CHAPTER - II
INTRODUCTION

Prawn farming in ponds has a long history of empirical development and 'green-thumb' expertise, but the scientific investigation and documentation are relatively far from complete. The availability and growth of micralgae/phytoplankton is the most critical aspect of fish production in ponds culture. The phytoplankton growth and the interlinked ecological factors in fish ponds is of concern to the fish farmers the world over.

productivity of the Vellar - Coolrum estuarine system and Bhatnagar (1971) for the Killai Backwaters.


Some studies were undertaken on the hydrographical condition and trace metal concentrations (Ganapathi and Raman, 1973; Sharma et al., 1982; Satyanarayana et al., 1985), distribution and abundance of Oscillatoria nigroviridis (Premila and Umamahaswara Rao, 1977) and on blooms of Skeletonema costatum (Ganapathi and Raman, 1979) and a detailed investigations to evaluate the ecological effect of pollution on phytoplankton communities of the Visakhapatnam Harbour in recent year (Umamahaswar Rao and Mohanchand, 1988) and distribution of particulate matter by Sarma et al., (1989).

A detailed examination of the temporal dynamics of Phytoplankton has been made in Mondovi - Zuari estuarine complex. In addition, phytoplankton community structure and succession were discussed in relation to the prevalent environmental conditions (Devassy and Goes, 1988). Also include primary production recently by Sumitra-Vijayaraghavan and Krishnakumari (1989).

The Cochin estuaries system have been studied intensively by Qasim and Reddy, (1967) for plant pigments; tidal amplitude (Qasim and Gopinathan, 1969), organic production
(Qasim et al., 1969); salinity tolerance of phytoplankton (Qasim et al., 1972), seasonal abundance of phytoplankton (Gopinathan et al., 1974; Joseph et al., 1975), contribution of homoplankton (Qasim et al., 1974; Vijayaraghavan et al., 1974) and on primary productivity of the entire estuarine system (Nair et al., 1975).

Detailed description of the environmental condition and other particulars of the backwaters are reported earlier (Ramamirthan and Jayaraman, 1963; Wellershaus, 1971; Qasim, 1972). Extensive hydrographic data have been collected (George and Krishnakartha, 1963; Desai and Krishnankutty, 1967; Qasim and Gopinathan 1969; Shynamma and Balakrishnan, 1973; Balakrishnan and Shynamma, 1976) and nutrient distribution (Joseph, 1974, Sreedharan and Mohammed Salih, 1974; Lakshmanan et al., 1987). Considerable amount of work in relation to primary productivity has been done by Qasim et al. (1969), Qasim (1973, 1979), Gopinathan et al. (1984) and Rajagopalan (1985).

The Cochin estuarine system

The estuarine system of Cochin includes a system of inter-connected lagoons, bays and swamps, penetrating the main land with innumerable prawn culture fields, both seasonal and perennial ones, enclosing many islands in between, and with a total area approximately amounting to 500 sq.km. The backwater around Cochin is located along latitude 9 58’N and longitude 76 15’E, and this part of the estuary form a more or less a northward extension of the Vembanad Lake. The upper reaches of backwater are connected to the Arabian Sea by a Channel, about
450 m wide. These regions are relatively deeper, with depth ranging from 5-15 m and are marked by constant flushing with flood and ebbtides with a maximum range of 1 m. The lower reaches of the estuary are shallower, with very little tidal influence and have low salinity.

The estuarine system has two permanent openings into the Arabian Sea - one at Cochin and the other at Azhikode. There are five major rivers which empty into the backwater system through their tributories and branches. On the southern half, the river Pamba and Muvattupuzha join the Vembanad Lake. On the northern half, the river Periyar joins the backwaters through its tributories. All the rivers periodically enrich the area by bringing along with them nutrient-rich water and considerable quantity of particulate organic matter. The northern half of the estuary has high saline concentration and high tidal amplitude because of the two openings to the sea whereas in the lower reaches, especially in the southern area, the tidal amplitude and salinity are lower. The various environmental parameters are greatly influenced by the tidal rhythm. In the backwater, the tides are of a mixed, semi-diurnal type with a maximum range of 1 m.

