

EFFECTS OF MANURING SCHEDULE ON WATER QUALITY AND BIOLOGICAL PRODUCTIVITY

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West Bengal University of Animal and Fishery Sciences
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Master of Fishery Science
in
Aquaculture**

By

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CERTIFICATE

This is to certify that the work recorded in the thesis entitled **“Effects of manuring schedule on water quality and biological productivity”** submitted by **Miss. Ankita Pradhan** in partial fulfilment of the requirements for the degree of **Master of Fishery Science (Aquaculture)** in the Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, is the faithful and bonafied research work carried out under my supervision and guidance. The results of the investigation reported in this thesis have not so far been submitted for any other degree or diploma.

The assistance and help received during the course of investigation have been duly acknowledged.


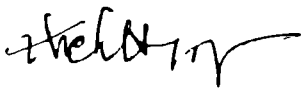
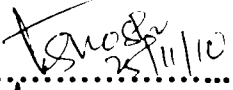
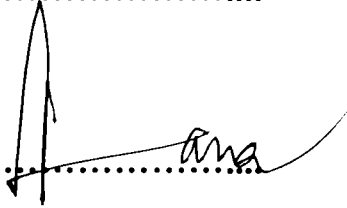
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APPROVAL SHEET

APPROVAL OF EXAMINERS FOR THE AWARD OF THE DEGREE OF MASTER OF FISHERY SCIENCE (AQUACULTURE)

We, the undersigned, having been satisfied with the performance of Miss. Ankita Pradhan in the Viva-Voce Examination, conducted today, the *25th Nov.....*, 2010, recommended that the thesis be accepted for the award of the Degree of Master of Fishery Science in Aquaculture.

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List of Abbreviation

APHA – American Public Health Association

GPP – Gross Primary Productivity

SGR – Specific Growth Rate

ANOVA – Analysis of Variance

r – Correlation coefficient

W – Weekly

WF – Weekly with fish

F – Fortnightly

FF – Fortnightly with fish

M – Monthly

MF – Monthly with fish

C – Control

CDB – Cellulose Decomposing Bacteria

AHB – Aerobic Heterotrophic Bacteria

BOD – Biochemical Oxygen Demand

NH₄ – N Ammonium nitrogen

NO₂ – N Nitrite nitrogen

@ - At the rate of

et al., - And others

AOCA – Association of Official Analytical Chemists

Chapter I

INTRODUCTION

1. Introduction

Application of nutrients through fertilizer and manure is one of the prerequisites for augmenting fish production under pond culture conditions. Application of nutrients compensates for the nutrient deficiencies and augments biological productivity mediated through autotrophic and heterotrophic pathways (Schroeder, 1974; Moav *et al.*, 1977; Debeljak *et al.*, 1990; Jhingran, 1995; Das and Jana, 1996).

Fertilization through inorganic nutrients in aquatic systems readily renders themselves available in ionic forms to the phytoplankton operating in the base line of the production pathway. Organic manures on the contrary, supports the production pathway slowly but sustaining for longer periods because it has to pass through complex biochemical pathways towards releasing inorganic nutrients in plant available forms. In aquatic system, organic manure contribute a huge amount of combustible matter which oxidizes and produce CO₂ that helps in algal photosynthesis and also helps in the reduction of dissolved atmospheric nitrogen to ammonia. The decomposition of organic manure is carried out by bacteria and fungi, actinomycetes (Persson *et al.*, 1980; Boyd, 1995; Gaur *et al.*, 1995) and the released essential nutrients upon such decomposition help to sustain the biological productivity of the system (Rath, 1993).

Organic manure as a class are composite in nature and contain almost all the major and minor elements required in the metabolic cycle (Jhingran, 1995). The use of manure in aquaculture supports the production of protein using inputs of little nutrient value to man or livestock (Wohlforth and Hulata, 1987). Animal manures have a long history of use as a source of soluble phosphorous, nitrogen and carbon for algal growth and natural food production (Knud-Hansen, 1998). They often facilitate the utilization of chemical fertilizers under appropriate pond fertilization practice (Pillay, 1995). Fertilization with low cost organic manure mitigates the problem of solid waste disposal and it has a sustainable effect on pond fertilization. Because of such definitive advantages over inorganic chemical fertilizers, organic manures are preferable and extensively used in fish culture pond. However, as manure is made of plant material or the unassimilated fraction of animal feed, it has high fiber content and low nitrogen content. It decomposes



at a comparatively slow rate, and large inputs of manure into ponds can result in the accumulation of organic sediment (Boyd, 1995).

