AQUACULTURE AND FISHERIES ENVIRONMENT

SANJAY KUMAR GUPTA
PAWAN KUMAR 'BHARTI'

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AND
FISHERIES ENVIRONMENT

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NEW DELHI-110 002

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Plankton Dynamics in Freshwater Fish Ponds in India

Madhumita Das; Biswajit Dash and Loveson L. Edward

ABSTRACT

The culture of Indian major carps in freshwater ponds involves use of chemical fertilizers and organic manures to enhance the photosynthetic food chain for planktivorous carps. Planktons include both phyto and zooplanktons are the natural food item in freshwater fish ponds. Study on diversity of both phytoplankton and zooplankton community gives an idea on the trophic status of a fishpond ecosystem. Plankton compositions in freshwater fish ponds can be categorized as Chlorophyceae, Bacillariophyceae, Dinophyceae and Myxophyceae as phytoplankton whereas zooplanktons are categorized as Copepoda, Cladocera, Rotifera, Ostracoda and Protozoa. Further studies are essential to study plankton dynamics in freshwater ponds through enrichment of autotrophic and heterotrophic pathways to enhance fish production of different production systems.

Keywords: Plankton dynamics, India, Fish pond, Production system.

INTRODUCTION

Plankton, apart from being the basic units of production, plays an important role in transferring energy from a given trophic level to the next higher, leading to fish, the target energy harvest unit in aquatic systems. Planktonic community structure in a fish pond is regulated by the availability of nutrients and predation.

There are two general sources of nutrients in waters, natural and manmade. Nutrients that leach from soil and atmospheric deposition are natural sources and fertilizer, animal wastes, domestic sewage and industrial wastes are manmade sources (Rai and Gaur, 2001).

Pond fertilization practices using animal wastes are widely used in many countries to sustain productivity at low costs (Gupta and Noble, 2001; Majumder *et al.*, 2002) since soluble organic matter supplied to ponds by using manure stimulate phytoplankton growth. Animal wastes lead to increased biological productivity of ponds through various pathways, which result in an increase in fish production (Dhawan and Kaur, 2002). Planktonic organisms are potential bioindicators and their quality and quantity indicate the levels of fish pond ecosystems. Plankton populations in ponds have been studied by different workers throughout the world (Almazan and Boyd, 1978; Burford and Pearson, 1998; Wetzel and Linkens, 2000; Terziyski *et al.*, 2007). Scientific carp culture in fish ponds started in India at the Pond Culture Division of CIFRI, Cuttack, Odisha with the composite culture of three species of Indian major carps and three species of exotic carps (Alikunhi and Sukumaran, 1964; Lakshmanan *et al.*, 1971; Choudhuri *et al.*, 1974).

Phytoplanktons constitute a large and diverse group of autotrophic organisms ranging from unicellular to multicellular forms. They are photosynthetic organisms that occur in marine, freshwater, desert sands, hot boiling springs, snow and ice. Physico-chemical parameters and quantity of nutrients in water play significant role in the distributional patterns and species composition of different phytoplanktons in the aquatic systems. They are main source of food directly or indirectly for various animal groups. Phytoplankton is one of the main feed of silver carp and grass carp. Zooplanktons occupy an intermediate position in the food and are food of both fish fry and adults. The seasonal changes in zooplankton species are closely related to the physico-chemical and biological regime of aquatic ecosystems. Plankton dynamics in freshwater fish ponds in India were studied by Datta and Bandopadhyay (1987), Bhatish (1992) and Rajgopal *et al.* (2010).

SAMPLING AND SAMPLE PROCESSING

The plankton samples are collected from the surface waters of the fish ponds by filtering 50 litres of water through plankton net made of bolting silk cloth (No. 25; # 64 mm) and then samples are preserved in 5% formaldehyde solution. Total number of phytoplankton and zooplankton are estimated by the 'direct census method' using a Sedgewick Rafter plankton-counting cell (APHA, AWWA, WPCF, 1998; Yijian, 1990).The plankton counts are expressed as no./l and percentages of phytoplankton and zooplankton fractions are calculated.