The chief characteristics feature of the estuary is that during the monsoon months, it receives a considerable amount of freshwater from the rivers and other sources and the habitat becomes highly turbid. The total annual average rain fall of the Cochin area is about (3200 mm) of which nearly 75% occurs during the months from May - September.
Prawn culture systems

The dynamic environment of the estuarine system of Cochin and the connected backwater play a significant role in the fishery of the area in general and the prawn fishery in particular. In recent years, due to high demand for prawns, efforts are being made to augment their production through prawn/shrimp farming. It is estimated that about 5120 ha. of cultivable fields are situated in and around the Cochin estuarine system.

Several publications namely, Qasim et al. (1969), Qasim and Gopinathan (1969); Qasim and Shankaranarayanan (1972); Gopinathan et al. (1974); Nair et al. (1975); Pillai et al. (1975); Madhupratap et al. (1977) provide information on the hydrobiology and ecology of the Cochin Backwater and adjacent areas, but aimed accounts dealing with productivity parameters of prawn culture system situated in the estuarine complex are limited. The main objective of this study is to assess the productivity of the seasonal and perennial culture ponds through data our primary production in detail and related hydrological properties of the ponds since estimation of the biological capacity of the water in the ponds is a prerequisite in determining the stock strategies and in the evaluation of the production.

Abiotic factors

Abiotic factors particularly chemical characteristics of the environment exert profound influence on the growth and
survival of aquatic organisms. The culture ponds are mostly the extension of the estuarine and backwater system, and are therefore subjected to wide variation in the environmental condition when compared to the sea. Regular monitoring of the environmental conditions therefore become essential to understand optimum environmental condition for the culture of the organisms. In depth investigations on the fluctuations of hydrological properties such as salinity, dissolved Oxygen, temperature, hydrogen-iron concentration (pH) and Redox potential (Eh) as well as the nutrients such as nitrates, phosphates and silicates essential to phytoplankton assumes importance as they play a major role in regulating the growth, abundance, recruitment and distribution of the fauna and flora in a given culture ecosystem.

Biologic factors

(i) Algal production

Estimation of primary production is of considerable basic value because of its significance to fisheries science and problem connected with aquatic ecology. In the studies related to marine or estuarine food chain in the culture ecosystem, the estimation of standing crop of phytoplankton is a pre-requisite since animals need food for growth and survival and therefore the chlorophyll estimation indicate total plant material available at the primary stage of food chain. Further, availability phytoplankton pigments, and the possible ratio between different pigments and the taxonomic identification of phytoplankton species, play major roles in the assessment of production in the culture ecosystems.
(ii) Algal population

It is well known that the most important factors which lead to the occurrence of fish and prawn in an aquatic environment is the availability of food and hence basic productivity controls the distribution and abundance of the organisms cultured. Phytoplankton, mainly constituted by diatoms, dinoflagellates, blue-green algae and a variety of minute forms called nanoplanktons are the primary producers in the culture systems. The utilization of the organic materials produced by them is carried out by zooplankton and both form the forage of prawns and fishes.

Enrichment studies:

A significant input of enriching substances into the estuarine environment inevitably induces a modification in the ecosystem. This in turn influence the energy circuit and food web as well as the structure and dynamics of the animal communities.

In view of this, an indepth study on the fluctuations in hydrography and availability and abundance of nutrients, and their linkage on the production and population characteristics of algal communities has been taken up in selected prawn culture ponds in and around the estuarine habitat at Cochin and the results presented and discussed, and conclusions drawn in the document.

STUDY AREA

The present investigation was carried out at Narakkal (76 14'E Long., 10 03'N Lat.), a fishing hamlet in Vypeen
Island about 10 km north-west of Cochin, Kerala (Fig. 1). The land strip enclosed within the Arabian Sea on the western side and the Vypeen Channel, a branch of the Cochin backwater system on the eastern side, is characterised by several low-lying fields and coconut groves, interconnected by brackishwater canals. The canals are connected to the Cochin backwater system through a gut located at the mouth of estuary, in the south and by another at Azhikode at the northwern end of the island, which facilitate entry of tidal water. Three different prawn culture ecosystems were selected for the present study viz., a perennial prawn culture pond of Central Institute of Brackishwater Aquaculture (referred to as CIBA Pond in the text, area 0.6 ha), perennial canals in the coconut grove where prawns are farmed (referred to as COCO Field in the text, area: 1.0 ha) and a seasonal culture pond locally called POKKALI Field (area: 0.8 ha), all of which are situated at Narakkal near Cochin.

