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MANDAPAM CAMP
16-18 September 1987

Papers Presented
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(Indian Council of Agricultural Research)
P. B. No. 2704, E. R. G. Road, Cochin-682 031, India

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Technical Session III

RESEARCH IN MARICULTURE FISHERIES

Paper - 36

RESEARCH IN THE ASSESSMENT OF CAPTURE AND CULTURE FISHERIES ALONG THE INDIAN COAST

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ABSTRACT

A review of the research conducted at National Institute of Oceanography, Goa, to assess the capture and culture fishery potential of India is presented in the paper. The primary, secondary and benthic productivity of estuaries and backwaters are elucidated by taking the Mandovi-Zuari estuarine system as an example. The productivity of the coastal and oceanic waters around India are discussed. The expected fishery yield and present level of exploitation are assessed and further course of action discussed in this paper. In culture fisheries the contributions of NIO in the fields of mussel culture, shrimp culture, brine shrimp culture, seaweed culture, horse-shoe crab culture and fish culture are reviewed and discussed.

INTRODUCTION

India, with an extensive coastline of over 6,100 km and an exclusive economic zone (EEZ) of above 2 million sq. km, contributes about 46% of the total exploited living resources from the Indian Ocean. The marine fisheries of India are dominated by pelagic fishes like sardines and mackeral, though demersal fishes like butter fish, pomfrets, sciaenids, and more importantly the shrimps, contribute substantially. Unlike the pelagic, the demersal fisheries show less annual and seasonal fluctuations. Research and scientific management have greatly helped in the development of Indian Ocean fisheries. Although the growth rate in fishing industry has come down during the last few years, it had registered a growth rate of over 4% in the 1950s and 1960s (Dalal and Parulekar, 1985). This growth rate has been possible due to the research and development efforts in the field of fishery science, technology and oceanography by various central and state organisations and Universities.

The present paper briefly describes the salient findings of research conducted at the National Institute of Oceanography (NIO), Goa to assess the capture and culture fishery potential of India.

AREAS OF STUDY

The role estuaries and backwaters play in the productivity of coastal waters of India need not be over-emphasized. The National Institute

of Oceanography has conducted a number of studies at major estuaries and backwaters of India. The Cochin backwaters has been studied for nearly two decades and the results have been published periodically (Qasim *et al.*, 1969; Qasim, 1970; 1973 and 1979). The Mandovi-Zuari estuarine system (Goa) situated along central West coast of India (lat. 15°25'-15°30'N long 73°45'-73°55'E) has been extensively studied. It is a tide dominated estuary which is homogenous vertically with lateral variations in salinity. It also develops a salt wedge. Annual variations in salinity are large (0-34°/$_{oo}$) while the variations in temperature are about 5-6°C (Qasim and Wafar, in press). The depth of the euphotic zone varies from 0.75 to 6 m with greater depths during the inter - monsoon period (Devassy, 1983).

Several programmes have also been undertaken in Vembanad Lake (Madhupratap, 1978), the Auranga, Ambika, Purna and Mindola estuaries of Gujarat (Nair, Gajbhiye *et. al.*, 1981), and the Shastri and Kajvi estuaries of Maharashtra (Achuthankutty *et al.*, 1981) to assess the part played by the major estuaries in the west coast of India on its productivity potential and fishery. Along the east coast of India the Hooghly and Mahanadi estuaries have been studied.

Biological oceanographic studies in the Indian Ocean received considerable impetus during the International Indian Ocean Expedition (1960-65). A number of reports and Atlases have been published as an outcome of this major effort. Subsequently, primary, secondary and benthic productivity of the Indian Ocean have been estimated based on samples from more than 170 cruises of R. V. *Gaveshani* and more than 40 cruises of ORV *Sagar Kanya*.

From the coastal and oceanic areas of the seas around India, studies conducted upto 10°S lat. only are included in the present paper, although a number of oceanographic cruises and expeditions had been undertaken by the National Institute of Oceanography beyond this region including the Antarctic continent.