PHYTOPLANKTON AND ZOOPLANKTON SPECIES RICHNESS AND COMPOSITION

The biomass and species composition of plankton in an aquatic ecosystem gives an insight of the nutrient status. Phytoplanktons are the major primary producers in fish pond ecosystems which are grazed by zooplanktons. Phytoplankton community includes Chlorophyceae, Bacillariophyceae, Dinophyceae and Myxophyceae (Rao, 1975; Prasad and Srivastava, 1992). Zooplankton plays a crucial role not only in converting plant food to animal food but also themselves as a source of food for higher organisms especially in the fish pond ecosystem. Zooplankton community includes Copepoda, Cladocera, Rotifera, Ostracoda and Protozoa. The availability and adaptations depends on the surrounding environmental factors. Plankton density of fish ponds mainly depends upon the temperature, photoperiod and pH, which elicit a significant correlation. Variation in plankton density relates to the physical structure of pelagic environment of a pond ecosystem.

PHYTOPLANKTON

Chlorophyceae

The Chlorophyceae are one of the classes of green algae, distinguished mainly on the basis of ultrastructural morphology. They are usually green due to the dominance of pigments chlorophyll a and chlorophyll b. The chloroplast may be discoid, plate-like, reticulate, cup-shaped, spiral or ribbon shaped in different species. Most of the members have one or more storage bodies called pyrenoids located in the chloroplast. Pyrenoids contain protein besides starch. Some algae may store food in the form of oil droplets. Green algae usually have a rigid cell wall made up of an inner layer of cellulose and outer layer of pectose. Temperature plays an important role in the periodicity of blue green algae as emphasized by Mahar *et al.* (2004).

BACILLARIOPHYCEAE

Bacillariophytes are called "Diatoms" which are major group of algae and are among the most common types of phytoplankton. Diatoms are a widespread group and can be found in the oceans, in freshwater, in soils and on damp surfaces. The photosynthetic pigment of diatoms is brown, and occurs usually in the form of two identical plastids running the length of the cell and in the centric diatoms in the form of numerous sometimes clumped granules. Most diatoms are unicellular, although they can exist as colonies in the shape of filaments or ribbons, fans, zigzags or stars. Planktonic forms in open water usually rely on turbulent mixing of the upper layers by the wind to keep them suspended in sunlit surface waters. The siliceous skeleton common to all varieties is frequently described as structured like a pill box or petridish and offers two possible views — the valve view (as in viewing a petridish from the top) and the side or girdle view. Some species actively regulate their buoyancy with intracellular lipids to counter sinking. When conditions turn unfavourable, usually upon depletion of nutrients, diatom cells typically increase in sinking rate and exit the upper mixed layer ("bust").

Hawkes (1969) examined the thermal tolerance of different groups of algae and suggested that diatoms grow best at temperatures below 25°C and blue-green algae at temperatures above 30°C. Tucker (1985) studied the diatoms of Mississippi channel catfish ponds. Ecological study of diatoms of a freshwater pond of Ranchi, Bihar was studied by Bose (1987).

DINOPHYCEAE

Dinoflagellates are unicellular and possess two dissimilar flagellae arising from the ventral cell side. The class Dinophyceae is of uncertain origin. Some scientists even considered the Dinophyceae to be mesokaryotes (intermediate between the prokaryotes and the eukaryotes), however, this view is no longer accepted. Roughly half of the species in the group are photosynthetic (Gaines and Elbrächter 1987), the other half is exclusively heterotrophic and feeds via osmotrophy and phagotrophy. They are important components of freshwater ecosystems. Frequent dinoflagellate blooms occur in freshwater bodies. Frempong (1984) studied the seasonal sequence of diel distribution patterns of *Ceratium hirundinella* in a eutrophic lake. Ki and Han (2008) recorded *Peridinium umbonatum* from Togyo Reservoir, Korea.

