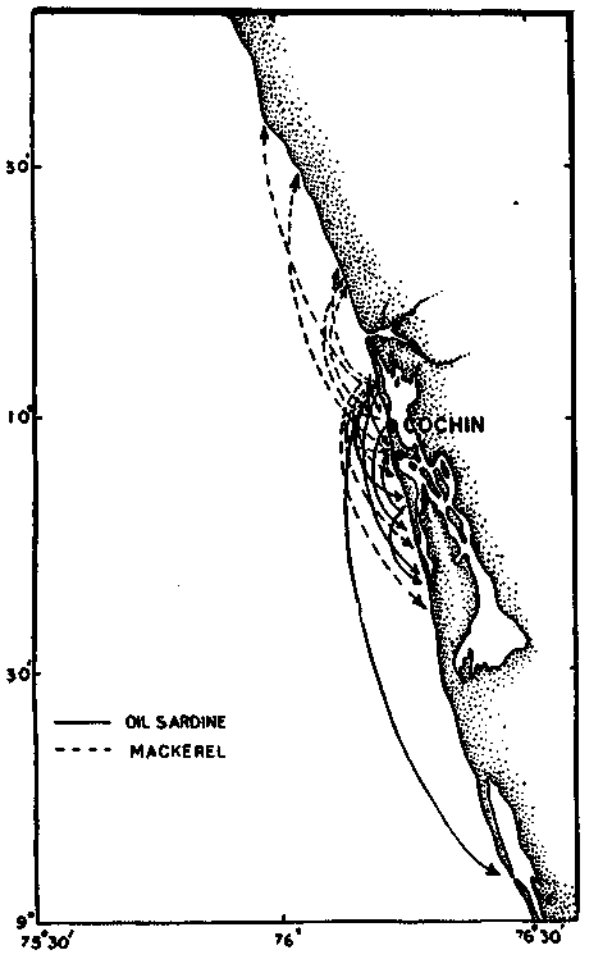
Tagging Experiments on Fishes

Tagging of fishes, despite its importance as a means to elucidate the important aspects of their biology such as migration, growth, recruitment, mortality, stock and racial composition, had not been attempted in India until the late 1950's. Mark release experiments were undertaken in the country for the first time by tagging of *Hilsa* in the Hoogly estuary and of the Gray mullets and certain other brackish water fishes in the Chilka lake. Tagging of marine fishes was undertaken for the first time in 1964 with the lobster, *Panulirus homarus*. Subsequently, tagging experiments on mackerel and oil sardine were commenced from Karwar, Mangalore and Goa. Realising the importance of tagging of commercially important marine fishes, a National Tagging Programme was initiated in 1975. This programme is progressing at present.



Recoveries of tagged oil sardine and mackerel (Karwar region)

The lobsters were tagged with suture tags and released at Muttom (Kanyakumari District) during 1965–1966. Of the total 134 lobsters released, 29% were recovered, the longest duration before recapture of the tagged lobster being 615 days after marking. The results of these investigations have shown that the lobsters do not stray far out of the fishing grounds; that their recruitment takes place at a very early stage; that the species grows very fast and attains commercial size at the end of the first year; that their growth rate slows down after the second year the maximum fishable size being attained by 5 years; that the males grow faster than females and that the fishery is supported mainly by the first and second year class lobsters.



Recoveries of tagged oil sardine and mackerel (Cochin region)

Tagging experiments on Indian mackerel and oil sardine were conducted during 1966–1969 using a variety of tags such as opercular, loop, dart, semi-internal and opercular button tags of different colours from Karwar, Mangalore, Kozhikode, Cochin and Vizhinjam on the west coast, and from Mandapam and Waltair on the east coast. During this period, a total of 4,599 mackerels and 22,439 oil sardines were tagged and released from different centres. This was followed by intensive and wide propaganda for the recovery of the tagged fish. The recovery rate for the mackerel was 0.61% and for oil sardine, 0.28%. Non reporting of recaptured specimens by the fishermen is believed to be the main reason for the poor rate of recovery, though high initial tagging mortality and mortality due to attrition from the shedding of tags and predators might have contributed for the low recovery rate. These preliminary investigations have indicated that the loop and opercular tags are not suitable for tagging mackerel and oil sardine as the other tags such as red and blue tags register higher recovery rate. It is also observed that the movement of mackerel and oil sardine is limited to the normal fishing grounds and that this movement is parallel to the coast. Large scale tagging of mackerel and oil sardine is in progress.

Tagging of commercially important penaeid prawns was started in 1972 from Cochin, Goa and Madras. Modified Peterson disc tag was used in these experiments. During 1972–74, 3053 prawns comprising *P. indicus*, *P. monodon*, *P. merguiensis*, *P. stylifera*, *M. dobsoni*, *M. affinis* and *M. monoceros* were tagged and released in the inshore and offshore waters and in the estuarine regions. The overall percentage rate of recovery was 2.1%. The results of these experiments indicated that the modified Peterson disc tag is suitable for prawns measuring over 40–45 mm size; that the recoveries are generally made within 2–18 days of release; that the movements of prawns are restricted within the fishing grounds and that they grow at a fast rate. Further intensive tagging experiments on prawns under the National Tagging Programme is in progress.

Recently, tagging of catfish at Waltair has been initiated.

Organic Productivity, Plankton and Fishery Oceanography

Organic productivity and phytoplankton

Early studies on phytoplankton and productivity were confined to taxonomic accounts of the main

constituents of diatoms and on their seasonal and quantitative fluctuations together with the environmental factors regulating their occurrence. Altogether about 300 species of diatoms, 200 species of dinoflagellates and more than 50 species of other components of phytoplankton have been identified and described from the Indian seas. In addition, studies on littoral and freshwater diatoms of India including electron microscope studies have also been conducted in a few laboratories.

During the last two decades, there has been considerable progress in the study of organic production in the Indian Seas. Off Calicut, standing crop of phytoplankton was measured by various methods which led to the conclusion that the production on the west coast of India is of a high order which can be compared to any other fertile regions in the world. Detailed measurements were made from the Gulf of Mannar and Palk Bay, west coast of India and Lakshadweep Sea, using oxygen and radioactive carbon methods from the early nineteen sixties. It was found that the shallow regions of the Gulf of Mannar and Palk Bay are very highly productive with an annual gross production of 443 and 561 gC/m^2 respectively.

On the west coast, the maximum production is towards the coast within 50 m depth and gradually decreases seawards. The mean value within 50 m is 1.24 gC/m^3/day with the highest rate during the southwest monsoon season. The minimum is during the premonsoon when the mixed layer is deepest and moderately high rates are found during the postmonsoon. The daily rate of production for the rest of the shelf is 0.47 gC/m^2/day and for oligotrophic regions outside the shelf, it is only 0.18 gC/m^2/day.

The annual gross production for the inshore regions on the west coast within 50 m is 453 gC/m^2 and for the rest of the shelf 170 gC/m^2. This would amount to an annual gross production of 50 x 106 tonnes of carbon for the inshore regions comprising 1,14,520 sq.km and 30×106 tonnes for 1,68,790 sq. km of the outer shelf regions.

The rates of primary production on the east coast are 0.63 gC/m^3/ day on the shelf and 0.19 gC/m^2/day outside the shelf and annual estimated gross production is 25×10^6 tonnes of carbon for 1,11,150 sq km of the shelf.

By comparison with areas where there is intensive exploitation and by tracing the carbon production through the different tropic levels using various ecological efficiency factors, an estimate of a potential harvest of about 3–4 million tonnes of fish has been derived for the Indian seas which is about 3 times the present yield.

Similar calculations have been made for 51 $x10^6$ sq. km of the Indian Ocean for which the International Indian Ocean Expedition data are available. The annual net production is computed at 3.9×10^9 tonnes of carbon which is about one-fifth of the estimated world organic production, while the catch is only one-twentieth of the world production of marine fish. The shelf areas of the Indian Ocean alone account for 0.56×109 tonnes of carbon or about one-seventh of the total production in the Indian Ocean. The potential yield from the Indian Ocean at the present level of world fishing is about 11 million tonnes of fish. The Indian Seas could provide an annual sustainable yield of about one-fourth of the potential yield from the Indian ocean as the productivity studies indicate.