BIOLOGICAL PRODUCTIVITY AND CAPTURE FISHERIES POTENTIAL

Estuaries and Backwaters

Phytoplankton production: In Mandovi-Zuari estuarine system maximum abundance of phytoplankton occurs during the post-monsoon period. On an average, annually the phytoplankton cell counts vary from 4.75×10^3 to 1370×10^3 cells/l. Primary production values in the Mandovi estuary during post-monsoon, monsoon and pre-monsoon are 1077, 262 and 570 mgC/m^2/day respectively (Verlencar, 1982). Average primary production for the entire estuarine system is 510 mgC/m^2 /day (Devassy, 1983).

Zooplankton producton: Secondary productivity of Mandovi-Zuari estuarine system was calculated from the biomass data and it ranged from 1 to 83 mgC/m^2/day (Bhattathiri *et. al.*, 1976; Goswami, 1979). The average production rate was 22 mgC/m^2/day (Goswami, 1979). The mean biomass of zooplankton in this estuarine complex was reported as 0.12g/m^3 (Goswami and Selvakumar, 1977). The total secondary production from this area was estimated to be 1078 tonnes C/yr by Selvakumar *et al* (1980). The zooplankton abundance in tropical estuaries is basically controlled by the prevailing salinity regime and flushing effect. In the Cochin backwaters biomass is high during the pre-monsoon period, very low during monsoon period and intermediate during the post-monsoon period (Qasim *et al*, 1969; Wellershaus, 1974). The average secondary productivity of Cochin backwaters is estimated to be 15.4 gC/m^2/Year (Madhupratap, 1987).

Benthic production: The macro benthic biomass and production in this estuarine complex was studied by Parulekar *et al.*, (1980). The annual mean biomass calculated by these authors was 4.08 gC/m^2. Low production was found in the monsoon months. High production rates were obtained both during pre-and post-monsoon seasons depending upon the area and its proximity to the sea.

Predictions and fish yield: Based on the above studies using a conversion of 1% primary

production or 10% secondary production (Qasim, 1977), the tertiary production of this estuarine system of approximately 92km² is estimated as 1,200 tonnes/year (Qasim and Wafar, in press). The present fish yield from the brackish and freshwater regions of Goa is about 1,400 tonnes/year of which nearly 80% comes from the Mandovi - Zuari estuarine system. Thus the calculated tertiary yield is reasonably accurate and helps to maintain a sustainable yield.

Although a prediction of the final biological yield from an estuary is possible by an assessment of the productivity rates at various trophic levels as has been made above, in certain estuaries like the Cochin backwaters and the Hooghly-Matlah estuary, detritus also plays a very important role in the trophic chain and final fishery yield. In such cases, the demersal fishery would nearly dominate. In the Cochin backwaters settled detritus production is on an average 14.96 gC/m²/day (Qasim and Sankaranarayanan, 1972) whereas average primary production is only 0.77gC/m²/day (Qasim *et al.*, 1969). Thus the energy available for intake in the case of demersal fishes is nearly 20 times greater than that available for pelagic forms.

Coastal Waters

Biological productivity of coastal waters ranks in importance next to estuaries. The average primary production in the shelf waters is about 164 gC/m²/year (Whittle, 1977). Within the coastal waters primary productivity rates differ considerably. In areas < 50 m depth where the major fishing effort is concentrated, the primary productivity is at least six times higher than that of the coastal waters of <60m depth (Qasim, 1979).

Primary production: Along the west coast of India, upwelling occurs during south-west monsoon and reaches its peak in July-August. During this process the nutrients from deeper waters are brought to the surface in addition to the amount added through river run-off. Measurements on primary productivity along the Indian coast and from the Indian Ocean were made from about 480 stations north of 10°S lat. during the IIOE and later on board INS *Darshak*, R. V. *Gaveshani*, and ORV *Sagarkanya*. About 150 stations were occupied for primary productivity studies from 28 cruises of R. V. *Gaveshani* (V. P. Devassy, pers. comm.). The primary production attains its highest values during the post-monsoon period which range from 0.48 to 2.45 gC/m²/day with an average value of 1.19 gC/m²/day (Nair *et al.* 1973). Pooling all seasonal data Qasim *et al.* (1978) obtained an average production rate of 0.76 gC/m³/day.