MYXOPHYCEAE OR CYANOPHYCEAE

They are large group of prokaryotic, mostly photosynthetic organisms. Cyanobacteria are organisms with some characteristics of bacteria and some of algae. Though classified as blue-green algae or photosynthetic bacteria, they resemble the eukaryotic algae in many ways, including some physical characteristics and ecological niches and were at one time treated as algae. They contain certain pigments, which with their chlorophyll, often give them a blue-green colour, though many species are actually green, brown, yellow, black, or red. They are common in soil and in both salt and freshwater, and they can grow over a wide range of temperatures, from Antarctic lakes under several metres of ice to Yellowstone National Park's hot springs in the U.S. Cyanobacteria are often among the first species to colonize bare rock and soil (Desikachary, 1959). Some are capable of nitrogen fixation and others contain pigments that enable them to produce free oxygen as a by-product of photosynthesis. Under proper conditions (including pollution by nitrogen wastes) they can reproduce explosively, forming dense concentrations called blooms, usually coloured an opaque green. Cyanobacteria played a large role in raising the level of free oxygen in the atmosphere of early Earth. Despite their name, different species can be red, brown, or yellow, blooms (dense masses on the surface of a body of water) of a red species are said to have given the Red Sea its name. Nitrogen-fixing cyanobacteria need only nitrogen and carbon dioxide to live. Toxic cyanobacteria are found worldwide in inland *Microcystis*, are almost always toxic, but non-toxic strains do occur.

Temperature plays an important role in the periodicity of blue green algae as emphasized by Mahar *et al.*, (2004). Genus *Oscillatoria* has been found to be very tolerant to pollution and frequently grows in polluted waters (Rai & Kumar, 1976).

Bloom of Cyanophycean algae in lake is an obvious signe of cultural eutrophication which is basically caused by addition of sewage effluents (Horn and Goldman, 1994).

ZOOPLANKTON

Copepods

Copepods are a group of small crustaceans found in the sea and nearly every freshwater habitat. Some species are planktonic (drifting in sea waters), some are benthic (living on the ocean floor), and some continental species may live in limno-terrestrial habitats and other wet terrestrial places, such as swamps, under leaf fall in wet forests, bogs, springs, ephemeral ponds and puddles, damp moss, or water-filled recesses (phytotelmata) of plants such as bromeliads and pitcher plants. Many live underground in marine and freshwater caves, sinkholes or stream beds. Copepods are sometimes used as bioindicators. Copepods form a subclass belonging to the sub phylum Crustacea (crustaceans). Copepods are divided into ten orders. Some 13,000 species of copepods are known, and 2,800 of them live in freshwaters.

Copepods are typically 1 to 2 millimetres long, with a teardrop-shaped body and large antennae. Although like other crustaceans they have an armoured exoskeleton, they are so small that in most species this thin armour, and the entire body, is almost totally transparent. Some polar copepods reach 1 centimetre. Most copepods have a single median compound eye, usually bright red and in the centre of the transparent head, subterranean species may be eyeless. Like other crustaceans, copepods possess two pairs of antennae; the first pair is often long and conspicuous. Copepods typically have a short, cylindrical body, with a rounded or beaked head. The head is fused with the first one or two thoracic segments, while the remainder of the thorax has three to five segments, each with limbs. The first pair of thoracic appendage is modified to form maxillipeds, which assist in feeding. The abdomen is typically narrower than the thorax, and contains five segments without any appendages, except for some tail-like "rami" at the tip. About 70% of its dry weight is fat. Planktonic copepods are important to global ecology and the carbon cycle. They are usually the dominant members of the zooplankton and are major food organisms for small fish, whales, seabirds and other crustaceans such as krill in the ocean and in freshwater. Some scientists say they form the largest animal biomass on earth (Boxhall and Defaye, 2008). Predation of copepods on larger species of phytoplankton will favour gelatinous colonial species of Cyanobacteria and green algae thus causing an increase in their abundance, as observed in enclosure experiments by Sommer *et al.* (2003).

CLADOCERANS

Cladocerans commonly called "Water Fleas" are primarily-freshwater small-sized (0.2-6 mm, and up to 18 mm in single case of (*Leptodora kindtii*) branchiopod crustaceans, inhabiting pelagic, littoral and benthic zones. Four Cladoceran orders are recognised (Fryer, 1985): Anomopoda, Ctenopoda, Onychopoda, and the monotypic Haplopoda. Most species occur in continental fresh or saline waters, although two ctenopods and several onychopods from the family Podonidae are truly marine and a few more ctenopod, anomopod and onychopod species occur in brackish waters. Seven known species may be regarded as true inhabitants of subterranean environment, and a few others (of the family Chydoridae) live in semi-terrestrial conditions. The trunk and appendages of most Cladocerans (Anomopoda and Ctenopoda) are enclosed in a bivalved carapace. Tagmosis of the body is obscure (except in *Leptodora kindtii*, the single representative of Haplopoda), and a single eye and ocellus are usually present. Antennules are uniramous, while antennae are biramous (except in females of Holopedium), natatory, with 2-4 segments per branch. Four to six pairs of trunk limbs are either mostly similar in shape (Ctenopoda, Onychopoda, Haplopoda) or modified individually for various functions (Anomopoda). Cladocera is an ancient group of Palaeozoic origin. About 620 species are currently known, but we estimate that the real number of species is 2-4 times higher.