In India, cow dung is the most common organic manure applied to fish ponds (Singh and Sharma, 1999). Organic matter in cow manure accelerates the development of large bacterial population as a result of decomposition (Buschiel, 1983). Hassan (1990) observed that zooplankton biomass varied from 0.12 to 9.48 mg l⁻¹ in cow manure treated ponds, where nauplii were the dominant group (59.3%) among zooplankton, followed by rotifers (24.8%), copepods (11.9%), and cladocerans (4.0%). Grag and Bhatnagar (1999) compared the effects of five different doses of organic manure (5,000; 10,000; 15,000; 20,000; 24,000; kg ha⁻¹ yr⁻¹) on the pond productivity in terms of plankton production and fish biomass in fresh water fish ponds.

Optimal manuring rate is the highest amount of organic matter that can be utilized in a pond ecosystem without showing any adverse effect on fish growth and water quality. Using regression analysis, Edwards *et al.*, (1996) indicated that a more efficient use would be a daily input of a maximum of 1 kg dry matter (DM) per 200 m² pond. In India, Alikunhi *et al.* (1955) manured the nursery ponds with cow dung at the rate of 11,208 to 22,417 kg ha⁻¹. They concluded that heavy manuring with cow dung colours the water dark brown and the average production of plankton in ponds manured @11,208 kg ha⁻¹ is reported to be more than in those manured @16,812 kg ha⁻¹. A net yield of 2928.54 kg ha⁻¹ yr⁻¹ of major carps under polyculture condition was achieved with addition of cow dung at the rate of 0.10 g nitrogen (Javed *et al.*, 1992). Saha *et al.*, (1980) reported that cow manure application in major carp nursery ponds yield 50-60% more fish than the untreated ponds. The use of cow manure resulted in an increase of gross fish production from 0.18 to 1.8 g m⁻¹ day⁻¹ in about 40 days (Costa and Keemibiahetty, 1993). Benerjee *et al.* (1969) observed that poultry droppings along with cow dung resulted in faster growth rate of *C. carpio* spawn than cow dung alone.

However, organic manuring also leads to severe depletion of dissolved oxygen, high biological and chemical oxygen demand, and high ammonia levels (Boyd, 1982) leading to stress in cultured fish (Parker, 1996). Over manuring may also promote incidence of disease (Pillay, 1995). Pond fertilization using high amounts of animal wastes are known to have caused noticeable harm to the environment (Quines, 1988), by proliferating the growth of pathogenic bacteria

like *Aeromonas* sp. and *Pseudomonas* sp. (Hojovec, 1977; Sugita *et al.*, 1985; Jinyi *et al.*, 1987). Fresh water fish in Indian ponds commonly suffer from bacterial diseases such as various kinds of skin ulcerations, albinoderma, erythroderma, furunculosis and vertical scale disease primarily caused by *Aeromonas* sp. and *Pseudomonas* sp. (Das, 2004).

Public health concerns related to helminthes requiring fish or other aquatic organisms as intermediate hosts in organic manured ponds have been well documented (Larsson, 1994; Santosh, 1994; Polprasert, 1996; Eгна and Boyd, 1997). It seems apparent that organic manure, if used, should be applied with caution in view of the above facts.

Though, several studies have been made in different countries with variable sources of manures under aquaculture conditions with different test fishes, the results are not homogenous and reproducible. This is because of the variability of chemical composition of the manures of diverse origin and variable cultivable conditions. Therefore, the present investigation has been designed to examine the impacts of manuring schedule upon the physico-chemical and biological conditions of fish culture system and the growth of fish as well.

