CHAPTER II

PHYSICO-CHEMICAL FEATURES OF THE CULTURE SITES

Introduction

A knowledge of the biotic and abiotic factors affecting the culturable species of fish/shellfish is a pre-requisite for their successful culture. The culture performance of shrimps and their survival and growth are influenced by environmental conditions. Factors controlling the quality of water which determines to a great extent the success or failure of culture operations, are extremely varied; maintenance of optimum water quality is essential for the optimum survival and growth of shrimps.

Successful management of an aquaculture system depends on a constant supply of nutrients necessary for the optimal growth of the cultured species. A constant supply of nutrients depends heavily on rapid recycling, which is one of the most important factors for maximising production in pond culture. Phosphate and nitrate play a significant role in the production of aquatic organisms, especially micro- and macroplants. The supply of nutrients is also dependent on the fertility of the bottom soil and soft sediment, which form the habitats for bottom organisms, particularly shrimps.

For augmenting fish/shrimp production in pond culture, the growth of plankton and aquatic macrophytes is critical, especially because
most fish/shrimp raised in warm water ponds in less developed countries are dependent largely upon natural food. Phytoplankton is used by the primary consumers (zooplankton), which serve as the major food source for a wide variety of organisms including fish. Phytoplankton growth and the associated ecological factors in fish ponds have concerned fish farmers the world over. Lin (1970) stated that carp farmers in China judge the water quality of the ponds by the colour of the water; the degree of greenness of water reflects the abundance of phytoplankton.

In brackishwater ponds with moderate or high salinity, diatoms are the dominant phytoplankton. Diatoms require fairly large amounts of nitrogen; nitrogen is often as important, or even more important than phosphorus for the growth of phytoplankton. A healthy diatom bloom will improve shrimp growth rate and survival; it shades the bottom, decreases toxic forms of ammonia and increases the appetite of shrimps (Wyban et al., 1990). Feed consumption rate is greater, and growth rate double, in waters with rich phytoplankton than in clear waters. However, the exact reason for this is not understood yet.

Sick et al. (1972) published a research report establishing selected preliminary environmental and nutritional requirements for penaeid shrimps. Lee et al. (1986), and Wyban et al. (1987a) reported that shrimp growth was not correlated with the water quality parameters. Huang et al. (1990) found that the buffering capacity of pond water changed remarkably after the removal of organic matter; they suggested that the buffering capacity of pond water may be used as an
index for the quantity of organic matter in pond water. Hopkins et al. (1991) studied the relation among feeding rate, paddle wheel aeration rate and the expected dissolved oxygen at dawn in intensive shrimp culture ponds. The results of this study indicate that the dissolved oxygen at dawn can be predicted based on the amount of feed applied per unit aeration. Visscher and Duerr (1991) studied the water quality, and the microbial dynamics in shrimp ponds receiving bagasse-based feed. In 1992, Boyd published an excellent report (Boyd, 1992) on the role of water quality and aeration in shrimp farming, which can be considered as a practical manual for water quality management of shrimp culture ponds. Hudson and Lester (1992) published the results of their study on the relation between water quality parameters and ectocommensal ciliates on cultured P. japonicus; they noted that as the water quality decreased, the number of Zoothamnium increased and the number of Cothurnia decreased.

Feed cost is usually the heaviest operating expense in aquaculture, often representing half of the total operating expenses of a fish farm. One effective alternative to overcome this is fertilization. It will not only simplify the whole process of fish/shrimp culture, but also will lower the labour cost and the total operating expenditure. The excellent review by Hickling (1962) on pond fertilization has emphasised the efficiency of inorganic fertilizers and organic manure for increasing the productivity of fish ponds. Bhimachar and Tripathi (1966) expressed the view that lack of adequate
fish food organisms is one of the major causes of low productivity of brackishwater fish ponds. They recommended the application of fertilizers for increasing pond productivity. Importance of the use of fertilizers and manure for brackishwater fish culture has also been emphasised by Pillay (1954), Lin (1968), Chen (1972) and Djajadiredja and Poernomo (1972). Beneficial effect of combined treatment with different inorganic fertilizers has been reported by Hepher (1962), Wrobel (1962) and Singh et al. (1972). Blanco (1970) reported that production in brackishwater ponds can be enhanced considerably by the addition of nitrogen and phosphorus fertilizers along with organic manure. The addition of phosphorus and nitrogen to aquatic systems increases phytoplankton and zooplankton population (Boyd, 1979). Chattopadhyay and Mandal (1980) studied the influence of cow dung along with inorganic fertilizers on some chemical and biological properties of the water and soil of brackishwater ponds.