The experimental pond (Plate - Ia) selected for the study (0.6 ha. area) is connected to the mainfeeder canal by a wider sluice gate. The average depth was found to be 100 cm. The pond is stocked predominately with prawns and chanos.

The canals in the coconut grove (Plate - Ib) are primarily dug up between rows of coconut treas to irrigate the grove, but the waterbody is profitably utilized as a culture system by trapping seeds brought in by the tide, and allowing them to grow within the canals. The canals are connected to be mainfeeder canal by a small inlet. The depth of these canals ranges from 40-50 cm. Water circulation was found to be
relatively low when compared to the other two culture systems. It had an area of about 1.0 ha.

The 'pokkali' field, (Plate - Ic) located further away from both the canals of the coconut grove and the experimental pond, is used for culture of fish and prawns from December to April, during which period, the saline nature of water in conducive for culture. The culture is wound up by April when the field is utilized for cultivating a special variety of paddy called 'pokkali'. The mean depth of the field was found to be 50 cm and it had an area about 0.8 ha. Though further away from the other two culture systems, it is connected by the same feeder canal that supplies water to the other two culture systems.

**HYDROGRAPHY**

There are a number of reports on the prawn culture practices in Kerala (Panikkar, 1937; Menon, 1954; Gopinath, 1956; George et al., 1960; George, 1974; Gopinathan et al., 1982) but they are mainly concentrated on the biological aspects of shrimp culture. The culture ponds are mostly the extension of the estuary and backwaters, and therefore subjected to wider variation in environmental conditions when compared to the open sea. A regular monitoring of the environmental conditions therefore becomes essential to understand the optimum environmental conditions for the culture of prawn. Physico-chemical factors, such as temperature, salinity, dissolved oxygen, pH and Eh was carried out during the period of investigations.
Water temperature influences the bio-chemical reactions and microbial release of nutrients taking place in the pond ecosystem, as well as the physiology of fauna. The pond having the optimum height of water, the bottom water will be less warm than the surface water, which exposed to the Sun. Such variation will not be felt much in shallower ponds. As temperature increases, the ability of water to dissolve oxygen decreases.

The degree of salinity in water reflects geological and hydrological conditions. Farmers should have a through knowledge of the salinity profile of the tidal water of the site before selecting the site for construction of farm. It should also be ascertained that there is no chance of large scale fresh water influx to the farm as sudden fall in salinity would give stress to the prawn.

In a normal pond, the oxygen producing and consuming processes keep a dynamic balance which maintains the concentration of dissolved oxygen within the range tolerable to all the organisms. Concentration of dissolved oxygen decreases with increasing temperature and salinity.

Water that contains dissociated or free hydrogen and hydroxyl ions which give an acidic or neutral reaction to water depending upon their relative concentration pH of the water which is influenced by the soil pH and concentration of carbon dioxide, carbonates and bicarbonates in the water. Phytoplankton and other aquatic vegetation remove carbondioxide from the water during
photosynthesis, so the pH of a body of water rises during the day and decreases during the night.

Material and Method:

The following parameters were measured during sampling at fixed time of 0600 hrs for a period of two years from January 86 to December, 1987. The temperature was measured in situ with the help of an ordinary thermometer. Salinity of water was measured by Mohr-titration method (Strickland & Parsons, 1968). Dissolved oxygen content estimated by Winkler method (Strickland & Parsons, 1968) with due precaution.

pH was measured using a digital pH meter, and Eh was also measured by the same instrument but using an Eh electrode specifically designed for this purpose.