The objectives of the present study are to compare the relative responses of three manuring schedules viz. weekly, fortnightly and monthly with cow manure upon:

- a) the physicochemical and biological parameters of fish culture system
- b) the population density of selective bacteria viz. aerobic heterotrophic and cellulose decomposing bacteria, and
- c) the growth responses of test fishes *Labeo rohita* and *Cyprinus carpio*.

Chapter II

REVIEW OF LITERATURE

2. Review of Literatures

The biological productivity in aquaculture ponds is primarily governed by nutrients. Therefore, pond fertilization through organic and inorganic sources has become one of the most important management protocols in aquaculture. Application of nutrients compensates for the specific nutrient deficiency and augments biological productivity mediated through autotrophic and heterotrophic pathways (Schroeder, 1974; Moav *et al.*, 1977; Debeljak *et al.*, 1990; Jhingran, 1995; Das and Jana, 1996).

In aquatic system organic manure contribute a great amount of combustible matter which oxidizes and produce CO₂ that helps in algal photosynthesis and also helps in the reduction of dissolved atmospheric nitrogen to ammonia. The decomposition of organic manure is carried out by bacteria, fungi and actinomycetes (Persson *et al.*, 1980; Boyd, 1995; Gaur *et al.*, 1995). As a result, the released essential nutrients help to sustain the biological productivity of the system (Rath, 1993). The bio-geochemical cycling bacteria, therefore, play a key role in the nutrient dynamics of fish ponds, where the microbial activities are regulated by various environmental factors in fish culture ponds managed under different stocking combinations and with management variables (Jana and Patel, 1984; 1985; 1990; Jana and Roy, 1985; 1986; Jana and De, 1993).

2.1. Productivity levels

With regards to nutrient loading and resultant productivity level, water bodies have been classified with different trophic states (Whalen, 2010). They are as follows:

2.1.1. Oligotrophic

Oligotrophic refers to a class of water body that exhibit low productivity, low levels of phosphorous and chlorophyll, few rooted aquatic plants and algae, deep transparency readings (8.0 m or 26.5 ft) and usually high dissolved oxygen levels throughout the water column.

2.1.2. Mesotrophic

The term mesotrophic describes a middle stage between oligotrophic (low productivity) and eutrophic (high productive). This type of water body has



intermediate levels of phosphorous and chlorophyll, and Secchi disk transparencies of 4 m to 8 m (13.3 to 26.5 ft).

2.1.3. Eutrophic

Eutrophic refers to water body with high productivity, high levels of phosphorous and chlorophyll, low Secchi disk readings, and abundant biomass with a lot of accumulated organic matter on bottom. Eutrophic water bodies are susceptible to algal blooms and oxygen depletion in the hypolimnion. The comparative account of selective parameters with regards to productivity status of a water bodies (Table1.) has been well classified by Wetzel (1983).

Table1. Phosphorus and chlorophyll concentrations and secchi disk depths characteristic of the trophic classification of water body (after Wetzel, 1983).

Parameter	Oligotrophic	Mesotrophic	Eutrophic
Total Phosphorus (mg/m ³)			
Avg.	8	26.7	84.4
Range	3.0 - 17.7	10.9 – 95.6	16 – 386
Chlorophyll <i>a</i> (mg/m ³)			
Avg.	1.7	4.7	14.3
Range	0.3 - 4.5	3 – 11	3 – 78
Secchi Disk Depth (m)			
Avg.	9.9	4.2	2.45
Range	5.4 - 28.3	1.5 – 8.1	0.8 – 7.0

2.2. Pond fertilization

The natural productivity of a fish culture system depends largely on the availability of natural food organisms and on favourable environmental conditions for the fish and optimum dose of fertilizers into the fish ponds (Ayyappan, 2006). Fertilization is so far the most useful technique to make up or provide the essential nutrients for enhancing natural productivity through production of aquatic biota which serve either directly or indirectly as the food of fishes (Olah *et al.*, 1986; Knud- Hansen, 1998). Usually the fertilizers used in aquaculture are inorganic or organic in nature or a combination of both (Pillay, 1995).