Intense organic and chemical fertilization of fish ponds can replace all the conventional feed requirements and give fish yields of 15-31 kg/ha/day, with no supplemental feeding (Tang, 1970; Yashouv and Halevi, 1972; Schroeder, 1974; Schroeder and Hepher, 1976; Moav et al. 1977). Such yields are similar to those attained with conventional feeds containing 25% protein and 10% fish meal. Benthic microbial activity increases in response to sedimentation of phytoplankton blooms and benthic biomass is capable of doubling because of increased microbial production (Graf et al., 1982). Research done in Israel by
Schroeder (1978) on organic fertilizers in fish culture systems may have applications to shrimp culture. This study has shown that increase in the microbial community which uses manure and organic matter, is adequate to increase fish growth in earthen ponds; increase in the benthic biomass would likewise be expected to increase shrimp production. Chattopadhyay and Mandal (1982), Chakrabarti (1984) and Andarias (1990) studied the influence of organic and inorganic fertilizers on the quality of the soil and water in brackishwater culture ponds.

In semi-intensive and intensive culture, shrimps are fed artificial feed. The major part of the feed settling to the bottom is consumed by shrimps. Inorganic nutrients released into the water from shrimp excrement and from microbial decomposition of uneaten feed, stimulate phytoplankton blooms. Phytoplankton have a short life span and they continually die and settle to the bottom. In some places water supplies contain settleable solids of appreciable organic matter content that gets deposited on the pond bottom. The net effect is that a sediment containing appreciable amounts of organic matter is accumulated over a period of time. This alters the shape of the pond bottom, reduces pond volume and provides organic substrate for microorganisms. Water currents are the weakest at the soil-water interphase. Here, since microorganisms rapidly decompose organic matter, dissolved oxygen may be exhausted faster than it is delivered by water movement (Boyd, 1993). This can result in anaerobic conditions
at the bottom, even though the water above may be thoroughly oxygenated. In anaerobic soil and sediment, microorganisms can produce nitrite, ferrous iron, hydrogen sulphide, methane and other reduced compounds that can harm shrimp. Thus, even if the water quality variables of the water column are within tolerable ranges, poor soil condition can be a severe limitation to shrimp production, and this may be the prime reason for the poor growth, disease and mortality often occurring in intensive and semi-intensive ponds.

The importance of soil in brackishwater aquaculture system has been emphasised by Djajadiredja and Poernomo (1972). Soil nutrients and their role in plankton production are well studied (Banerjea, 1967; Banerjea and Ghosh, 1967; Banerjee and Banerjee, 1975; Mollah et al., 1979; Chattopadhyay and Mandal, 1980, 1982,; Singh, 1980; Chakraborti et al., 1986; Pradeep and Gupta, 1986). Maguire et al. (1984) studied the macrobenthic fauna of brackishwater shrimp farming ponds. Simpson and Pedini (1985) investigated on the problems of acid sulphate soils in the tropics and suggested management measures which can reduce the level of acidity. Gilbert and Pillai (1986) analysed the physico-chemical parameters of the soil in aquaculture systems located around Cochin backwaters. Chien (1989) studied the sediment chemistry of tiger shrimp ponds, kurama shrimp ponds and redtail shrimp ponds. Chien and Ray (1990) have made a comprehensive study on the effects of stocking density and presence of sediment, on the survival and growth of P. monodon larvae. Kungvankij et al. (1990) have reported on the

Even though literature related to hydrobiological parameters of brackishwater culture systems of India is available from the sixties onwards (Varma et al., 1963; Mandal, 1964), information available on the physico-chemical characteristics of shrimp culture ponds of Kerala is fragmentary and far from complete. George (1974) studied certain aspects of shrimp culture in the seasonal and perennial fields of Vypeen islands, Kerala. Gopinathan et al. (1982), who studied the environmental characteristics of the seasonal and perennial shrimp culture fields in Cochin, Kerala, found significant regional differences in primary productivity and in the faunistic composition of the epifauna and benthos of these fields. Chakraborti et al. (1985) studied the physico-chemical characteristics of brackish water ponds in Kakdwip, West Bengal, and their influence on the survival, growth and production of P. monodon. They found that P. monodon production was positively correlated with salinity and temperature in the water phase,
and organic carbon, phosphorus and nitrogen in the soil phase, but not with depth, turbidity, pH, total alkalinity and primary productivity. Mathews (1992) studied the ecological characters of extensive type of shrimp culture fields in the Cochin area.