Secondary production: Throughout the coastal, area zooplankton abundance is generally bimodal with two peak periods. February-April and September-October (Rao, 1979). The studies carried out on zooplankton samples of IIOE and R. V. *Gaveshani* indicate pockets of high zooplankton biomass in the areas off Bombay, Goa, Mangalore and Cochin. The Bay of Bengal showed a gradual southward increase in zooplankton biomass with higher values in the region between Visakhapatnam and Madras. Goswami (1985a) has obtained an average secondary production of 24.52mgC/m²/day along the central west coast of India which is less than the values reported by Qasim *et al.* (1978) for the west coast and Goswami (1985b) for Goa coast. Nair *et al.* (1981) observed an average biomass of 17.6ml/100m³ along the east coast of India in June. Madhupratap *et al.* (1981) estimated the average secondary productivity of the Andaman Sea as 288 mgC/m² with a range from 185.6 to 608.6 mgC/m². Studies based on IIOE (IOBC, 1968-73) have shown that some part of Bay of Bengal is equally rich in zooplankton as the Arbaian Sea. Qasim *et al.* (1978) estimated the secondary productivity of coastal waters of Indian Ocean as 2.5 x 10⁶ tonnes C/Year.

Benthic production: Parulekar *et al.* (1982a) have estimated the benthic production of Arabian Sea, Lakshadweep Sea, Andaman Sea and the Bay of Bengal based on the OCEANOX cruises (1973-74) on board INS *Darshak* and data obtained from 56 cruises of R. V. *Gaveshani* (1976-80). The nearshore areas of >30m depth mainly contribute for high biomass

production and the standing crop decreases with the increasing depth. The macrofauna is the chief contributor for biomass production in the shelf region while along the slope and deeper areas the meiofauna dominate (Parulekar *et al.*, 1982a).

The biomass for the whole area varies from 0.01 to 610 g/m². The mean biomass was 17.61 g/m² for Arabian Sea, 7.32 g/m² in the Andaman Sea, 5.32 g/m² in the Bay of Bengal and the lowest of 0.74 g/m² in the Lakshadweep Sea. In the shelf region of Arabian Sea the benthic productivity ranged from 1.0 to 2.3 gC/m²/year while it varied between 0.6 and 3.1 gC/m²/year in the Bay of Bengal. In the Andaman and Ladshadweep Seas the annual production is of a low magnitude and it varies from 0.7-7.8 gC/m²/year (Parulekar *et al.*, 1982a).

Prediction and fish yield: Adopting the previously mentioned trophic conversions, the tertiary yield was calculated as 0.185 $\times$ 10^6 tonnes C/year. Using the live weight conversion factor of 10 the potential yield was calculated to be about 2 million tonnes/year. Qasim *et al.*, (1978) have calculated a sustainable yield of 0.8 million tonnes/year from these values.

The potential demersal yield computed from the studies of Parulekar *et al.*, (1982a) was 0.75 million tonnes for Arabian Sea and 0.33 million tonnes for the Bay of Bengal, totalling to about 1.08 million tonnes/year for the shelf waters of India. At present only 0.45 million tonnes are exploited from a possible 0.65 million tonnes which suggests that there is a scope for increased efforts to further our demersal fisheries.

Oceanic Waters

Oceanic waters are relatively less productive. However, this is compensated by the enormous area (almost 92%) they occupy of the total marine expanse. Such low rates of primary production in the oceanic waters are directly related to the impoverishment with macro-nutrients, particularly inorganic nitrogen (Wafar *et al.*, 1986). The same holds good with zooplankton production as well. The availability of lesser number of phytoplankters to form food of zooplankton itself would be the main reason for this poor secondary productivity. Pant (1981) observed a primary productivity of 4.4 mgC/m³/hour at Great Nicobar Island which was higher than any other region in the Andaman Sea. Qasim and Ansari (1981) found that detrital carbon in the Andaman Sea constitutes about 92% of the total particulate carbon while phytoplankton and zooplankton constitute small fractions of the total suspended matter.