The overall objective of fertilizer and manure application is to increase the productivity of the fish pond. While inorganic fertilizers mainly increase the quantity of primary producers, organic fertilizers such as cattle dung, pig and poultry manure, biogas slurry, compost and other livestock wastes serve as a class of composite for stimulating abundant growth of zooplankton, insect larvae and other forms of fish food organisms (Jhingran, 1983; Olah *et al.*, 1986; Akand, 1986).

2.2.1. Organic fertilization

Pond fertilization practices using animal wastes are widely used in many countries to sustain pond productivity at low cost (Peker and Olah, 1990). This is most extensively adopted in China where all farmers raise livestock to supply nutrients for fish farming (FAO, 1997; Dutta and Gaswami, 1988; Patra and Ray, 1988; Kestemont, 1995; and Zoccarato *et al.*, 1995). In contrast, inorganic fertilizers are expensive and their use by small farmers may be limited (Swift, 1993).

2.2.1.1. Manure

The manuring of fish pond is considered an important scientific aspect for increasing fish production (Doria and Leonhardt, 1993). Organic manure as a class are composite and contain almost all the nutrient elements required in the metabolic cycle. They enrich the organic matter content of soil and water and within the limits of manurial dose, release carbon dioxide and nutrients on decomposition sustaining the fertility of water. Their merit lies in imparting a comparatively slower rate of release of nutrients to the water over a long period of times as the decomposition proceeds. They often referred to as an aesthetic value of a pond (Jhingran, 1995). The use of manure in aquaculture supports the production of protein using inputs of little nutrient value to man or livestock (Wohlforth and Hulata, 1987). Animal manures have a long history of use as a source of soluble phosphorous, nitrogen and carbon for algal growth and natural food production (Knud-Hansen, 1998). They often facilitate the utilization of chemical fertilizers under appropriate pond fertilization practice (Pillay, 1995). Fertilization with low cost organic manure mitigates the problem of solid waste disposal and it has a sustainable effect on pond fertilization. Because of such definitive advantages over inorganic chemical fertilizers, organic manures are preferable and extensively used in fish culture pond. However, as manure is made

of plant material or the unassimilated fraction of animal feed; it has high fiber content and low nitrogen content. It decomposes at a comparatively slow rate, and large inputs of manure into ponds can result in the accumulation of organic sediment (Boyd, 1995). Manure is not directly consumed by aquaculture species. It is decomposed by micro organisms to yield mineral nutrients that stimulate plant production. Fine particles of decomposing manure and associated microbial flora serve as a food for microscopic animals that may be consumed by plankton feeding fish (Wohlfarth and Schroeder, 1979).

2.2.1.1.1. Composition of manure

Organic manure is classified according to their source and carbohydrate contents (Jhingran, 1995; Pillay, 1995). Therefore; it seems apparent that the basis for such classification is indirectly indicative of its inherent C: N: P ratio. The composition and nutritive value of organic manure depends on several factors like age, breed variety, digestibility, composition of the feed, physiological condition of the animal etc. (Rath, 1993; Das and Jana, 2003). These factors also influence the ratio between solid and liquid excreta. The composition of fresh manure from a number of animal species (Table2.) was illustrated by Martyshev (1983) apparently based on the conditions in the then USSR (Pillay, 1995). Besides, a vast array of extrinsic factors largely determines the extent of decomposition and regeneration as well.

Table 2. Composition (%) of different animal manure (After Pillay, 1995)

Composition	Pig	Cattle	Duck	Chicken
Water	72.4	77.3	7	56
Organic matter	25.0	20.3	6	26
Total nitrogen (N)	0.45	0.45	1	1.6
Proteinic nitrogen	-	0.28	-	-
Ammoniacal nitrogen	-	0.14	-	-
Phosphorus (P ₂ O ₅)	0.19	0.23	.4	1.5
Potassium (K ₂ O)	0.60	0.50	0.6	0.9
Calcium (CaO)	0.18	0.40	1.8	2.4
Magnesium (MgO)	0.09	0.11	-	-
Sulphuric acid (SO ₃)	0.08	0.06	-	-
Iron and aluminium	0.07	0.05	-	-
Sesquioxides (R ₂ O ₃)			-	-

2.2.1.1.2. C: N: P ratio of manures

The C: N: P ratio greatly influences the decomposition rate of any manure and indicates its nutrient supply potential as well. This ratio again is highly variable from one source to another. Pillay (1995) documented (Table 3.) N: P as well as C: N ratio of different manures.