The organic productivity of the Cochin Backwater, Vellar Estuary at Porto Novo, Mandovi Estuary in Goa have also been investigated in recent years. Annual gross production measured in the Cochin Backwater using various techniques has been found to range from 272–293 gC/m^2 and net production from 184–202 gC/m^2. Detailed investigations conducted in the Vembanad Lake and connected backwaters have shown that for a total area of 300 sq. km the annual gross production ranges from 150–650 Cg/m^2 with the maximum during pre and post monsoon periods. The total organic production has been estimated at 100,000 tonnes of carbon.

The seasonal and spatial abundance of phytoplankton in the Cochin Backwater indicated that two peak periods are usually observed with the diatoms playing the major role. An analysis of variance indicates that the spatial variation is as high as the seasonal variation. In addition, plant pigments,light penetration and nutrient cycle also have been studied in the Cochin Backwater.

The productivity of coral reefs, on the southeast of India, Lakshadweep sea and Andaman seas,

seagrass bed and liberation of particulate organic matter by coral reefs in an atoll have also been studied as part of the organic productivity investigations.

Zooplankton

Research on zooplankton carried out in the country mainly relates to studies on the standing crop of zooplankton organisms in the tropic cycle and their inter-relationship in the ecological niches, and the correlations between the plankton and fishery resources. The taxonomy, distribution, ecology and biology of several groups of zooplankters such as amphipods, cladocerans, copepods, chaetognaths, euphausiids, ostracods, siphonophores, appendicularians, bryozoans, pteropods, gastropods, cumaceans, anthozoans, hydromedusae, etc. have been described. Several new species have been described and new records have been made for all the groups of the above plankters. The occurrence and abundance of larval cephalopods along the southwest coast and the Lakshadweep sea have been investigated. Detailed investigations of bioscattering and deep scattering layers were undertaken along the west coast and Lakshadweep seas to study the diurnal vertical migrations, areas of the occurrence and biological constituents. Interesting relationship between the local fisheries and the abundance of different groups of zooplankton of coastal waters have been recorded at different centres. It has been found that several species of plankters occur in greater quantities on the west coast than on the east coast and this is reflected in the quantity and composition of catches in the respective regions.

A wealth of information on the zooplankton of the inshore waters, their abundance in space and time along with the hydrological data is available for centres Bombay, Karwar, Mangalore, Calicut, Cochin, Vizhinjam, Mandapam, Tuticorin, Madras, Waltair, Minicoy and Port Blair.

Based on the data collected during the International Indian Ocean Expedition plankton atlases depicting distribution pattern of fish eggs and larvae, standing crop of zooplankton and seasonal variations of several groups of zooplankters have been prepared.

Fishery oceanography

While dealing with fish and fisheries resources of India it is essential to have an idea about the geographical, climatic and oceanographic features which together profoundly influence fisheries resources of the country. The vast alluvial plains of the north, the Deccan plateau, the mountain barriers which surround the plains to the west, north and east are some of the characteristic features of peninsular India. The atmospheric temperature and rainfall provide wide contrasts during different seasons in the various parts of the country. Recorded temperatures range from —9.5°C to 49.5°C and annual rainfall from less than 127 mm to 11,000 mm. The northeast monsoon during winter and the southwest monsoon during summer months characterise the weather conditions and the heavy precipitation accompanying these monsoons result in the fluctuations in the physical, chemical and biological features of the rivers, estuaries and the seas around India.

The hydrography of the waters around India was surveyed in the past by the expeditions of *Challenger, Investigator, Valdivia, Dana, Discovery II, Mabahiss,* etc. and by the ships of the British Admirality.

Systematic investigations on the oceanographic conditions in the inshore and offshore waters was initiated in 1957 by the CMFRI with the co-operation of the Indo-Norwegian Project (now known as Integrated Fisheries Project). The first vessel utilised for this purpose was *M. O. Kristensen* followed by *R. V. Kalava* and from 1961 onwards a fully equipped Research Vessel, *Varuna* was put into operation. More than 175 cruises were undertaken by these vessels and about 3,500 oceanographic stations were occupied. Very valuable information on various oceanographic parameters were collected, especially in relation to the inshore demersal and pelagic fisheries.

From the investigations carried out by *R. V. Varuna,* a large convergence zone has been found during early winter along 8°N around 74°E meridian. These convergence zones form suitable spawning and forage grounds for fishes. Around Lakshadweep islands there exists circulatory movements upto a notable depth (100–200 m) from the surface and this helps to maintain the highly productive waters in the vicinity of fishing grounds for pelagic oceanic species such as skipjack tunas.

In recent years, the Pelagic Fishery Project has carried out extensive oceanographic surveys with their vessels *R. V. Rastrelliger* and *M. V. Sardinella.* The

valuable information collected by them along the west coast from Ratnagiri to south of Cape Comorin has resulted in a better understanding of the stock, abundance and distribution of important pelagic fishes such as oil sardine, mackerel and anchovies. Our knowledge of oceanography of the Indian Seas has also been greatly enriched by the findings of the International Indian Ocean Expedition. and by the continued research effort of the institutions such as CMFRI, PFP and NIO.

While some detailed information is available about the equatorial current systems, the IIOE brought to light the Somali stream - a fast moving current which links up with the south west monsoon current and establishes a clockwise circulation in the Arabian Sea and Bay of Bengal. As a result of this circulation a southerly drift gets established along the west coast of India and a weak north easterly current along the east coast.

The northern Arabian Sea is characterised by high temperature and salinity and in contrast lower salinities have been observed in the Bay of Bengal due to the influence of major perennial rivers and estuaries.

The monsoon systems set in motion a process of upwelling which is more pronounced along the west coast of India. Valuable data has been collected on the commencement of upwelling in deeper waters and the areas of upwelling. These investigations while pointing to the relative richness of the waters along the southwest coast, should also help in understanding the fluctuations in the major fisheries in this area. Small-scale upwelling takes place along the east coast also in some areas.

The shifting of the oxygen minimum layer to the surface in some parts of the Arabian Sea during certain seasons results in mass mortality of fishes. Even very productive areas can be influenced by oxygen minimum layers. In the shelf waters of Gulf of Cambay and in some parts of the Arabian Sea azoic conditions prevail with deficient oxygen content.

Seasonal fluctuations in the nutrients (inorganic phosphates, nitrates and silicates) of the shelf waters along the southwest coast have been investigated and the area between Quilon and Alleppey and off Calicut was found to be relatively richer in nutrient concentration. The east coast of Andaman and Nicobar Islands is also fairly rich in phosphate content.

Marine pollution

Water pollution and fish mortality on a small scale have been known since long back from the maritime States of Maharashtra, Kerala, Tamil Nadu and West Bengal. Occasional fish mortality has been reported from the vicinity of the industrial cities mainly in the estuarine areas. Research on marine pollution is, however, limited to the local and isolated problems pertaining mostly to the fresh water and estuarine resources, and on problems like radiation hazards in the marine environment and up take of metals etc. carried out at the Baba Atomic Research Centre, Bombay, till recently. An awareness on a national scale on aquatic pollution is, however, created only after India's active participation in the International Conference on Human Environment at Stockholm in 1970. Since then, survey on the large scale occurrence of tar-balls on the west and east coasts of India has been carried out. Monitoring of pollution at Bombay, Goa, Karwar, Cochin and Trivandrum has been taken up. Investigations conducted on the pollution in the Hooghly-Matlah estuarine system have shown that the total load discharged per day works out to 106 tonnes of BOD, 2,308 tonnes of total solids, 1057 tonnes of suspended solids, and 1251 tonnes dissolved solids. The Kulti estuary in West Bengal used to have important fishery resources till a few years ago. But it has in recent years been heavily polluted by Calcutta sewage, and the seeds of commercially important fishes and prawns are significantly absent in the upper strethesc of the estuary, the caustive factor being the formation of "Sewage pollution block" which prevents up stream migration of the larvae and juveniles. Apart from this, research is progressing on the bioassay and toxicity testing aspects with different pollutants such as BHC, DDT and Malathion.