AVAILABLE NUTRIENTS

The plant life in seawater require certain micronutrients for their growth. The most important micronutrients are compounds of nitrogen and phosphorus. Those type of organisms which have siliceous frustules (diatoms) also require a supply of silicon. The principal inorganic form of nitrogen is as nitrates, nitrites and to a certain extent as ammonia. Inorganic phosphate exist in the seawater practically as orthophosphate. The principal sources of silicate in the ocean, are river run off and the glacial weathering of rocks. The growth and sedimentation of siliceous plankton is the principal biological processes stripping silicon from the ocean.
Tidal water is one of the sources which supplies nutrients to the pond ecosystem. Land run off through river discharge and consistent incursion of sea water have profound influence on the nutrient concentration of the tidal water prawn fields around the Cochin and Azhikode bar mouths which also are highly productive because of the influence of the Pampa and the Periyar rivers and the constant incursion of sea water through the two bar mouths.

Some work has been done on the estuarine by Suryanarayana Rao and George (1959); Krishnamoorty and Vincent (1981); De Sousa et al. (1981). Sarala Devi et al. (1983); Lakshmanan et al. (1987) but the prawn culture systems in this area around Cochin were not extensively studied until recently by Gopinathan et al. (1982) and Gopalakrishnan et al. (1988).

Material and Methods

Sampling was done between January to December, 1986 and 1987 in the perennial ponds; and from January to May 1986 as well as 1987 in the seasonal pond in 4 sites. Samples were collected in the morning 0600 hrs. and analysed immediately.

For the determination of inorganic nutrients nitrate-N, nitrite-N, ammonia-N, phosphate-P and silicate-Si the method given in the FAO Technical Paper No. 137 (1975) was adopted.

ALGAL PRODUCTION

Considerable amount of work on productivity studies in Cochin backwaters has been done by Qasim et al. (1969) Qasim
According to them the gross production ranged from 0.35-1.50 gC/m³/day. The estimated annual gross production for the entire Vembanad Lake comprising about 300 KM is about 1,00,000 tonnes of Carbon (Nair et al., 1975).

Several attempts have been made to relate productivity parameters with that of potential yield or optimum sustainable yield (Subramanyam, 1959; Prasad and Nair, 1963; Nair et al., 1969; Prasad et al., 1979; 1970; Qasim et al., 1978). It has been observed by Steemann Nielsen and Jensen (1957) that the landings of commercial fish catch in intensity exploited water is about 0.4% of the organic matter produced by the phytoplankton. A maximum sustainable yield of 0.2% would be a more realistic estimate which would amount to just about 5 million tonnes of fish for the EEZ (Nair and Pillai, 1983).

In the case of prawn culture systems the carrying capacity of the pond depends mainly on its primary production, which is the organic matter produced in the pond in the form of microflora including phytoplankton, benthic algae and photo synthetic bacteria using the radiant energy of the Sun and the nutrients available in the pond. The floras thus formed is the food of the fauna of the pond directly and indirectly. Growth and production of prawn in the pond varies according to the level of primary production.

Based on the degree of Primary Productivity, prawn fields has been classified as: highly productive (1500 mg C/m³/day)
moderately productive (500-1500 mgC/m³/day) low productive (500 mgC/m³/day), (Gopinathan et al., 1982).

The rate of primary production can be measured either directly or indirectly by estimating the standing stock of phytoplankton and using a conversion factor. For direct estimation, the production is either measured experimentally by enclosing water samples in bottles or by utilizing difference in the water masses during a certain period by measuring the property at the beginning and the end of this period. All of the pioneer works concerning productivity were based on the standing stock.

In recent years, the concentration of pigments active in photosynthesis, primarily chlorophyll has been employed as an index of the standing stock of plants and also as a means of estimating the rate of primary production (Ryther and Yentsch 1957). Consumption of carbon dioxide (Atkins, 1922) or nutrient salt (Steele, 1958; Cooper, 1957) as a means of measuring primary production have also been used. Daily variation the oxygen content of the water between morning and afternoon has also been used as a means of estimating the organic production in certain marine areas (Dedosov, 1958).

The plant pigment content of phytoplankton assumes great importance in productivity studies because of the use of these compounds for estimating the primary production and gross photosynthetic potential. Either total pigments, total chlorophyll, or the single pigments may be measured. Pigment analysis primarily chlorophyll determinations, have been used in
recent year (Krey, 1958). The spectrophotometric technique introduced by Richards with Thompson (1952) with subsequent revisions (Parsons and Strickland, 1968) have long replaced the less accurate standardisation procedure of visual matching of pigment extract with standard methyl sulphate and potassium chromate (Harvey, 1534).

