Present study relates to the fish growth, optimization and profitable fish production through pond sediment and water resources maps on sustainable basis. All blocks of Nadia district of West Bengal comprising of hot moist sub-humid agro-ecological region were thoroughly surveyed and physico-chemical characteristics of pond water and sediments were analysed. Based on the sediment and pond water resources an improved the fertilizer and manure management schedule, as well as maps have been prepared and demonstration of carp polyculture were carried out. All the fish species attained higher growth in the ponds of hot moist sub-humid agro-ecological regions (alluvial soils) following new nutrient management map over control. The average total fish production in experimental and control ponds was 5.184 and 3.095 tonnes/ha/yr, respectively.

INTRODUCTION

Agro-ecologically the district Nadia (3926 sq. km) is located in the hot sub-humid agro-ecological region of 22°53'-24°11' N latitude and 88°48'-88°09' E longitude. The district is an alluvial formation of the rivers belonging to the Ganga-Bhagirathi system. The top surface appears to be formed of recent alluvium. Below the top surface there is evidence of the existence of an underlined plinth of the older alluvium which under different conditions formed three dissimilar soil associations: Ganges riverine lands, Ganges flat lands and Ganges low lands. Geomorphologically the district comes under natural levee, floodplain and back swamp by the river Bhagirathi and its tributary Jalangi. Evaluation of sediment and water resources in different agro-ecological regions is one of the important factors which determine the aquaculture productivity. Fertilization and manuring schedule prepared by Banerjee (1967) is still a baseline for optimizing pond fish production. As a result of variation in sediment and water characteristics a vast heterogeneity of productivity parameters are observed in different blocks, even in same agro-climatic condition. Without proper knowledge of such physico-chemical variations a general practice of nutrient management results lowering in fish production. Practically it
is difficult to analyse, interpret and follow differential fertilization schedule in fish culture by the end users or even by the fisheries extension officers. Moreover, excessive fertilization without understanding actual need deteriorates pond productivity, which in terms affects sustainable production of fishes in long run (Ayyappan and Jena, 2001, 2003; Yadav, 2009). Present study was an attempt for mapping the sediment and water resources of Nadia district in order to prepare improved aquaculture management strategies for maximization of fish production on sustainable basis.

MATERIAL AND METHODS

Eighty six different pond sites in seventeen blocks of Nadia district were surveyed, besides undertaking two composite polyculture trials following improved schedule of nutrient management in the State Govt. Fish Farm at Dokorta, Kalyani and farmer’s pond at Chakdah, Nadia (Table 1). Selected physico-chemical parameters of pond water attributes viz., pH, dissolved oxygen, free CO$_2$, total alkalinity, total hardness, dissolved organic matter, phosphate-phosphorus and primary productivity, and sediments attributes viz., pH, texture, CEC, Available N, P, K and organic carbon were analysed by the following standard methods (APHA, 1992; Jackson, 1964; Piper, 1966; Boyd, 1982). Based on the sediment and pond water characteristics an improved fertilizer and manuring management schedule as well as maps using GIS packages have been prepared. Based on the topographical position two representative sites were selected for experimental purposes. The experimental and control ponds were stocked with advanced fingerlings of Indian major carps and exotic carps. Catla (Catla catla) and silver carp (Hypophthalmichthys molitrix), rohu (Labeo rohita), mrigal (Cirrhinus mrigala) and bata (Labeo bata) in the ratio of 3:1:3:2:1 were stocked @ 6000 fingerling/ha (80-90 mm/8-10 g) in both experimental and control ponds in all the sites. Supplementary feed comprising mustard oil cake and rice bran at 1:1 ratio by weight was applied daily in the experimental as well as control ponds. Feeding was done @ 6% of biomass stocked per day up to three months, @ 2% from fourth to eighth months and @ 1.5% from ninth month onwards till the harvest. Growth increments were evaluated at monthly intervals.