Table 3. N: P and C: N ratio of different manures.

Manure	N:P ratio	C:N ratio
Buffalo manure	2	-
Cow manure	3	18
Duck manure	2	-
Goat and sheep	2	-
Horse manure	-	25
Night soil	2	6-10
Pig manure	2	-
Poultry manure	2	15
Urine	11	0.8

2.2.1.1.3. Nutritive value of animal manure

Animal manures applied in a pond in fine particulate or colloidal state stimulate heterotrophic growth of bacteria by providing necessary surface area for their attachment and facilitates their mineralization. The mineral fraction is directly available for photosynthesis, but apparently because of limited light penetration in manured ponds, phytoplankton production is reduced. However, the production of zooplanktonic organisms is generally more rapid and they feed on the nanoplankton and bacteria produced in the pond. Heterotrophic production is at its maximum level at the soil water interface in fish ponds and this is conducive to abundant benthic growth (Pillay, 1995).

2.2.1.1.4. Decomposition of organic manure

Decomposition refers to the physical breakdown of the material, usually measured as mass loss, while mineralization refers to the release of inorganic nutrients available for plant uptake. It is primarily a biological process resulting from enzymatic activities of micro organisms and influences a variety of ways by activities of the soil fauna (Visser, 1985).

The components of decomposition are grouped into abiotic and biotic factors. Organic decomposition depends largely on physical factors like temperature, the supply of oxygen, moisture, pH, available minerals and the C/N ratio of the added material. Likewise biotic factors like, microbial population, age and lignin content of the added residue and degree of disintegration largely determines the rate of mineralization and supply of inorganic nutrients from the added manures.

2.2.1.1.4.1. Abiotic factors

2.2.1.1.4.1.1. Temperature

It is very difficult to separate the effects of temperature on early decomposition from that of many other environmental factors, because temperature often co-varies with other factors that also affects decomposition. Paul and Clark (1996) observed that decomposer organisms have a wide range of temperature optima even though their activities often show a positive correlation with increased temperature (Swift *et al.*, 1979). A change of 10⁰C in mean annual temperature was associated with a 4 to 11 fold increase in the decomposition of leaf litter of a dominant species at a particular site (Vitousek *et al.*, 1994).

2.2.1.1.4.1.2. Oxygen

Oxygen supply is essential to aerobic micro-organisms, the primary agents in decomposition. Thus, reduction in air supply will result in reduced decomposition rates (Broadbent *et al.*, 1964; Kowalenko *et al.*, 1978; Clark and Gilmour, 1983).

2.2.1.1.4.1.3. Moisture

Decomposition rates increase with increasing moisture if temperature is adequate (Bunnell *et al.*, 1977). However, very high moisture severely constrains the activity of microbial communities (Bunnell *et al.*, 1977; Couteaux *et al.*, 1995).

2.2.1.1.4.1.4. pH

Microbial populations are highest in soils with a neutral pH. Neutral soils, therefore, are more conducive to decomposition than acidic or alkaline soils. Since many soils in the coniferous nurseries are commonly acidic, the addition of lime could manipulate soil pH and supply calcium, accelerating initial decomposition. Lime additions, however, need to be monitored carefully to prevent an excess in pH and subsequent infection by damping-off fungi (Ajwa and Tabatabai, 1994).

2.2.1.1.4.2. Biotic factors

2.2.1.1.4.2.1. Micro-organisms

When exposed to organic tissue, bacteria "invade"- eating and digesting the tissue, breaking it down into simpler forms for other bacteria and organisms to consume. As a group, bacteria are considered to be nutritionally diverse, which means that they can eat almost anything, living or dead (Brian and Parker, 1991).