ROTIFERS

Rotifera or wheel animalcules are one of the most interesting groups of freshwater invertebrates. They belong to the subphylum Trochhelminthes, *i.e.* they are worms, although their bodies share no resemblance with typical worms such as oligochaets. Remane (1929-33) believed they were larvae of unknown worms that remained in the larval stage, but recent investigators (Clement, 1980) confirm their origin in Platyhelminthes. Having no paleontological evidence, we presume that rotifers are a very old group of invertebrates, a product of the aerobic phase in the development of our planet.

Rotifers are characterized by a corona (a ciliated area or a funnel-shaped structure at the anterior end) and a specialized pharynx called a mastax, which serves as a jaw. the most The rotifers ordinarily encountered are amictic females, *i.e.* they parthenogenetically produce diploid eggs. Usually in the autumn mictic haploid eggs are formed from which, without fertilization, males appear. They are known only in a minority of species and are reduced in size and in organs. A digestive system is totally absent and males perish within some hours or few days. From the fertilized eggs special resting ('winter') eggs evolve, having a thick protective cover resistant to desiccation, freezing and other unfavourable factors. The next spring, females hatch from these resting eggs and start a new amictic generation. Species having males once per year are monocyclic, twice per year, dicyclic and several times per year, polycyclic. In the order Bdelloidea, where no males occur, they are acyclic. Rotifers possess no respiratory organs and respire by their whole body surface. For this reason they are unable to live in an anaerobic milieu. Only few very resistant species tolerate microaerobic habitats, e.g. *Rotaria neptunia* and *R. rotatoria*. There exist about 2000 species of rotifers. Pennak (1953) indicated 1700 species, less than 5% of which are restricted to brackish and marine environments.

OSTRACODS

Like the copepods, the ostracods are very much frequent in both freshwater and marine environments. They are microcrustaceans and about 2000 living species exists in the world. The larger marine species are also known as "Mussel shrimps" or "Seed shrimps", but the freshwater ostracods are usually smaller than a millimetre. In freshwater ponds they are usually found scuttling around among the submerged plants and debris at the shallow edges and less commonly in the open waters. They swim smoothly with appendages extended from between the two halves of their carapace. When disturbed, they withdraw their limbs and clamp the halves of their tiny shells tightly together. They are perhaps less attractive creatures than the other small crustaceans due to the opaque and sometimes strongly patterned shell which makes it difficult to see their internal structure. Young specimens are the most rewarding for microscopical examination, as their shells are generally more transparent than those of the adults. Ostracods are very similar in appearance, making it less than easy for the non-expert to distinguish one species from another or even one genus from another.

Study of ostracods was initiated in the 18th Century (Oertli 1982), regionally only the Holarctic fauna of freshwater ostracods is considered reasonably well documented (Meisch 2000; Martens *et al.*, 2008). Their narrow environmental preferences define them as potential bioindicators for monitoring of recent freshwater conditions (Külköylüoðlu 2004). The development of either a single species or an ostracod assemblage is influenced by physical–chemical properties of waters (salinity, temperature, pH, and dissolved oxygen), hydraulic conditions, bottom grain sizes or sedimentation rates. Harshey *et al.* (1987) reported abundance and high density of ostracoda in hard water.

PROTOZOANS

Protozoa are a diverse group of unicellular eukaryotic organisms. Protozoa commonly range from 10 to 52 micrometers, but can grow as large as 1 mm and are seen easily by microscope. The largest protozoa known are the deep-sea dwelling xenophyophores, which can grow up to 20 cm in diameter. They were considered formerly to be part of the Protista family. The protozoa of the freshwater environment range in size from about 1mm in the case of Stentor and some of the multinucleate amoebae, down to 5µm or so in the case of the smaller flagellates and they are extremely varied in both appearance and lifestyle. Protozoa exist throughout aqueous environments and soil, occupying a range of trophic levels (Honigberg *et al.*, 1964).