Monitoring studies on marine environmental damage are being carried out in the Cochin Backwater and the industrial suburbs. Causative factors for mass fish mortality in the region have been studied. The intensity of sewage pollution from human and animal waste is monitored by the determination of indicator organisms and BOD measurements. The relationship of micro-organisms to the sediment structure is also

investigated. Toxicity experiments in order to determine the LC - 50 using crude oil and pesticides are conducted. Phytotoxicity measurements are also made. Besides, following the grounding of an oil tanker TRANS HURON at Kiltan Island (Lakshadweep) extensive ecological observations on the immediate and long term effect of oil pollution on the marine biota are made. Regular monitoring programme on marine and estuarine pollution at Calicut, Karwar and Tuticorin is being continued.

COASTAL AQUACULTURE
(mariculture and brackish water culture)

As the fishing pressure steadily increases especially along the narrow coastal belt where indigenous crafts operate in considerable numbers, the yield from capture fisheries can not be expected to be of a sustained nature and already signs of overfishing were discernable in the case of prawns in some areas along the southwest coast. Further the various environmental factors cause considerable fluctuations in the yield from capture fisheries. In order to overcome these difficulties and to increase production of fish and other animals on an area or watershed basis, increasing attention has been paid to mariculture and sea farming in the recent years. The significant results obtained especially by the CMFRI are detailed as follows:

Fish culture

Many species of fishes such as milkfish, mullets, perches and eels are suitable for culturing in low lying areas and impounded brackish water. The work carried out by C.M.F.R. Institute at Tuticorin has shown that the production of milk fish in saline lagoons and in saline ponds can be substantially increased by resorting to proper management procedures. A production rate of 857 kg per hectare was obtained. The institute has developed methods of culturing the eel, *Anguilla bicolor*, in running water. This species is abundant along the east coast and they breed in the open sea. The elvers ascend the rivers during rainy season. Elvers are collected from suitable locations and are reared in experimental culture tanks. This species has given a production rate of 38,000 kg per ha. at the end of a period of two years. Cultivated eels have a good export market and are in great demand in countries like Japan. Another species of fish, *Sillago sihama* is also being successfully cultured by the Research Centre at Mangalore. This species grows to about 200 mm in 7 months.

Marine prawn culture

In India prawns are cultured at present in Kerala and West Bengal in the brackish water ponds and low lying areas adjacent to the backwaters by traditional methods. The young ones of different species of marine prawns such as *P. indicus, P. monodon, P. semisulcatus, M. monoceros, M. dobsoni, M. affinis* and *M. brevicornis* brought in by tidal currents are trapped and cultured in these fields. In the seasonal fields of Kerala, paddy is cultivated during the monsoon months (June-September) and prawns in the other months (October-May), while in the perennial fields, prawns are cultivated throughout the year. In West Bengal, culture fisheries is carried out in the brackish water ponds, called "Bheris". About 4500 ha of fields are utilised at present for prawn culture in Kerala and 9600 ha in West Bengal. The yield of prawns from these fields varies from 500 to 1200 kg per ha per annum, the average production being about 700 kg per ha per year. The total production of prawns from the fields of Kerala is estimated to be about 3500 tonnes per year. The prawn culture practices of the seasonal and perennial fields of Kerala have been evaluated and improvement measures involving culture of selected species such as *P. indicus*, and *P. monodon* for longer duration of 3–4 months have been suggested for enhancing the efficiency of management and production.

Rearing of prawn larvae at the Prawn Culture Laboratory of CMFRI, Narakkal

Intensive investigations on culture of prawns have been taken up only recently and these are directed towards developing techniques for large scale culture of prawns on scientific and modern lines. As a result of these investigations, commercial prawns such as *P. indicus, P. monodon, P. merguiensis, M. monoceros, M. dobsoni, M. affinis* and *P. stylifera* have been spawned in the laboratory and their larvae reared through different stages up to stocking size under controlled conditions. One of the species, *M. dobsoni,* has been successfully domesticated, as the stocked juveniles grown in the brackish water ponds attained sexual maturity and spawned in the brackish water medium liberating viable eggs which have been further reared through different larval stages to stocking size in the same medium. The requirements of medium, environmental conditions and food for the culture of individual species have been studied. Fairly good percentage of survival rate has been achieved in the rearing experiments. In the case of palaemonid prawns, a salinity range of 20–25% is found to be ideal for spawning and rearing of their early larvae. Besides these, techniques for mass culture of several species of diatoms, *Artemia salina,* and zooplankters which form the food of larvae and juvenile prawns have also been developed. A survey of the seed resources in the surf region, estuaries and backwaters is being undertaken. The konkan krishi Vidyapeeth, Ratnagiri is also engaged in the prawn culture and *P. merguiensis* and *Macrobrachium* are the species being cultured. In the CIFE farm at Kakinada polyculture of fish (chanos) and prawns (*P. monodon*) has been undertaken with promising results, similar to those obtained by CIFRI in polyculture of prawns and fish at their Kakdiwp farm, Calcutta.

The results of field experiments carried out at different centres have indicated that (1) the prawns grow very fast in the culture fields and reach marketable size in 3–4 months; (2) encouraging production could be raised by culture of prawns in salt pans with simple management procedures; (3) prawns can be cultured along with other compatible fishes such as *Chanos chanos,* mullets and *Etroplus*; (4) by intensive culture, a production rate between 1000–1500 kg could be realised per ha per annum.

Realising the importance of transfer of technology to various levels for quicker development and establishment of an organised culture fisheries for prawns, steps have been taken to train both technical personnel and actual farmers through organised training programmes under the Krishi Vigyan Kendra, Narakkal (Cochin) and through short-term courses.

Mussel culture

The culture of mussel in India was initiated in 1971. Two species, namely, *Perna indica* (Brown mussel) and *Perna viridis* (Green mussel) occur in the country, the former confined to the southern most peninsular region from Quilon to Tirunelveli Coast, while the latter is distributed all along the rest of the Indian Coast. Experiments conducted at Vizhinjam on the culture of brown mussel followed the "Suspended" or "Raft culture" method using ropes. The seeds of mussel were collected from the natural beds and transplanted to these ropes. The results of the experiments have shown that the seed mussel of average weight of 0.29 g transplanted in September grew to an average weight of 34.97 g in September of the next year, and a production of 22.97 kg per metre length of rope was recorded. The annual production rate was estimated at 60 tonnes of mussels with shells, per ha. In 1975, culture of green mussels in the open sea at Kozhikode employing the raft culture techniques was taken up. In the experiments conducted at this centre, the seed mussel of average length 26.7 mm and live weight of 1.48 g transplanted in December grew to a size of 80 mm weighing 28.7 g in April. The production rate for a period of 5 months amounted to 235 tonnes per ha. It is also observed that the growth of mussels in the farm is very rapid (12 mm per month) as compared to those in the natural bed (8 mm per month). The results of these experiments indicate great prospects for culture of mussels in the inshore waters of our coast. Culture of green mussels on rafts in the open sea at Kovalam near Madras is progressing. The Konkan Krishi Vidyapeeth, Ratnagiri has taken up an ICAR scheme for culturing mussels along Ratnagiri Coast. Further intensive investigations on the culture of mussels and studies on the economic viability of the culture operations are in progress.

Culture of edible oysters

Experiments on the culture of edible oysters were started in the country as early as the beginning of this century. However, these were given up due to

unsatisfactory progress. Nevertheless, intensive investigations on the culture of the edible oyster, *Crassostrea madrasensis* have been taken up recently at Tuticorin. The techniques of oyster culture consists of two items, namely, collection of spat by employing different methods and growing this spat to the adult stage by different methods such as rack culture, long line culture pole culture, tray culture etc. The different methods of capture of spat on lime coated tiles, oyster shells strung on galvanised iron wire, empty coconut shells,

Edible oyster

rubberised coir mats etc. are being tried. The best time of the year for spat collection varies with species, locality, fluctuation in temperature, salinity, tide, etc. Investigations are also being carried out to develop the hatchery method of inducing the oysters to breed under controlled conditions. Preliminary experiments carried out at Tuticorin have shown encouraging results on the culture of oysters and have indicated that the growth of cultured oysters is relatively faster than in the natural beds.