RESULTS AND DISCUSSION

Maximum pond area of the district covering blocks of Chakdah, Ranaghat-II, Hanskhali, Krishnanagj, Shantipur, Krishnanagar-I&II, Nakasipara, Chapra, Tehata-I, Kaliganj and Karimpur-I&II showed nearly neutral reaction (pH 6.5-7.5), whereas, alkaline water pH was observed in the blocks of Haringhata, Krishnanagar-I, Nawadip, Tehatta-II and Kalyani (Fig. 1). Dissolved oxygen contents of pond water varied from as low as 1.2 mg/l to as high as 11.6 mg/l. Ponds of northern part of the district covering Chapra, Nakasipara, Kaliganj, Tehatta-I&II and Karimpur-I&II blocks (Fig. 2) contained low content of dissolved oxygen (<5 mg/l). From ground observations it was noticed that
much of the ponds of these blocks were utilized for jute retting. Increase in organic load due to retting in these pond bottoms attributed for such low dissolved oxygen condition, making it unfavourable for fish growth. Yearly removal of excessive organic load, discontinuation/reduction of subsequent application of organic manures and inorganic fertilizers and introduction of stress tolerant fish species are suggested for increasing fish production in these sites. Total alkalinity, an attribute that controls the supply of dissolved CO$_2$ in ponds, particularly at time of need, which in terms reflects productivity were at optimum level ranging between 50-120 mg/l in Chakdaha, Kalyani sub-division, Ranaghat-I&II, Santipur, Krishnanagar-I&II, Chapra, Kaliganj and Karimpur-I. However, moderately high level of total alkalinity (>120 mg/l) was observed in some ponds of Haringhata, Hanskhali, Nakasipara, Nabadvip, Tahatta-I&II and Karimpur-II blocks, where municipal effluents were disposed (Fig. 3). Some part of Ranaghat-I block was observed moderately low level (<50 mg/l) of alkalinity. Application of lime for these ponds was suggested. Spatial distribution of total hardness of pond water of Nadia district varied from medium to high level (42-208 mg/l). Majority of the pond in the district showed high level of hardness (Fig. 4), especially in the blocks of Haringhata, Hanskhali, Krishnanagar, Chapra, Nabadvip, Nakasipara, Tehatta-I&II and Karimpur-I&II. It might be due to indiscriminate use of lime during retting period. Study of these maps therefore, be helpful for the Extension Officers to manipulate nutrient management practices in different way. Total hardness of rest of the blocks was at optimum level (50-120 mg/l). Dissolved organic matter of pond water in the districts was favourable for fish growth ranging from 4-8 mg/l, which covered the blocks of Chakdaha, Ranaghat-II, Santipur, north part of Ranaghat-I, Krishnanagar-I&II, Nabadvip, Hanskhali, north-east part of Chapra, Kaliganj and Karimpur-I&II. High level of dissolved organic matter concentration (> 8 mg/l) were observed in the blocks of Haringhata, west part of Ranaghat-I, north part of Krishnanagar-I, Krishnaganj, Chapra, Nakasipara and Tehatta-I&II (Fig. 5). The concentration of PO$_4$-P showed low level (<0.05 mg/l) in major area of Nadia district. Slightly higher concentration (>0.2 mg/l) was recorded at Kaliganj and Nakasipara blocks, might be due to decomposition of organic matter in jute retted ponds. Northern part of Tehatta-I block recorded productive level (0.05-0.2 mg/l) of phosphate in pond water (Fig. 6). Wide variation in the concentration of primary productivity (Fig. 7) might be due to the variation of nutrients status of sediment, intensity of sunshine and reaction of pond water. Net primary productivity (NPP) of pond area of the district recorded as low to optimum levels (115-1688 mgC/m$^3$/hr). Optimum levels of NPP (800-1800 mgC/m$^3$/hr) covering blocks namely Haringhata, Chakdah, Ranaghat-I&II, Santipur, Krishnanagar, Nabadvip, Krishnanagar-I&II, Nakasipara and northern part of Kaliganj whereas, medium range of NPP (500-800 mgC/m$^3$/hr) were observed in the blocks of Hanskhali, Kalyani subdivision and east part of Kaliganj (Fig. 8). Low level of NPP (<500 mgC/m$^3$/hr) was recorded in the blocks namely Chapra, Tehata-I&II and Karimpur-I&II might be due to jute retting.
Table 1. Nutrient management schedule in composite fish culture in Nadia district, W.B.