The seasonal distribution and variations in plankton populations in different water bodies including fish ponds have been investigated (Talling, 1987; Pradhan *et al.*, 2008). In the Indian subcontinent also, this biotic community has received due attention by several workers, with regard to its ecology, productivity and enhancement measures (Nasar, 1977; Ayyappan and Gupta, 1982). Among the biological parameters planktons are considered to be bio-indicators of water quality. The quality of both phytoplankton and zooplankton is influenced by various environmental factors (Jana and De, 1983) as well as nutrient levels (Das and Jana, 1996).

Phytoplankton constitute major fraction of primary producer in water bodies. They play important role in biosynthesis of organic matter in fish pond ecosystems. Phytoplankton primary productivity was studied by Atay and Demir (1998). Arvola (1984) observed a positive correlation between primary production and phytoplankton population. Chowdhury and Mamum (2006) studied the responses of phytoplankton on nutrient additions. A relationship between phytoplankton biomass and phosphate concentrations was studied by Gruendling (1983). Paloheimo and Zimmerman (1983) analyzed the factors influencing phosphorus-phytoplankton relationship. Phytoplankton dynamics was studied by Patralekh (1991) that was apparently regulated by zooplankton predation. Riemann (1983) compared phytoplankton primary production with bacterial secondary production. Further, Currie (1990) reported algal abundance determined by phosphorus availability to be influencing bacterial populations in the water medium.

Zooplankton constitute the organisms of the secondary trophic level which consume the food material synthesized by phytoplankters and transfer the energy to the next trophic level in the pond ecosystem. They also occupy a central position between autotrophs and other heterotrophs and are important link between food web of freshwater ecosystem. The importance of zooplanktons as fish food both for adults and fry has been stressed by different workers (Geiger, 1983). The presence and dominance of zooplankton species play very significant role in the functioning of freshwater ecosystems. These animals are usually filtrators, sedimentators or predators (Karabin, 1985). There are several studies regarding distribution, abundance and seasonal succession of zooplankton (Vasisht and Sharma, 1975; Arshaduddin and Khan, 1991). The biomass of zooplankton was estimated by Rosen (1981). The effects of physico-chemical factors on the seasonal abundance of zooplankton in a pond at Punjab, India, were analyzed by Bhatish and Kumari (1986). The aspects of population dynamics and ecology of rotifers have been studied by Neill (1984). The effects of filter-feeding zooplankton on phytoplankton in fish ponds were studied by Vyhnalek (1983).

Strong relationships exist between phytoplankton and zooplankton. Selective grazing by zooplankton is an important factor affecting the structure of zooplankton communities. However phytoplankton structure also influences the taxonomic composition and dominance of zooplankton. Interrelationships between phytoplankton and zooplankton populations have been analyzed by Saran and Adoni (1985). A study on algal diversity of a small eutrophic bog pond was made by Estep and Remsen (1985). Spodniewska (1979) observed phytoplankton as the indicator of Lake Eutrophication. Pandey *et al.* (1992) studied the species composition of phytoplankton and zooplankton communities. The variations in percentage compositions of major groups of phytoplankton and zooplankton during seasonal cycles were studied by Singh (1990).

Plankton dynamics of carp polyculture ponds (0.04 ha each) manured with cow manure and biogas slurry was studied by Das (1996). The mean plankton counts in the surface waters of comprising four treatments: *(i)* cow manure at 10t/ha/yr, urea at 100 kg N/ha/yr and single super phosphate at 50 kg P/ha/yr, *(ii)* biogas slurry at 15t/ha/yr and inorganic fertilizers as in the previous treatment, *(iii)* biogas slurry at 30t/ha/yr and iv) and biogas slurry at 30t/ha/yr with supplementary feed were in the ranges of 740-1900, 1060-2160, 960-3740 and 1170-3860/l. Higher counts were observed during March-June in all the treatments. Treatment 4 showed higher plankton counts followed by treatments 3, 2 and 1, the respective mean counts being 2550, 2220, 1480 and 1420/l. The composition of phytoplankton in the net plankton were higher in slurry applied ponds with corresponding means of 53.6, 52.6, 54.7 and 60.6%, indicating an increase in slurry applied ponds, the rest being the zooplankton contribution attributing to heterotrophy and mineralized nutrient availability. The phytoplankton comprised Myxophyceae, Chlorophyceae, Bacillariophyceae and Dinophyceae, the generic representations being *Oscillatoria*, *Anabaena* in Myxophyceae; *Pediastrum*, *Kirchneriella*, *Bulbochaete*, *Selenastrum*, *Botryococcus*, *Ankistrodesmus* in Chlorophyceae; *Cyclotella*, *Nitzschia, Synedra, Navicula, Amphora, Gomphonema*, *Pinnularia* in Bacillariophyceae and *Ceratium* in Dinophyceae. The zooplankton comprised Protozoa, Rotifera, Cladocera, Ostracoda and Copepoda with the generic representations being *Arcella, Euglena* in Protozoa; *Asplanchna, Filinia, Brachionus*, *Keratella, Hexarthra* in Rotifera; *Bosmina, Moina, Daphnia, Ceriodaphnia, Macrothrix* in Cladocera; *Cypris* in Ostracoda and *Diaptomus, Cyclops* in Copepoda.