On the other hand, actinomycetes are a higher form of bacteria, similar to fungi, and second in number to bacteria. They don't respond well to acidic conditions (pH < 5) or high moisture conditions, but operate best at medium temperature areas of the compost. Actinomycetes take over during the final stages of decomposition, often producing antibiotics that inhibit bacterial growth. They liberate carbon (C), nitrate nitrogen (NO₃) and ammonium nitrogen (NH₄-N) making nutrients available to plants (Moriarty, 1987).

Fungi are smaller in number than bacteria or actinomycetes, but larger in body mass. Fungi are simple organisms that lack a photosynthetic pigment. The individual cells have a nucleus surrounded by a membrane and they may be linked together in long filaments. Fungi live on dead or dying material and obtain energy by breaking down organic material. Like actinomycetes, fungi are present during the early and final stages of composting, when the organic material has been changed to a more digestible form. Of the major micro-organisms, fungi function best under acidic conditions (Persson *et al.*, 1980; Boyd, 1995; Gaur *et al.*, 1995).

2.2.1.1.4.2.2. Macro-organisms

Macro-organisms or physical decomposers are the visible organisms involved in transforming organic material into compost. Micro-organisms decompose chemically, while macro-organisms are higher up in the food chain and decompose physically - by digging, grinding, chewing, digesting, sucking and churning. These are the following- ants, millipedes, snails and slugs, nematodes, fermentation mites, springtails, centipedes, sow bugs, flies, white worms, earth worms (Park, 2001).

2.2.1.1.4.3. Mechanism of decomposition

Organic residues are decomposed to inorganic substances such as carbon dioxide, ammonia, phosphate, and water, which are lost from the soil by volatilization, leaching, or erosion (Boyd, 1995). According to Anderson (1987), variables controlling decomposition of organic matter are types of decomposers,

environmental quality, and characteristics of the residue. The substances that are decomposing more readily are known as labile organic matter, and those that decompose slowly are known as refractory organic matter.

Percentage decomposition of different components of a plant residue in one year were sugar- 99%, hemicelluloses- 90%, cellulose- 75%, lignin- 50%, waxes- 25%, and phenols- 10%. Swift *et al.* (1979) divided decomposition into three processes viz- comminution, catabolism and leaching. Comminution is a reduction in particle size of organic residues by animals feeding on them and by physical forces. Catabolism is the enzymatic degradation of substrate by soil bacteria, fungi, actinomycetes and animals. Leaching is the downward movement of soluble organic matter in the soil.

2.2.1.1.4.3.1. Leaching of nutrients

It must be appreciated that only a fraction of the P, N and C in the manure will become available for algal growth. Most of the nutrient release occurs within a few days of adding the manure to the pond, primarily through leaching and the breakdown of soluble organic molecules (Amir Ullah, 1989; Nath and Lannan, 1992). A certain percentage of manure-P, -N, and -C will remain bound in particulate matter, and will eventually be buried in pond sediments. Manure nutrient concentrations, and the percentage of manure-P, -N, and -C which becomes available for algal uptake, depend primarily on the animal's diet, texture of the manure like liquid or solid, and the age and storage conditions of the manure (Muck and Steenhuis, 1982).

The source-animal's diet is important because what comes out of an animal is directly influenced by what it consumed (Little and Muir, 1987; Ullah, 1989). Animals fed high-protein diets typically have manures richer in N and P than manure from similar animals that rely on scavenging for their sustenance. Secondly nutrient availability is related to the consistency or form of the manure. Liquid excretions (e.g., urine) already contain algal nutrients in soluble forms, and more nutrients will be released with the decomposition of soluble organic matter. Smaller percentage of the total manure-N, P, and C in solid wastes will become available for algal uptake (Colman and Edwards, 1987; Knud-Hansen *et al.*, 1991a). The third factor affecting the percentage of available nutrients is the age and storage conditions of the manure. Fresh manure contains more nutrients than manure which has been stored for some while. During manure storage, aerobic

decomposition results in the release of CO₂ and ammonia, reducing both the total amount and percentage of N and C available to algae when the manure is eventually put in the pond (Muck and Steenhuis, 1982; Ullah, 1989).