Evidently, hitherto no serious attempt seems to have been made to study the influence of the water quality parameters on the overall performance of shrimp cultured in the small-scale, semi-intensive, monoculture systems of this State. It was, therefore, thought worthwhile to study some of these aspects in the selected culture ponds in the hope of evolving as comprehensive a picture as possible of the culture system. The water quality parameters (water temperature, salinity, DO, pH, alkalinity, nitrate, nitrite, phosphate and ammonia), which are believed to be the major factors deciding production from aquaculture, were given importance in this study.
Materials and Methods

During the culture period, fortnightly collections of water samples were taken from the selected culture ponds; collection was done between 8 and 10 a.m. Altogether five samples—four from the corners and one from the centre of the ponds—were collected from each pond. Water samples, for the estimation of pH, salinity, total alkalinity, nitrate-N, nitrite-N, ammonia-N and reactive phosphorus, from the five sites of each pond were thoroughly mixed and from the mixture a 2 litre sample was brought to the laboratory in polythene bottles. In the laboratory all the parameters were estimated in duplicate.

Air, water and soil temperatures were measured at the site itself, using a 0-50°C high precision thermometer. The pH of water was determined by using an Elico Digital pH meter, Model U-120 (Elico, India), immediately on reaching the laboratory.

Dissolved oxygen contents of the surface and bottom water were estimated by the Winkler's method with the azide modification (Anon, 1975). For this, water samples from the surface and bottom (five samples each) were collected in BOD bottles, appropriately fixed at the site itself and brought to the laboratory; DO of each set of water samples was estimated and the average was calculated which was reckoned as the DO of surface or bottom water of a pond.

Total alkalinity was estimated employing the method suggested by Boyd and Pillai (1984). The nutrients—nitrate-N, nitrite-N and
reactive phosphorus—were estimated by using the method of Morris and Riley as described by Strickland and Parsons (1968). Ammonia-N was determined by using the phenol hypochlorite method (Solarzano, 1969). All the parameters are expressed in ppm.

A Secchi disc tied to one end of a nylon rope was lowered in the water column in five different parts of the pond and the depth at which the disc just disappeared was measured with a metre scale. The average of the five readings was taken as the Secchi disc visibility and was expressed in cm. The depth of the pond was measured by lowering the Secchi disc up to the bottom at five parts of the ponds, and measuring the length of the rope from the disc to the upper water surface; the five values were averaged and this value was taken as the average depth of the pond.

In addition to the aforementioned parameters, soil temperature and soil pH were also determined. For measuring the pH of soil, about 25 g soil was dried and stirred with distilled water and allowed to settle; pH of the supernatant was measured with an Elico pH meter.

For all parameters, in each pond, eight collections/measurements were made during one culture operation, the average of which was reckoned as the value of a parameter for a given pond for that culture operation. The weighted average of the averages for three ponds in one culture operation was calculated to get the value of the parameter for the I or II culture operation in a region in an year. Mean values for a year were calculated as the weighted averages of the values for the six
culture operations in the relevant year. From the average values for the 12 culture operations in a region, the weighted average was calculated and this was reckoned as the mean value of the parameter for a given region. The method of calculation of the relevant means of physico-chemical parameters is shown in Chart I. The data were analysed statistically employing ANOVA and simple linear correlation analyses (Zar, 1974).

Results

The results of the analyses of physico-chemical parameters of the culture sites are consolidated in Table 5 and Figs. 2–9.

Mean air and water temperatures (°C) in the three regions were somewhat similar. But soil temperature registered higher mean value for Pallithode (30.06 ± 0.56) than both for Chellanam (29.10 ± 0.57) and Kannamaly (27.72 ± 1.32). Mean salinity (ppt) in Pallithode was also higher (18.30 ± 5.82) than in Chellanam (14.41 ± 4.91) and Kannamaly (13.29 ± 3.78).

Water pH in all the three regions was slightly toward the alkaline side; the highest mean value was recorded for Chellanam (7.86 ± 0.27) and the lowest for Pallithode (7.28 ± 0.11). Mean pH of soil in Chellanam (7.21 ± 0.10) and Kannamaly (7.13 ± 0.10) was also slightly alkaline. But in Pallithode mean soil pH tended to be nearly neutral or slightly acidic (6.93 ± 0.10).
Mean dissolved oxygen contents (ppm) of surface water in Pallithode (6.05 ± 0.52) and Chellanam (6.06 ± 0.23) were slightly higher than in Kannamaly (5.84 ± 0.34). A more or less similar trend was noted for mean DO of bottom water in the three regions.