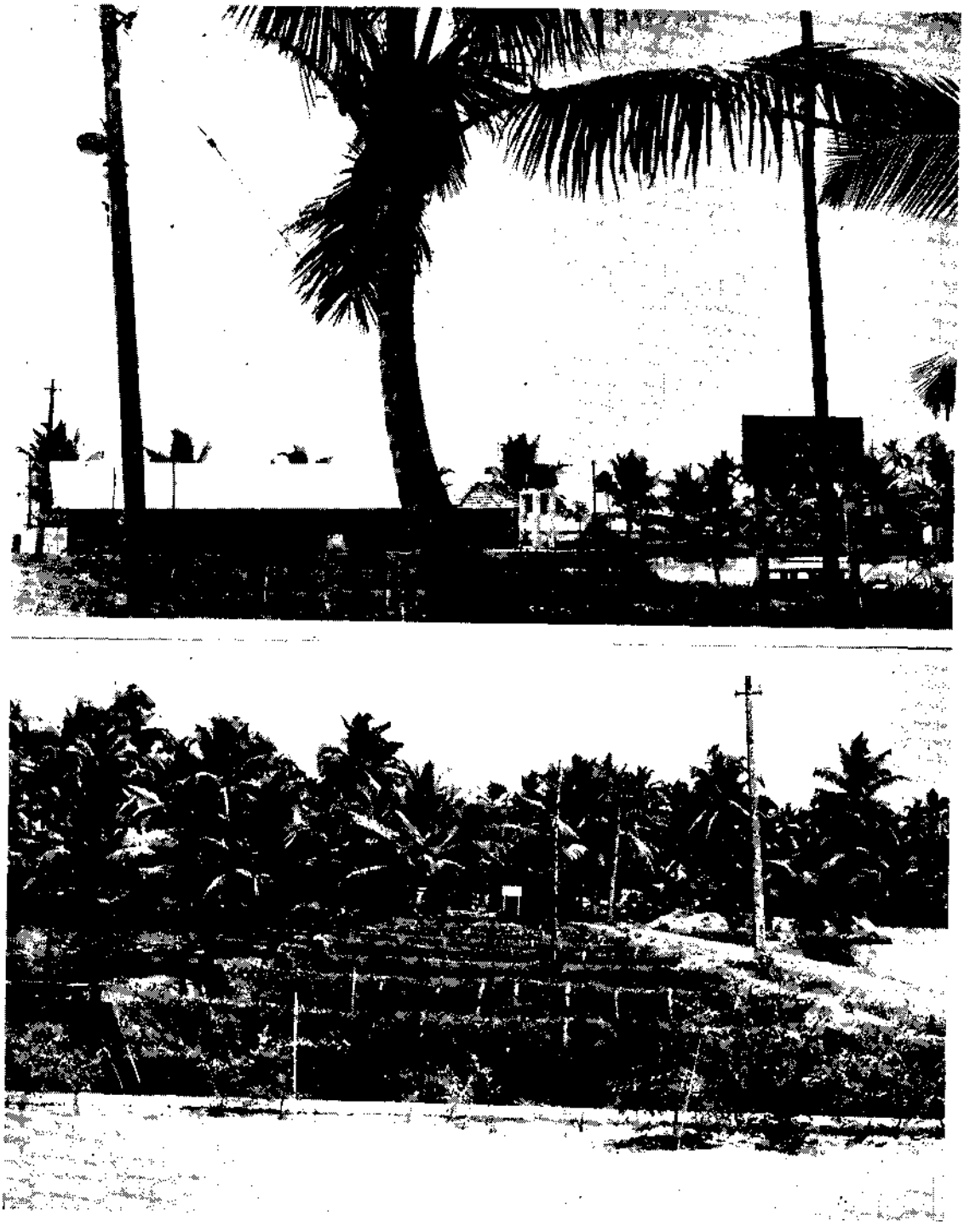
Pearl culture

The techniques for production of cultured pearls and farming of pearl oysters were developed indigenously at the Central Marine Fisheries Research Institute in 1973. Prior to this, attempts to develop the techniques had been made at two centres at Krusadai Island by the Department of Fisheries, Tamil Nadu and at Sikka by the Department of Fisheries, Gujarat, but without much success. The pearl culture project was started in 1972 at Tuticorin with a field laboratory and open sea oyster farm at Veppalodai. Raft culture was introduced to rear the pearl oysters. The important species cultured is *Pinctada fucata*. The surgery is performed in the shore laboratory after conditioning the oysters with menthol. The operation consists of grafting a piece of mantle of the donor oyster in the gonad or hepatopancreas region of the oyster, followed by the implantation of a spherical shell-bead nucleus. The breakthrough in production of spherical pearls was achieved in July 1973.

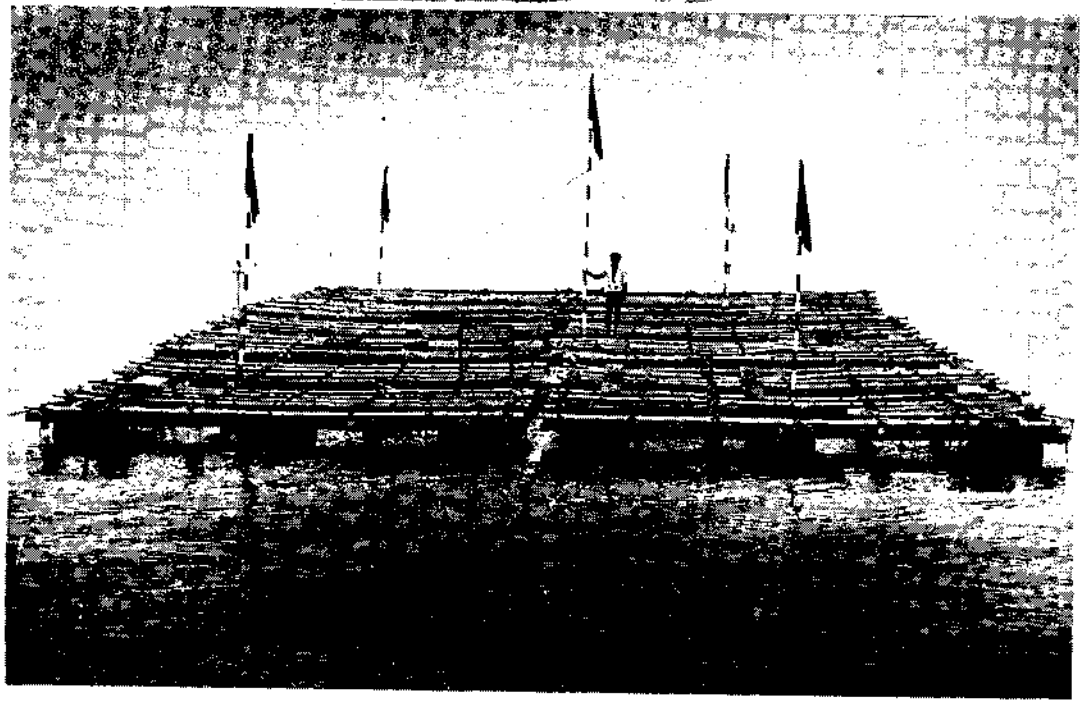
Although cent per cent success has been achieved in certain batches, the average production is about 60–70%. Multiple production of pearls in individual oysters has been achieved. The size of nucleus employed ranges from 2 mm to 7 mm diameter depending on the size of the oyster and choice of single or multiple implantation. The rate of deposition of nacre is high in the tropical sea and hence the duration of post-operative culture is considrably reduced, requiring only 3 months to 18 months for the range of 3 mm-8 mm pearls for maturity. The shell beads required have been produced from the conch-shell wastes (after preparing the conch bangles), using the grinding technique. The surgical tools have been fabricated indigenously.