Strong relationships exist between phytoplankton and zooplankton and selective grazing by zooplankton is an important factor affecting the structure of phytoplankton communities. One of the important phenomenons manifested by plankton is the diurnal vertical migration. Both phytoplankton and zooplankton show vertical migration. Sometimes the zooplankton escapes predation by fish through vertical or horizontal migration. The vertical distribution of plankton varies with the time and season and lower plankton counts are recorded in manured fish ponds during afternoon hours due to vertical migration (Lauridsen and Lodge, 1996). Daily and seasonal diel variations of plankton in Indian waters have been studied by Ayyappan *et al.* (1988) and Das (1996).

Fig. 7.1: Application of Biogas Slurry in Fish Ponds

ROLE IN FISH POND ECOSYSTEM

Fish ponds are multipurpose fish culture systems as they can be used for brood stock stocking and maturation, breeding by various methods, nursery rearing of fry and grow out culture. Extensive fish farming production system, semi-intensive production system, intensive and super intensive systems are the different fish farming production systems categorized according to the degree of intensification. Two patterns of food webs exist in a fish pond ecosystem. One is direct where phytoplankton is directly consumed by herbivorous or omnivorous fish and in the indirect one phytoplankton is consumed by zooplankton which is further consumed by carnivorous and omnivorous fishes. Phytoplankton produces large amounts of organic matter through photosynthesis and release large quantities of oxygen into pond waters. Respiration and photosynthesis of phytoplankton affects the pH, carbon dioxide concentration and dissolved oxygen and play a central role in maintaining water quality in fish ponds.

Extensive fish farming production system is mainly based on the plankton produced in the ecosystem. Pond fertilization through organic and inorganic sources is a regular management protocol in aquaculture (Bhakta *et al.*, 2006). Almost all extensive and the majority of semi- intensive aquaculture operations in India are dependent on the use of chemical fertilizers and organic manures (De Silva and Hasan, 2007). The purpose of pond fertilization is to augment fish production through autotrophic and heterotrophic pathways (Jha *et al.*, 2008). Natural food supply is enhanced by using organic and inorganic fertilizers and low-cost supplemental feeds derived agricultural by-products which enhances the photosynthetic food chain through algal-zooplankton interactions (Schroeder *et al.*, 1990; Halwart *et al.*, 2002). It is well known that high fish yield can be achieved by higher abundance of plankton in culture systems (Jha *et al.*, 2004). Even though the number of studies is already large, serious problems remain in understanding and managing interrelations among fish stock, zooplankton and phytoplankton interrelations to attain the optimal balance.

CONCLUSION

The plankton compositions in fish ponds can be categorized as Chlorophyceae, Bacillariophyceae Dinophyceae and Myxophyceae in case of phytoplankton and Copepoda, Cladocera, Rotifera, Ostracoda and Protozoa in zooplankton. In India carps cultured in fish ponds are planktivorous in nature and the study of their diversity is of paramount significance. Planktons are the most important component of a trophic system, a thoughtful utilization of the plankton community in a pond ecosystem with proper management practices will certainly enhance the levels of fish production. Further work is needed for diversification and enhancement of freshwater fish production and to study the plankton diversity in different freshwater fish pond ecosystems.

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ISBN 93-5056-408-4

9789350564080

₹ 1350/-