Mean alkalinity (ppm) in Chellanam was as high as 92.67 ± 11.78. In Kannamaly it recorded a mean value of 72.54 ± 8.50 and in Pallithode, a comparatively low value of 65.12 ± 17.54.

Nitrate-N (ppm) had a very high mean value for Kannamaly (0.64 ± 0.09) compared to Chellanam (0.31 ± 0.07) and Pallithode (0.27 ± 0.07). But, mean nitrite-N (ppm) was strikingly similar in all the three regions (0.08 ± 0.01 - 0.02). Mean ammonia-N (ppm) values for Chellanam and Kannamaly were similar (1.89 ± 0.25 and 1.90 ± 0.30, respectively); it registered a slightly higher value for Pallithode (2.22 ± 0.59). Mean values of reactive phosphorus (ppm) were the same in Pallithode and Chellanam (0.03 ± 0.01), whereas it was as high as 0.08 ± 0.03 in Kannamaly.

Mean values of Secchi disc visibility (cm) were more or less similar for Chellanam (35.56 ± 3.15) and Kannamaly (36.36 ± 3.26); a slightly higher value was noted for Pallithode (40.35 ± 6.11).

On the whole, the results suggest that all the physico-chemical parameters tested in the three regions were conducive for shrimp culture. The mean values of most of the parameters (except salinity, alkalinity, nitrate-N and reactive-P) for the three regions were apparently more or less similar. However, in single factor ANOVA (based
on the data for 12 culture operations in each region) revealed that all parameters, except air temperature, water temperature, salinity, DO of surface water, nitrite-N, ammonia-N and Secchi disc visibility, registered statically significant differences between the three regions (Table 5). Since such significant regional differences were registered, data on nine water quality parameters (temperature, salinity, pH, DO of surface water, alkalinity, nitrate-N, nitrite-N, ammonia-N and reactive-P) of ponds in which the three different feed types (clam meat alone, clam meat + compounded feed and pelleted feed) were used, were compared statistically (single factor ANOVA). The results showed that, of the nine parameters, only three (pH, alkalinity and ammonia-N) differed significantly between the three feed treatments (pH : $F = 7.501, P < 0.01$; alkalinity : $F = 9.210; P < 0.001$; ammonia-N : $F = 4.990, P < 0.05$).
Fig. 2  Air, water and soil temperature in the culture sites of the three regions

Fig. 3  Salinity of water in the culture ponds of the three regions

Fig. 4  Water and soil pH in the culture ponds of the three regions

Regions:

P - Pallithode
C - Chellanam
K - Kannamaly
Fig. 5  Dissolved oxygen content (DO) of surface and bottom water in the culture ponds of the three regions

Fig. 6  Total alkalinity of water in the culture ponds of the three regions

Fig. 7  Nitrate nitrogen (NO$_3$-N), nitrite nitrogen (NO$_2$-N) and ammonia nitrogen (NH$_3$-N) content of water in the culture ponds of the three regions

Regions:  
P - Pallithode  
C - Chellanam  
K - Kannamaly
Fig. 2

Temp. (°C)  

Regions  

Air  Water  Soil

Fig. 3

Salinity (ppt)  

Regions  

Fig. 4

pH  

Regions  

Water  Soil
Fig. 5

DO (ppm)

Regions

Surface Bottom

Fig. 6

Alkalinity (ppm)

Regions

Nitrogen (ppm)

Regions

$\text{NO}_3^-$ $\text{NO}_2^-$ $\text{NH}_3^-$
Fig. 8  Reactive phosphorus content of water in the culture ponds of the three regions

Fig. 9  Secchi disc visibility in the culture ponds of the three regions

Regions:  
P - Pallithode  
C - Chellanam  
K - Kannamaly
Fig. 8
Phosphorus (ppm)

Fig. 9
Visibility (cm)
Discussion

Chakraborti et al. (1985) studied the physico-chemical characteristics of brackishwater ponds in Kakdwip and their influence on the survival, growth and production of *P. monodon*. They found that shrimp production was dependent on salinity and temperature of the water phase and organic carbon, available phosphorus and available nitrogen in the soil phase, but not on depth, turbidity, pH, total alkalinity and primary productivity. However, many earlier and later workers disagree with Chakraborti and co-workers.