Since October 1973, the researches on pearl culture at Tuticorin are carried out under a collaboration scheme between the Central Marine Fisheries Research Institute and the Department of Fisheries of Tamil Nadu. Emphasis is laid on the development of pearl oyster resource to procure oysters required for the pearl culture operations. The recent surveys of the pearl banks of the Gulf of Mannar have indicated the possibility of a revival of the pearl oyster population, probably for the first time since the pearl fishery of 1961. Besides, spatfall has been observed in the coastal waters, particularly in the new artificially created harbour basin at Tuticorin. Through a Project of the Central Marine Fisheries Research Institute at Vizhinjam on the Kerala coast, the fall of pearl oyster spat in the fishing harbour under construction has been taken advantage of in raising pearl oyster stocks.

The Central Marine Fisheries Research Institute conducts two kinds of training courses in pearl culture.



Prawn culture laboratory and experimental ponds of CMFRI at Narakkal near Cochin

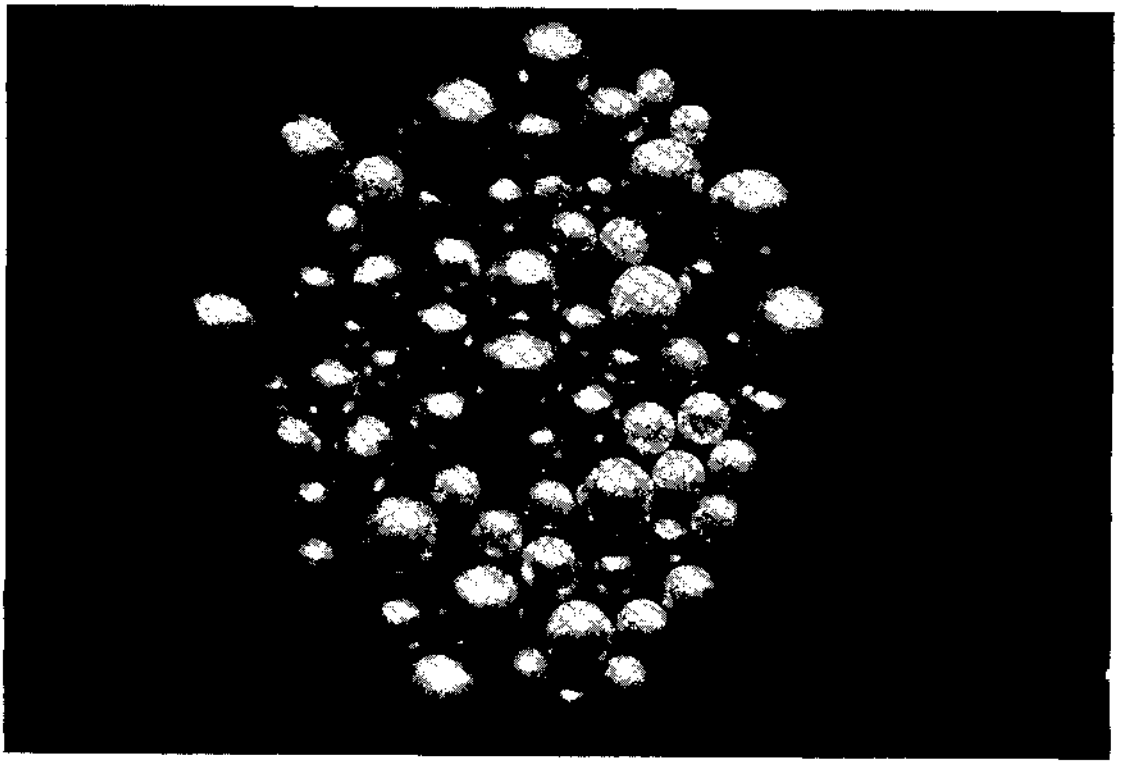


Top: Two tonnes of cultured mussels – a part of harvest taken at Calicut from open sea mussel culture
Bottom: Rafts used for mussel culture at Calicut Research Centre of CMFRI

Pearl oyster,
Pinctada fucata

Cleaning of cultured
pearl oyster

Pearl oyster surgery and implantation of nucleus



Cultured pearls produced by CMFRI, Tuticorin

The comprehensive long term programme of six months' duration is a Trainers' Training Course and the short-term programme of four weeks aims at technician's level training in the specific field. These courses are demand-based for the benefit of the maritime states.

Twin and Triplet pearls

The development of a sound technology for the production of cultured pearls and the knowledge of a possible revival of pearl oyster resource in the Gulf of Mannar, supported by the good spatfall in the new harbour basins as at Vizhinjam and Tuticorin have lead to the launching of a Pilot Project for semi-commercial production of cultured pearls.

Culture of seaweeds

The cultivable seaweeds are agar yielding plants like *Gracilaria* and *Gelidiella* species and algin yielding plants such as species of *Sargassum* and *Turbinaria*.

Preliminary culture experiments carried out with some of the economically important seaweeds such as *Gracilaria edulis, G. corticata, Gelidiella acerosa* and *Sargassum* spp. have indicated that the species could be cultured successfully in the coastal waters. Seaweed culture has been done by introducing fragments of the seaweed in the twists of coir ropes which are fabricated in the form of frames tied to wooden poles fixed in the coastal waters.

The experimental cultivation of *G. edulis* near Mandapam has revealed that the ideal time for planting is June-July. It was also found that three harvests could be obtained, the first, five months after planting, the second three months later and the third, a further two and half months later. The annual yield has been calculated as 3.5 kg of fresh seaweed per metre of rope.

In the case of *Sargassum*, duration of about 9–10 months was observed for it to settle on artificial substrata such as concrete cylinders after which rapid growth was observed and near-mature plants were seen within nine months. A growth of 37 to 52 cm for an initial height of 10 cm in *Sargassum cinctum* was reported within forty days. With *Gracilaria edulis*, 4–5 kg and 4 kg of seaweed per square metre in 4 x 2 metre and 2 x 2 metre size coir culture frames respectively within a span of 80 days for an initial 1 kg of seed material was obtained. In *Sargassum wightii* an average growth of 15.5 cm from an initial average height of 7.67 cm within 60 days was obtained. *Gelidiella acerosa* which was not giving encouraging results hitherto had shown a growth of 3 kg from an initial 1 kg after 77 days in the recent experiments. It was also observed that *Gracilaria edulis* cultured in Athankarai estuary showed slight bleaching than that cultured in inshore waters. Low salinities near the estuary mouth during rainy season have been found to be favourable for the growth of *Gracilaria edulis*.

An alternative method of culturing seaweeds is to rear the spores by keeping some suitable sbustrata like coral and concrete stones on which the spores settle, germinate and grow into adult plants. It lessens the utilization of the natural resources but the method by using fragments is easier and the yields are quicker. The spore output in algae such as *Ulva fasciata, Turbinaria* spp., *Sargassum* spp., *Gracilaria* spp. and *Gelidiella* spp. has been studied, and the number of spores produced in different species experimentally was found to be abundant by various workers.

INLAND FISHERIES RESEARCH

Before the establishment of the CIFRI in 1947 the research and developmental activites in the inland fisheries sector have been of a scattered and disorganised nature. Evolving suitable methods for the conservation, development and rational exploitation of the inland fishery resources in India was the main objective of the Institute.

Capture Fisheries

Capture fisheries investigations involved detailed studies on the fishery biology of a number of carps and

catfishes inhabiting the rivers and estuaries; hydrobiologic factors affecting the fisheries of several rivers and estuaries; besides locating spawn collection centres for the seed of major carps and culturable riverine and estuarine fishes and prawns. Studies on migration, life history and population dyamnics of commercially important fishse and environmental factors affecting the abundance of fish stocks have been undertaken.