In deeper waters (>1000m) Parulekar *et al.*, (1982a) observed an average benthic production of 1.3, 0.04, 0.39 and 0.75gC/m²/year in Arabian Sea, Lakshadweep Sea, Andaman Sea and the Bay of Bengal respectively. The macrofaunal biomass varied from 0.47g/m² to 13.32g/m² with an overall mean value of 2.62 g/m² in the central Indian Ocean (Parulekar *et al.*, 1982b). The areas along the slope and the deep sea can support a potential yield of 0.4 million tonnes in the Arabian Sea, 0.13 million tonnes in the Bay of Bengal and 0.07 million tonnes in the island groups.

MARICULTURE POTENTIAL

Besides its contributions in the field of Oceanography and fisheries the National Institute of Oceanography has also undertaken considerable research work in mariculture. The areas covered include molluscan culture, crustacean culture, seaweed culture and fish culture. For most of the studies the existing running seawater aquaculture facility (Chatterji *et al.*, 1983) has been made use of.

Molluscan culture: Of all the cultivable species of marine and estuarine plants and animals, the bivalves, because of their sedentary and gregarious habits, short food chain, and fast growth, form the most ideal organism for undertaking commercial cultivation on a large scale. By far the modest success achieved in the culture of edible bivalves pertain to mussels, *Perna viridis* and *Perna indica*. The techniques of culture of green mussel and the economics of the entire operation has been published (Qasim *et al.*, 1977; Parulekar *et al.*,

1984). An annual production of 368 kg/m² has been achieved by applying these techniques with *P. viridis* (Qasim *et al.*, 1977). Under aboratory conditions an annual growth of 89 mm has also been achieved with the above species (Chatterji *et al.*, 1984). Attempts to culture oyster, clams like *Paphia malabarica*, *Villorita cyprinoides*, *Donax incarnatus* and *Meretrix casta* from coastal waters of Goa have also been made with reasonable success (Parulekar *et al.*, 1984).

Crustacean culture: The brine shrimp *Artemia* which is present in large quantities in high saline lakes and salt pans has become a much sought after food organism for a large variety of aquatic animals. The National Institute of Oceanography has conducted a survey all along the coastline of India to find out potential resources of *Artemia*. This has led to the finding of new *Artemia* grounds along Saurashtra and Kutch coasts of Gujarat (Royan, 1979). The annual cyst production from these natuaral areas run to a few hundred kilograms which is not sufficient to meet the demand. Considering this NIO has been concentrating on the culture of *Artemia* since 1975 and has worked out the requirements for optimum growth and survival. The Indian strains *Artemia* requires 35°/$_{oo}$ salinity and 30°C seawater for efficient hatching (Royan, 1976). All the life stages of *Artemia* thrive well on unicellular algae as well as bacteria, yeast and rice bran.

It is observed that decapsulated *Artemia* cysts, when directly fed to the juvenile prawns *Metapenaeus monoceros* more than 50% food conversion efficiency could be attained (Royan, 1980). Similarly, when adult *Artemia* were fed to three species of penaeid prawns *M. dobsoni*, *M. monoceros* and *Penaeus indicus*, good growth and conversion efficiency were obtained (Royan *et al.*, 1987). Complete information on the population dynamics and growth characteristics of the Indian strain of *Artemia* from the salt pans in Tuticorin (Tamilnadu) and Mundra (Gujarat) are available (Royan *et al.*, 1978). By monitoring the salinity, temperature and the level of water in the condensor pans, a cyst production of 30 kg/ha/season could be achieved.