<table>
<thead>
<tr>
<th>Schedule</th>
<th>Physico-chemical Status of sediment and water</th>
<th>Requirements of fertilizer &amp; manures (kg/ha/yr)</th>
<th>Block Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Soil pH: 6.1-6.5</td>
<td>Urea: 200-250</td>
<td>Kaliganj and Ranaghat-I&amp;II</td>
</tr>
<tr>
<td></td>
<td>Organic carbon: 0.5%</td>
<td>SSP: 300-350</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soil available P: &lt;10 kg/ha</td>
<td>Cowdung: 10000-12000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soil available N:178-400 kg/ha</td>
<td>Lime: 550-600</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water hardness: 42-100 mg/l</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Soil pH: 6.6-7.5</td>
<td>Urea: 150-200</td>
<td>Kalyani subdivision, east part of Chakdah and Krishnanagar-I, west part of Chapra, middle part of Nakasipara, Tehata-I, south part of Karimpur-II and north part of Karimpur-I</td>
</tr>
<tr>
<td></td>
<td>Organic carbon: 5-0.75%</td>
<td>SSP: 250-300</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soil available P: 0-25 kg/ha</td>
<td>Cowdung: 8000-10000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soil available N:400-560 kg/ha</td>
<td>Lime: 400-450</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water hardness: 100-150 mg/l</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Soil pH: 7.6-8.4</td>
<td>Urea: 100-150</td>
<td>Haringhta, west part of Chakdaha, Shantipur, Krishnanagar-II, Nawadip, west part of Krishnagar-I, Hanskhali, Krishnaganj, north-east part of Chapra, Tehata-II, south part of Tehata-I &amp; Karimpur-I, north part of Karimpur-II</td>
</tr>
<tr>
<td></td>
<td>Organic carbon: 0.76-2.21%</td>
<td>SSP: 200-250</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soil available P: 26-35 kg/ha</td>
<td>Cowdung: 5000-8000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soil available N:561-743 kg/ha</td>
<td>Lime: 250-300</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water hardness: 150-208 mg/l</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Physico-chemical properties of the pond sediment are greatly influenced by the sediment texture. Clayey pond sediment absorbs important nutrient while sandy pond sediment allows nutrients for leaching. Major area of the district were medium to fine in texture varying from sandy clay (sc), silty clay (sic) and clay (c). West part of Kaliganj block varies from loamy sand (Is) to sandy loam (si) in texture. Major parts of Tehatta-I&II, Nakasipara and Chapra are clay to clay loam in texture. North part of Tehatta-II, east part of Ranaghat-II and Krishnaganj and west part of Ranaghat-I, Nabadwip and Shantipur blocks are also sandy clay loam to loam in texture (Fig. 9). As pond productivity management have direct relation with the physico-chemical properties of pond bottom sediment, mapping of pond sediment plays a useful predictive tool for nutrient management in fish culture. Pond sediments of Nadia district was neutral to alkaline in reaction (pH 6.1-8.4) which indicated the productive regions with respect of sediments pH. Major parts of this district belonged to moderate alkaline in nature (pH 7.8-8.4) with few exceptions. Major parts of the Nakasipara, Nabadwip and Hanskhali blocks showed slightly alkaline in reaction (pH 7.4-7.8). East part of Chakdah, central part of Krishnanagar and north part of Tehata block reflected neutral (pH 6.6-7.3) in reaction (Fig. 10).
Fig. 1. Mapping of water pH in Nadia

Fig. 2. Mapping of DO (mg/l)

Fig. 3. Mapping of total alkalinity (mg/l)

Fig. 4. Mapping of total hardness (mg/l)
REFERENCES

Fig. 5. Mapping DOM (mg/l)

Fig. 6. Mapping of phosphate-P (mg/l)