Estuarine fisheries

Major estuarine systems of India have been surveyed and information on the fish and fisheries of these regions along with environmental factors has been gathered. Similarly, the fisheries of the brackishwater lakes particularly of Chilka Lake in Orissa, Pulicat Lake in Tamil Nadu and Vembanad Lake in Kerala have been extensively studied. The species supporting the estuarine and brackishwater fisheries of the country are mostly the marine species which enter into these ecosystem tolerating wide variations of the salinity, the most important of which are, *Hilsa ilisha, Nematolosa nasus, Anchoviella* spp., *Anadontosoma chacunda,* mullets, catfishes, *Lates calcarifer, Etroplus* spp., threadfins, *Sillago sihama,* prawns and crabs. It is also found that this ecosystem serves as nursery ground for many of the marine fishes.

Riverine and Lacustrine fisheries

Detailed investigations on the fish and fisheries of the Ganga River System, of Bharmaputhra, Godavari, Krishna, Cauveri, Tapti and Narmada Rivers have been carried out. The fishery of the Ganga River System is supported by the major carps, (*Labeo rohita, L. calbasu, Cirrhinus mrigala, Catla catla*), cat fishes (*Mystus aor, M. seenghala, Wallago attu*) and the clupeid (*Hilsa ilisha*). The fish fauna of Bhramaputhra in Assam includes 126 species, the important commercial species supporting the fishery being *Labeo, Wallago attu, Puntius sarana, Notopterus notopterus, N. chitala* and *M. seenghala.* The principal fishes contributing to the fishery in the southern peninsular rivers are carps, cat fishes, *Hilsa ilisha,* murrels, eels, feather backs and prawns.

Studies carried out on the effects of construction of dams across the rivers have indicated that it adversely affects the fish migration. The dams on the Godavari, Krihsna and Cauveri Rivers have affected the *Hilsa* migration and led to the decline of the fishery. Indiscriminate discharge of domestic and industrial wastes has created pollution problems in many of the Indian rivers, causing destruction of spawning grounds of the important freshwater fishes such as major carps which require special environment for breeding. However, monitoring on pollution of important rivers has been taken up.

Besides the rivers, natural lakes with a total area of 0.72 million hectares, constitute another aquatic source for fishery production. However, research on lacustrine fisheries of India has been scanty, except for preliminary fishery survey along with the physicochemical and hydrobiological condition of a few lakes.

Reservoir fisheries

There are about 295 major and medium reservoirs in India. Fish production in some of the important reservoirs is as follows:

Reservoir	State	Fish production(kg/ha)
Govindsagar	Punjab	206.00
Rihand	Uttar Pradesh	9.31
Sardasagar	Uttar Pradesh	24.87
Dohra	Uttar Pradesh	27.58
Keetham	Uttar Pradesh	250.00
Dhandraul	Uttar Pradesh	20.02
Panchet	Bihar	4.09
Tilaiya	Bihar	3.46
Gandhi sagar	Madhya Pradesh	4.86
Hirakud	Orissa	0.21
Malampuzha	Kerala	5.03
Tungabhadra	Karnataka	4.13
Mettur Dam	Tamil Nadu	39.10
Bhavanisagar	Tamil Nadu	13.00
Amaravathi	Tamil Nadu	93.00
Nizam Sagar	Andhra Pradesh	3.30
Nagarjunasagar	Andhra Pradesh	1.76

Average fish production of the reservoirs works out to 6–7 kg per ha. Research and developmental efforts taken up to improve the reservoir fisheries are:

1) survey of the fish fauna of the reservoirs;
2) clearance of submerged obstructions;
3) establishment of fish farms;
4) stocking of the reservoir with selected species;
5) survey of fish seed resources;
6) topographical survey of the reservoirs; and
7) conservation and management of the reservior fisheries.

During recent years, survey of the fishery resources of the Tungabhadra, Bhavanisagar, Damodar Valley Corporation reservoir and Hirakud has been carried out. Introduction of Mahseers and *Macrobrachium malcolmsonii* in the Damodar Valley Corporation reservoir has been found to be successful. Major carps, peninsular carps, *Cyprinus carpio, Chanos chanos, Etroplus suratensis* and *Tilapia mossambica* have been stocked in the reservoirs of Kerala to increase their productivity.

Investigations on the ecology and fisheries of selected reservoirs in different agroclimatic zones of the country have been carried out under an All-India Co-ordinated Research Project on Reservoir Fisheries. Largely through manipulation and intensification of phase-wise fishing effort to 1.67 times over the conventional effort, the yield from the Bhavanisagar reservoir in Tamil Nadu, has been raised to 75 kg per ha. in 1976 as against 19 kg per ha in 1971. Investigations at Moolathuria on the Bhvani River has revealed the availability of spawn of *Catla catla, Labeo calbasu, Cirrhinus mrigala* and *L. fimbriatus* indicating possibility of natural stocking of the carp seed in the reservoir.

Cold water fisheries

Cold water fisheries of India is mainly constituted by trouts *Salmo gairdneri gairdneri, S. trutta, S. levensis* and *Onxorynchus norka,* the mirror carp (*Cyprinus carpio*), *Tina tina, Carassius carassius* and snow trouts. These fishes were introduced into the Indian waters from Japan, England, Sri lanka and Central Europe. The trout fishery at present exists in Nilgiris, Kodai Hills, high ranges of Kerala, Kashmir, and Himachal Pradesh in the lakes of Kumaon Himalayas. The important trout hatcheries in the country are at Avalanche, Rajamally (Tamil Nadu), Caribal and Harwar (Kashmir), Katrain (Kulu) and Barrot in Himachal Pradesh.

The taxonomy of the Nilgiri trout has been dealt with in detail. Various methods of augmenting the biota of the streams in the Nilgiris have been tried with a view to increasing the natural food supply for the trout. The measures adopted are improvement of calcium content by dumping coral rocks, plantation of weeds for providing shelter to the food organisms, etc. Paucity of food, overfishing and lack of facilities for the movement of the fish have been found to adversely affect the Nilgiri trout fishery. The insect and other animal life in the trout streams have been surveyed. *Cyprinus carpio* has been reported to also breed in the plains. Mahseer is an important food and game fish whose food and feeding habits, migration and breeding has been studied. It has been reported that the fish is insectivorous in the juvenile stage but become herbivorous in the adult stage.

Productivity of potential lakes supporting the cold water fisheries has been assessed. Studies have also been undertaken in physico-chemical features, surface plankton, vegetation, bottom biota, and catch/man/hr. Cumulative percentage of survival from green egg to fry stage has been studied. Field trials for feeding pelleted feed to brown trout and rainbow trout have been conducted. Brown trouts sampled from streams are found to feed mainly on developmental stages of *Trichoptera, Ephemeroptera* and *Diptera.* With the increase in size the fish preferred to feed on aerial insects and fish. Researches on the food and feeding of trouts have been intensified.

Inland Fish Culture

Culture of freshwater fishes in ponds is an age-old industry of the country, practised traditionally in the eastern states of West Bengal, Bihar and Orissa. The freshwater ecosystems such as ponds, tanks, lakes and reservoirs, irrigation and navigational canals, running and stagnant waters, sewage-fed basins and oxidation ponds, are suitable for culture operations. Although a variety of fishes are found to be amenable for culture, the commonly cultivated species are: Catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigal*), Silver Carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*). Among the prospective species suitable for culture in freshwater are the air breathing fishes (*Heteropneustus fossilis, Clarias magur, Anabas testudineus, Ophiocephalus* spp., *Notopterus* spp., etc) frogs, eels (*Anguilla bicolor, A. bengalensis*), trouts in cold waters of upland and masheer and other sport fishes in cold waters. Among prawns, *Macrobrachium rosenbergi, M. malcolmsonii, M. choprai,* and *M. idella* are ideally suitable.

During the past three decades, extensive research on different aspects of freshwater fish culture has been carried out. Noteworthy achievements of these studies are in the field of seed production, induced breeding, transporation of seed, composite fish culture and management of large scale fish culture.

Induced breeding of fishes

Necessary techniques have been evolved and perfected for inducing the Indian and Chinese major carps to breed through injection of pituitary extract. The techniques have been further simplified so that farmers could resort to induced breeding of fishes to meet their own seed requirement. The pituitary extracts are ampouled to solve the problem of preservation and use at desirable time. A 'Pituitary bank' has been set up at CIFRI Research Centre at Cuttack.