The conversion factors as given by Cushing (1958) for plant pigment unit and that of chlorophyll is as follows:

\[
1 \text{ P.P.U.} = 3.9 - 5.2 \mu \text{g Carbon}
\]
\[
1 \mu \text{g Chlorophyll} = 13.6 - 17.3 \mu \text{g Carbon}
\]

Using Harvey's (1934) method, Subramaniyam (1959) made quantitative determination of the standing crop of phytoplankton of the west coast. He found that the standing crop in terms of carbon varies from 0.06 g to 12.28 g over a metre square area of the sea surface with the highest values during the south-west monsoon. From these measurements he concluded that the west coast of India is one of the highly productive regions of the world.

A close relationship usually exists between the concentration of chlorophyll in the culture pond and the total abundance of phytoplankton.

Material and Methods

Samples of water for measuring primary production were collected from surface in the ponds in the morning at 0600 hrs and incubated in situ for 6 hours regularly and data collected for a period of two years (1986 to 1987).
Primary production measurements were made using Grander and Gram's (1927) light and dark bottle method as described by Strickland and Parson (1968). Dissolved oxygen was estimated by Winkler's titration method from which gross and net photosynthesis were calculated and expressed as mgC/m³/day.

Productivity was calculated as follows:

\[
\text{Gross primary production} = \text{Light bottle} - \text{dark bottle}
\]

\[
\text{Net primary production} = \text{Light bottle} - \text{initial bottle}
\]

\[
\text{Production } A = \frac{0.598}{PQ} \times (\text{ml}) \times 0.598
\]

\[
\text{Productivity in mgC/m}^3/\text{day} = A \times \frac{10}{T} \times 1000
\]

PQ (1.25)

T (duration of the experiment)

10 (assumed that photosynthesis takes place for 10 hours during a day)

For the estimation of phytoplankton pigments, one litre surface samples were collected and filtered through Millipore filters (type HB, 47mm, 0.45 micron pores) and dissolved in 10 ml of 90% acetone and stored under refrigeration over night. The acetone extract was centrifuged at 3000 rpm for 5 minutes and the sample analysed spectrophotometrically.

The spectrophotometric method described by Timothy Parson et al. (1984) with modification was followed for evaluating different fractions of chlorophylls viz., chlorophyll 'a', 'b', 'c', and also carotenoids.
Calculation

(Ca) Chlorophyll $a = 11.85 \times 10^{-6} - 1.54 \times 10^{-6} - 0.06 \times 10^{-6}$

(Cb) Chlorophyll $b = 21.03 \times 10^{-5} - 5.43 \times 10^{-5} - 2.66 \times 10^{-5}$

(Cc) Chlorophyll $c = 24.52 \times 10^{-6} - 1.67 \times 10^{-6} - 7.60 \times 10^{-6}$

$mg\ Chlorophyll/m^3 = \frac{C \times v \times 10}{V \times 10}$

Where $v$ is the volume of acetons in ml (10 ml),

$V$ is the volume of seawater in litres.

(Cp) Carotenoids $= 7.6 \times 10^{-4} - 1.49 \times 10^{-4}$

ALGAL POPULATION

There are several aspects of phytoplankton ecology that need elucidation such as factors leading to succession of phytoplankton to changes in environmental conditions. Answers to these involved problems could be obtained through experimental studies employing laboratory culture of selected phytoplankton organism. One of the pre-requisites for such studies is to know the distribution pattern of phytoplankters.

Species composition of phytoplankton communities in the pond is important because different taxa of planktonic algae present different dietary values in various development stages of fish or zooplankton. In general, phytoplankton species occurring in culture ponds includes members of Chrysophyta (diatoms and golden brown algae), Chlorophyta (green algae), Cyanophyta (blue-green algae), Pyrrophyta (dinaflagellates) and some flagellates.
The phytoplankton species composition in ponds may vary from few to a large number of species. The species diversity concept developed by Margalef (1958) for phytoplankton, is useful in describing the significance of species abundance in relation to the stability of the phytoplankton community. In general, higher species diversity indicates a greater stability in a given ecosystem (Odum, 1971), because the fluctuation in abundance of individual species would have influence on the entire community than the system of lower diversity.