Fig. 7. Mapping of ammonium-N (mg/l)

Fig. 8. Mapping of net productivity (mgC/m³/hr)
Fig. 9. Mapping of sediment texture

Fig. 10. Mapping of sediment pH

Fig. 11. Mapping of sediment organic Carbon (%)

Fig. 12. Mapping of sediment CEC cmol (p')/kg
Fig. 13. Mapping of sediment nitrogen (kg/ha)

Fig. 14. Mapping of sediment phosphorus (kg/ha)

Fig. 15. Mapping of sediment potassium (kg/ha)

Fig. 16. Nutrient management schedule for composite fish culture (CFC) of Nadia District
Organic carbon of Nadia district varied from 0.2-2.21%. Medium range of organic carbon (0.75%) prevailed in major area of the district. Blocks adjacent to Bangladesh like Chapra and Krishnaganj exhibited low organic carbon (0.5%). Karimpur-I&II, Kaliganj, west part of Nakasipara, Krishnaganj-I&II and east part of Ranaghat-II showed medium organic carbon (0.5-0.75%) (Fig. 11). CEC depends mainly on amount of clay, organic carbon and base saturation and other factors. Major parts of Nadia district exhibited low in CEC (less than 19.0). Eastern part of Karimpur-I, Nakasipara, Tehatta-I and Chapra showed medium level of CEC (Fig. 12) indicating the moderate level of availability of bases like Ca²⁺, Mg²⁺, Na⁺, K⁺, Fe²⁺, Mn²⁺, Cu²⁺ and Zn²⁺. Available Nitrogen in Nadia district varied 178-743 kg/ha. Karimpur-I&II, Tehatta-I&II, Nakasipara and Chapra showed low in available nitrogen (< 280 kg/ha). Kaliganj, Shantipur, Ranaghat-I and Chakdah exhibited high in available nitrogen (> 560 kg/ha). Major parts of Krishnanagar-I&II (Fig. 13) showed medium, range of available nitrogen (281-560 kg/ha). Available phosphorus is the most important macronutrient in pond productivity. Available Phosphorus of Nadia district varied 7-35 kg/ha. Majority of the area shows medium phosphorus level in the pond sediment ranging 10-25 kg/ha. Blocks like Karimpur-I&II, Kaliganj, Tehatta-II and Ranaghat-I&II slows low in phosphorus status (< 10 kg/ha) whereas, Hanskhali, Shantipur and northern part of Chakdah blocks exhibit higher available phosphorus (25 kg/ha). (Fig. 14). Available Potassium of Nadia district pond sediment varies from 65-340 kg/ha. Medium available potassium is generally observed in the major area of the district, indicating nature of alluvial soil. Kaliganj, Shantipur, Ranaghat-I&II and Chakdah blocks shows high available potassium (280 kg/ha). North part of Nadia district i.e., Karimpur-I&II, Tehatta-I&II and Chapra block shows low in available potassium (< 120 kg/ha). (Fig. 15)

The objective of fertilizer application in fish ponds is to enhance the growth of fish food organisms by improving the nutrient status of pond sediments and water. Usually fertilizer and manure management schedule are designed based on the native nutrients. Standard dose for liming and fertilization (both organic and inorganic) are considered for maintaining the nutrient level in pond sediment and water. A tabular and map of the fertilization, manuring and liming schedule with precautions is developed for following nutrient management during carp culture in the experimental sites (Table 1 and Fig. 16).
Comparison was done with respect to number of fish stocked, growth rate of fishes, survival and number of fish recovered. The average fish production in experimental and control ponds in Dokorta, Kalyani and Chakdah of hot moist sub-humid agro-ecological regions of Nadia were recorded as 5.184 tonnes/ha/yr and 3.095 tonnes/ha/yr respectively. The average growth of all fish species in experimental ponds was also higher over control (Fig. 17). Results of higher productions of fishes over control are indicative of improved nutrient management measures arising from pond sediment, water and primary productivity. GIS aided maps boost aquaculture productivity and productions in this district.

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