Injecting a fish with extract of pituitary hormone

Selective breeding and hybridization of fishes has been undertaken for the first time in India through induced breeding and several intergeneric hybrids of Indian and Chinese carps have been produced. The F_2 generations of some intergeneric and interspecific hybrids have been raised and some of them show better qualities than the parental stock.

The techniques of hatching carp eggs have been improved with the establishment of suitable hatcheries with continuous circulation of water.

Catla, rohu and mrigal have been experimentally induced to spawn twice, both at the beginning and again towards the end of the monsoon, thereby doubling the production of eggs from the same individual. The mullet (*Mugil cephalus*) was induced to breed for the first time in 1961. From 1971 onwards attempts were made to raise fry and fingerlings on an experimental basis.

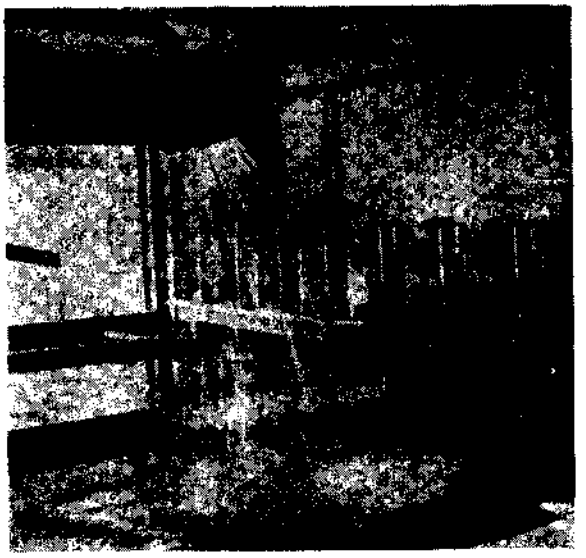
Seed production

Methods of seed production of cultivable varieties of fishes include collection from natural riverine source and production in *bundhs*. During the past 10 years several riverine stretches and collection centres of the seed of major carps have been located. Several new collecting gears have been designed. Production of seed in wet and dry bundhs involving stocking and care of breeders, location of breeding grounds in wet bundhs, collection of eggs and their further rearing have been described.

Along with success achieved in seed production techniques of rearing and preparation of nursery ponds have been considerably improved and modified so that a fish farmer could now nurse as many as 10 million spawn per ha. with survival rate of over 65%.

Mass culture of fish-food organisms

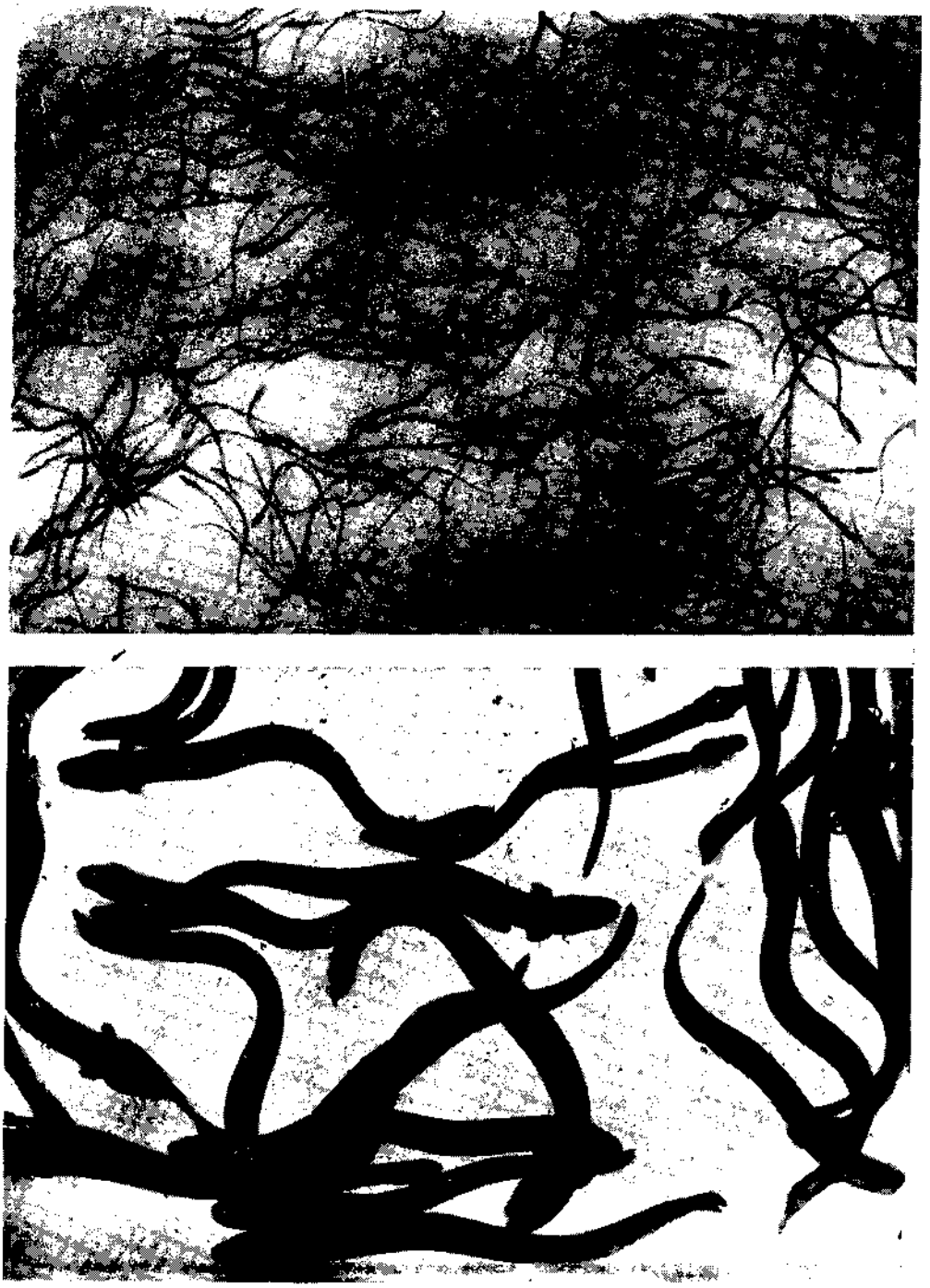
Mass culture of *Chlorella vulgaris* and *Daphnia similis* has been developed with inorganic fertilizers and poultry manure as sources of nutrients. Freshly cultured *Chlorella* was used as food of *D. similis*. This development would lead to establishment of fish-feed farms.