In this area the prawn culture system was not extensively studied until recently. In view of the growing importance of prawn culture in these system, a general ecology study was taken up. The environmental characteristics of these systems were described by Nair et al. (1988). Qualitative and quantitative aspect of phytoplankton and zooplankton in the seasonal and perennial prawn culture system of Cochin backwaters in relation to the environmental parameters were described by Gopalakrishnan et al. (1988).

Material and Methods

Sampling was done early in the morning from fixed stations in the ponds. During 1986, surface samples were brought to the laboratory and examined the phytoplankton in live condition and data recorded. Qualitative and quantitative studies on algae were carried out by "counting chamber method" during 1987.

The model now in common use is a combined plate chamber consisting of a top cylinder of 50 ml capacity and a bottom plate
chamber. The principle is to remove the upper part of the chamber (the sedimentation cylinder) after sedimentation leaving organisms in the bottom part, which can directly be examined under the microscope and enumerated. An aliquot of 25 ml of the sample was used, and Lugol's Iodine was used as preservative.

ENRICHMENT EXPERIMENT

In most fish ponds, nutrient enrichment by artificial fertilization is commonly practiced in order to increase fish production (Shen 1976; Hepher 1962; Chiou and Boyd 1974). As a result, the phytoplankton species diversity is minimized in the nutrient enriched system, which lead to relatively wide population density. The individual species of phytoplankton in fertilized pond water often undergo rapid cycles of population bloom, and massive die-off and may cause oxygen super-saturation as well as severe oxygen depletion. Excessive blooms of blue green algae frequently occur in nutrient rich water.

Since ponds which are managed, are often fertilized, nutrients concentration is generally high and phytoplankton productivity greater than the average natural waters. Boyd (1973) reported that chlorophyll concentration in a series of fertilized ponds than those in the unfertilized ponds. He also observed that chlorophyll values in fed catfish ponds averaged 102 mg/L, stimulated mainly by the nutrients released from the feed.

Studies on nutrient limitation have also shown that for marine coastal waters nitrogen in the form of nitrate and nitrate is usually the important limiting nutrient for the survival and
growth of phytoplankton biomass (Berland et al., 1980; Nixon and Pilson, 1983; Canaco et al., 1987). For brackish waters, phosphorus may play an important role, especially if fresh water inflow is high the case in Trandheim fjord (Sakshaug & Myklestad, 1973), the inner part of Manreille Bay (Berland et al., 1980), Bothnian Bay, located at the northern part of the Baltic sea (Allassarela, 1979) and Chesapeake Bay during winter (D’Elia et al., 1988).

Material and Methods

In vitro nutrient enrichment experiments with the natural population of phytoplankton from the culture pond were carried out during August, 1987 which represent the period monsoon. Water from the surface of the culture pond was collected early in the morning and maintained in circular type ten litre capacity tank. Experiments were conducted under the glass-roof laboratory of the hatchery of the Central Institute of Brackishwater Aquaculture (formerly Marine Prawn Hatchery Laboratory).

Nutrient experiments were performed in situ during the post-monsoon period of December, 1987 and pre-monsoon period of March, 1988, using twenty five litre capacity plastic tubs encircled by a net fixed in the culture pond (Plate - 1d).

Nutrients were added to the 20 litre sample, alone and in combination, to the water at the beginning of the experiments follows: 500 µg/l nitrogen, 1000 µg/l phosphorus and 5000 µg/l silica. For EDTA and tracemetal additions the amounts used are of
10 µg/l zinc, 100 µg/l manganese, 5 µg/l molybdenum, 5 µg/l cobalt, 5 µg/l copper, 1300 µg/l iron and 1300 µg/l iron and 1300 µg/l EDTA. Effects were measured with treatments such as N, P, S, N+P, N+S, P+S, N+P+S, T, N+P+S+T and along with the non-treated one. Phytoplankton biomass as well as their production was measured through the content of chlorophyll 'a'. Effects of treatment were also tested statistically for individual sampling on each date.

In general, the significance of prawn culture fishery and prospects and management were those of Muthu (1978b); Rao (1980); Silas et al. (1981); Silas (1983) and George (1983).