Furness and Aldrich (1979) reported that no relation existed between the growth of brown shrimp and dissolved oxygen or pH levels of pond water. Rubright et al. (1981) also reported similar results; they emphasised that, because of the complexity of biological communities in ponds, it is rather difficult to identify specific factors responsible for the increased shrimp yield. In fact, no experimental evidence exists to relate weight gain of shrimp with the primary productivity. Lee and Shleser (1984) found no correlation between growth rate of *P. vannamei* and water quality parameters. Garson et al. (1986) concluded that low survival of *P. stylirostris* and *P. vannamei* was not correlated with low dissolved oxygen. Lee et al. (1986), who studied the growth and production of *P. vannamei* in manure fertilized systems, reported that shrimp growth was not correlated with any water quality parameter.
The results of the present study also did not reveal any statistically significant correlation (simple linear correlation analysis) between water quality parameters and shrimp survival or growth. It would appear from the results that, the physico-chemical parameters of the ponds had only minimal influence on the growth and production of shrimps in the culture systems. However, it would be too premature to arrive at such a conclusion particularly in regard to poikilotherms, which are intimately associated with their milieu, so that even a minor alteration in the milieu may have significant effects on the life of these organisms (see Wedemayer, 1970).

The culture performance of shrimp are undoubtedly influenced by environmental conditions which are very complex, and extremely varied as shown by Chiang et al. (1990) (see Fig. 10). It is obviously the inadequacy of the methodology that conceals the interrelations between the physico-chemical parameters and the performance of shrimp in culture; we still attempt to correlate the performance of a poikilotherm in a given ecosystem with individual ecological parameters, forgetting or rather ignoring the complexity of the ecological cycles existing in that ecosystem. Evolving appropriate models that will account for the several ecological characteristics as well as their interrelations, alone is the remedy. And, until such models are evolved, fool-proof management measures in shrimp culture systems would remain elusive.
Analyses to find out correlations, if any, between the nine water quality parameters and the mean final weight of shrimp, biomass increase per day and production per hectare in culture operations with three feed types revealed that water temperature and biomass increase per day alone were consistently correlated (negatively) in the three feed treatments (Table 6).

Simple linear correlation analysis of the data for 36 culture operations revealed that survival rate was not correlated with salinity, water pH and DO of surface water. Similarly, salinity and production were also not correlated.

It may be concluded from the results that, the overall performance of shrimp in the 36 culture operations in the three regions studied were not consistently correlated with the physico-chemical features, as also reported by many earlier workers.
TABLE 6

Results of simple linear correlation analyses (r values) between selected water quality parameters and three culture parameters in relation to the three feed types

<table>
<thead>
<tr>
<th>Feed types</th>
<th>Clam meat</th>
<th>Clam meat + Dough ball</th>
<th>Pelleted feed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Culture parameters</strong></td>
<td><strong>Mean final weight</strong></td>
<td><strong>Biomass increase per day</strong></td>
<td><strong>Production per ha</strong></td>
</tr>
<tr>
<td><strong>Water quality parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>-0.158</td>
<td>-0.510*</td>
<td>-0.238**</td>
</tr>
<tr>
<td>Salinity</td>
<td>-0.725***</td>
<td>-0.356</td>
<td>-0.178</td>
</tr>
<tr>
<td>pH</td>
<td>0.058</td>
<td>-0.166</td>
<td>-0.617**</td>
</tr>
<tr>
<td>DO - surface</td>
<td>-0.082</td>
<td>-0.372</td>
<td>0.197</td>
</tr>
<tr>
<td>Total alkalinity</td>
<td>-0.053</td>
<td>-0.217</td>
<td>-0.109</td>
</tr>
<tr>
<td>Nitrate-N</td>
<td>-0.094</td>
<td>0.553*</td>
<td>-0.567**</td>
</tr>
<tr>
<td>Nitrite-N</td>
<td>-0.247</td>
<td>-0.057</td>
<td>-0.087</td>
</tr>
<tr>
<td>Ammonia-N</td>
<td>-0.603**</td>
<td>-0.049</td>
<td>0.248</td>
</tr>
<tr>
<td>Reactive phosphorus</td>
<td>0.375</td>
<td>0.514*</td>
<td>-0.430</td>
</tr>
</tbody>
</table>

* P < 0.05  
** P < 0.01  
*** P < 0.001
Fig. 10 Organic cycles in pond ecosystem
(after Chiang et al., 1990)
Fig. 10