Among the 55 species of shrimps and prawns accuring in commercial landing, 15 species are found suitable for aquaculture. Among them, priority is accorded to *Penaeus monodon*, P. *indicus* and *P. merguiensis* because of their demand and profitability. Seed survey has been carried out in all the major backwaters and estuarine systems, coastal lagoons besides the surf waters by various agencies. The seed resources of *P. monodon* are confined to certain localities. According to one estimate (Nair, 1986) about 1.5 billion postlarvae of penaeid prawns are immediately required to put 30,000 ha. of brackishwater area under shrimp culture. Trials to improve the hatching rate, survival and growth rate of penaeid larvae in hatchery are undertaken continuously as part of the mariculture programme. With the cooperation of traditional shrimp farmers, studies were conducted to improve the traditional method of paddy-cum-shrimp culture by incorporating more modern methods such as introduction of nursery pond, supplimentary feeding, retrieval of under sized juveniles and other management techniques (Gopalan *et al.*, 1978). Studies have indicated that short term high density farming of selected species like P. *indicus* would double the present annual yield of shrimps from paddy fields. A production of about 2300 kg/ha of marketable shrimps would be possible from the fertile Pokkali fields of Kerala in two short term crops of 12 weeks duration (Gopalan and Rao, 1981). *In vitro* fertilization of banana prawn *Penaeus merguiensis* has also been successfuly achieved and larvae reared with 28.6% survival rates upto mysis III stage (Nair, 1987).

The horse-shoe crab, a living fossil, has so much usefulness for humans that their value for biomedical research is ever increasing. The most important use of this crab lies in the presence of a reagent (LAL-lysate amoebocyte limulus) in its blood which is capable of detecting bacterial endotoxins, even if they are present in extremely minute quantities. Realising its commercial importance, the National Institute of Oceanography has undertaken a survey of the distribution of this crab along the Indian coast and it is observed that only

two species are available along the Orissa and West Bengal coasts. They are *Carcinoscorpius rotundicauda* and *Techpleus gigas* (Anil Chatterji, pers comm.). Observations made in the laboratory and fields indicate that the crabs breed year round. The females responded to 6 volt DC current and released a number of ripe eggs (Anil Chatterji, Unpublished data). Further work on the mass culture of these crabs is in progress.

Seaweed culture: The marine algae are important as food, feed and pharmaceutical compounds. The limited resource potential of the desired marine algal species and the increasing demand of the raw material have forced the need for marine algal cultivation. It is estimated that about 25,000 tonnes of dry seaweed is available from the areas already surveyed (Untawale, 1981). Rope net technique is the most commonly used method to culture marine algae and the techology is standardised. (NIO, 1985). A growth rate of upto 42.5 g/m²/day was achieved for *Gracilaria, Sargassum* and *Hypnea* by adopting these techniques (NIO, 1985). Coral stones have also been used to culture some small sized species like *Gelidiella acerosa*.

GENERAL REMARKS

From the voluminous work done on productivity of Indian waters the following are few of the outstanding conclusions. The productiviy of estuaries and backwaters of India is quite high although they exhibit strong seasonal pattern with very low values during the monsoon season. As an example the average primary productivity of Mandovi-Zuari estuarine system is 510 mgC m²/day while the secondary productivity is about 22 mgC/m²/day. The annual average macrobenthic biomass of the same area is about 4.08 gC/m². A comparison of the present fish yield from this area with the annual predictions shows that the exploitation here is nearly at the sustainable rate.

Pooling all seasons an average primary production of 0.76 gC/m²/day is observed in the coastal waters of India. The average secondary productivity along the central west coast of India is about 24.52 mgC/m²/day. The benthic productivity of shelf region of west coast of India was about 1-2 gC/m²/year. It is also computed that there is scope for further expansion of demersal fisheries of India in general.

Considerable research has also been carried out in the field of mariculture of mussels, oysters, clams, prawns, brine shrimps, horseshoe crabs and seaweeds. In many cases, like mussel culture the technoloy has been tested in the field for economic viability and are passed on to users. The results also indicate that there is tremendous scope for undertaking large scale culture of selected species from the above mentioned groups.

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