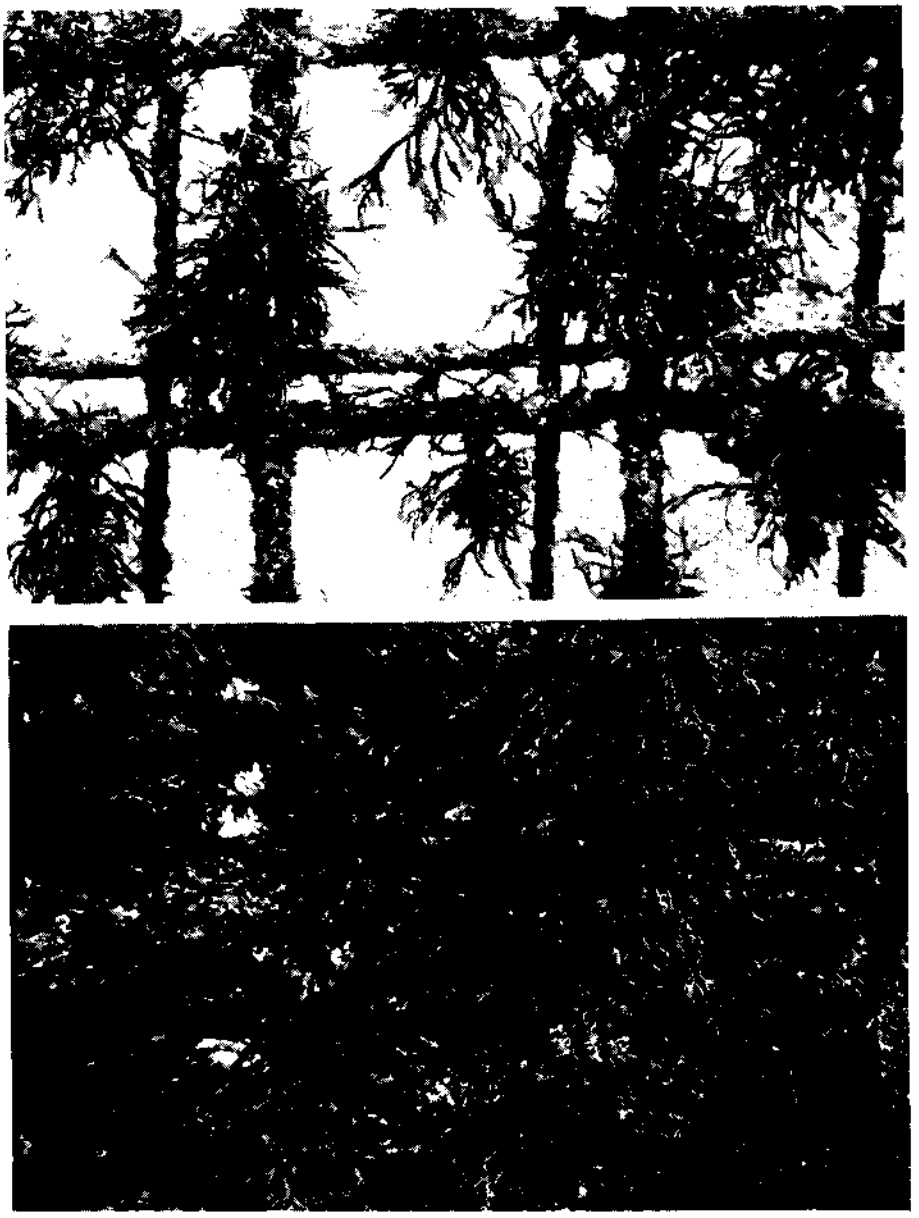
A glass-jar hatchery complex for induced breeding of fish

Composite fish culture

A system of pond management called mixed fish farming or composite fish culture which was practised in

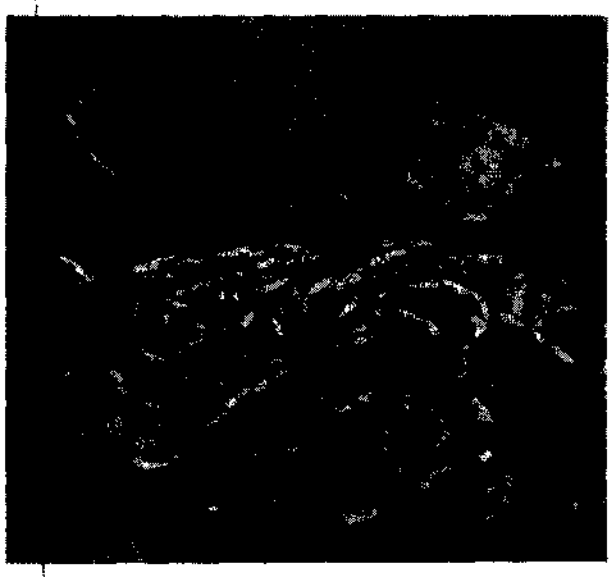


Top and Bottom: Elvers and cultured eel at CMFRI Regional centre at Mandapam Camp



Culture of sea weed *Gracilaria edulis*, CMFRI Regional Centre, Mandapam Camp

many parts of the Southeast Asian countries in ancient times, is now being practised in our country also with remarkable success. The basic principle of composite fish culture is that, fast growing compatible species of fish of different feeding habits, or different weight classes of the same species, are stocked together in the same pond so that all its ecological niches are occupied by fishes yielding high production per ha. of water body.



A haul of fish from a pond under composite fish culture

In order to increase the per-hectare production from fish culture ponds, initial experiments with differerent combinations of Indian major carps (Catla, rohu and mrigal) gave productions of 1,500–3,000 kg/ha/yr. However, when exotic carps (silver carp, grasscarp and common carp) alone were cultured, production of about 3,000 kg/ha/yr was obtained. But a combination of Indian and exotic carps in the ratio of 1:1 : 1;3 : 1.5: 2.5 of catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), silver carp (*Hypothalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*) and the common carp (*Cyprinus carpio*) gave a production varying between 2,200 to 4,200 kg/ha/yr. With intensive fertilization and supplementary feeding and higher rate of stocking (10,000 fingerlings/ha) gave a net production ranging from 8,000 to 9,000 kg/ha/yr. In these experiments each of the six species have attained a weight of over 1 kg. This technology when applied to a farmer's field would increase the yield sevarl times from the average production rate of 600 kg/ha/yr from fish ponds in India.

The technology of composite fish culture has been applied to different agro-climatic conditions through a Co-ordinated Project. The results are given in Table 4.

Table 4. *Yield from composite culture of Indian and exotic carps (six species combination)*

Centre	Production rate (kg/ha/yr)
Kalyani	6521–7820
Poona	5136–5596
Bhavanisagar	2570–3499
Jaunpur	4199–4693
Karnal	5135–6052
Sunkesulla	2602

In brackish waters composite culture of prawns and mullets (in a six species combination) gave a net production of 2,617 Kg/ha/yr.

Under the operational Research Project at Krishna Nagar, West Bengal, the technology of composite fish culture is demonstrated to fish farmers. Adopting suitable management policies and multiple cropping, yields of over 3,637 kg/ha/yr were obtained.

Air-breathing fish culture

Swampy or derelict waters which are not utilized for any productive purpose extend to about 0.6 million ha in our country. The carrying capacity of swamps is high due to organic matter in the bottom silt and the occurrence of a variety of benthic fauna. The air-breathing fishes such as *Heteropneustus fossilis, Clarias magur, Anabas testudineus, Ophiocephalus* spp., *Notopterus*, etc. constitute the natural fauna of swamps and they have high protein and low fat content. Under the Co-ordinated Project on culture of air-breathing fishes, in controlled and mixed culture of these fishes a gross production of 1,200 kg/ha per 7 months was obtained in Bihar. In Karnataka, the production of 3,159 kg/ha/8 months was obtained in the monoculture of murrels in swamps. In Assam, cage culture experiments yielded 35,000 to 50,000 kg/ha in 200 days when computed over the production per cage area.

Frog culture

In yard and field experiments, natural environment was stimulated for the culture of frogs such as *Rana hexadactyla*. This species breeds continuously for three months in rainy or cloudy weather. 100% hatchings of eggs was obtained and 3,000 tadpoles developed.

Provision in the ponds of *Hydrilla* and *Lemna* gave a high rate of growth and survival. A survival of 90% metamorphosed juveniles was possible. Early juveniles were fed with termites and other insects and these grew to 15–60 mm size. By induced breeding 7,600 hatchlings of *Rana tigrina* were obtained. A survival of 70% tadpoles was obtained by controlled feeding. Reduction of water column with progressive growth hastens metamorphosis.

Freshwater prawn culture

Culture experiments on fresh water prawns are mainly carried out on *M. rosenbergii, M. malcolmsonii,* and *M. idella.* All these prawns have been bred under laboratory conditions and their larvae reared to stocking size. Experiments on large scale culture of these prawns are progressing. Preliminary experiments on the field culture of *M. rosenbergii* have indicated that the species grows well in ponds stocked with silver carp and mrigal, and the monoculture of *M. malcolmsonii* with a stocking density of 20,000 per ha. has realised a net production varying between 285 and 380 kg/ha/year. Natural seed resources of *M. malcolmsonii* have been located over the anicuts at Dowaleswaram on the river Godavari and near Cuttack on the river Mahanadi.