2.2.1.1.5. Organic manuring and water quality

It is a well established fact that one of the most essential attributes towards the success of any aquaculture practice is the maintenance of appropriate water quality in the culture system. The available organic pool in manured ponds is usually duplicated everyday via bacterial production (Schroeder, 1987). Heterotrophic microorganisms, necessitating some organic sources of carbon in addition to inorganic forms for growth, have a significant role in the decomposition of organic matter and production of particulate food materials from dissolved organics (Jana and De, 1990). However, the role of heterotrophic bacteria in the food web and its effect on fish yield are poorly documented (Moriarty, 1987).

Organic manuring also leads to severe depletion of dissolved oxygen, high biological and chemical oxygen demand, and high ammonia levels (Boyd, 1982), leading to stress in cultured fish (Parker, 1986). Debeljak and Fasaic (1985) found that organic manure caused undesired deviations of oxygen and ammonia, while other parameters did not significantly change. Application of manures increased the free carbon dioxide, decreased in dissolved oxygen levels, whereas, pH values of soil and water declined slightly and the amount of nitrogen released from the organic manures to water and soil phases, increased gradually with the period of incubation (Chattopadhyaya and Mandal, 1980).

2.2.1.1.6. Role of heterotrophs in production pathway

The basic arrangement of an ecosystem comprises two strata, namely, an upper autotrophic stratum where light is present and which contains the photosynthetic organisms, and a lower heterotrophic stratum where there may not be much light but has the consumer nutrient regenerating decomposing organisms (Jhingran, 1995). Heterotrophic microorganisms, necessitating some organic sources of carbon in addition to inorganic forms for growth, have a significant role in decomposition of organic matter and production of particulate food materials from dissolved organics (Jana and De, 1990). In a pond ecosystem the nitrogen flow is mainly linked to heterotrophic (decomposition) processes. Thus, the biogeochemical cycling of heterotrophic bacteria plays a key role in the nutrient

dynamics of fish ponds (Milstein *et al.*, 2003). Heterotrophic microbes live off of nutrients that they scavenge from living hosts (as commensals or parasites) or find in dead organic matter of all kind (saprophages). Microbial metabolism is the main contributor for the bodily decay of all organisms after death (Zhu *et al.*, 2008). Heterotrophic microbes are extremely abundant in nature and are responsible for the breakdown of large organic polymers such as cellulose, chitin or lignin which are generally indigestible to larger animals. Generally, the breakdown of large polymers to carbon dioxide (mineralization) requires several different organisms, with one breaking down the polymer into its constituent monomers, one able to use the monomers and excreting simpler waste compounds as by-products, and one able to use the excreted wastes (Cabello *et al.*, 2004).

2.2.2. Planktons and aquatic food web

Plankton occupies the pelagic zone of the water column which is named after its pelagic inhabitants (Ricklefs, 2007). Plankton is the basis of freshwater and saltwater ecosystems, meaning that all aquatic life is dependent upon the energy and oxygen it provides. Plankton is important to the food web as the initial food source for every food chain. Phytoplankton is the primary producer of all aquatic food chains, gaining energy from the sun to perform photosynthesis, providing food, energy and oxygen needed to sustain plant and animal life. Energy not used by the phytoplankton for maintenance is available as food for the animals that consume it (Ricklefs and Miller, 2000).

Plankton's wide range of sizes makes them a beneficial food source for animals and other plankton. Even whale-sharks, one of the largest animals in the ocean, feed primarily on plankton. Filter feeders are the primary consumers of plankton, as they feed by filtering water through their mouths and consume the food that remains. Filter feeders include any number of species, such as fish, mammals, and squid. As the base of the food chain, the balance of energy in aquatic ecosystems is dependent upon the supply of plankton in the pelagic zone of the water column (Burnham, 2001).

Since the microbial food web was postulated (Azam *et al.*, 1983), food web interactions within the plankton of lakes and oceans have received a lot of attention (Ducklow, 1991; Stone *et al.*, 1993; Gaedke *et al.*, 2002). As main consumers of bacterial production, the productive protozoans play an important role among the plankton. They are an essential component of the pelagic food web

and thus of pivotal importance in the degradation of organic matter in aquatic ecosystems. In addition, several species of ciliates and flagellates are able to consume algae and other protozoans and could perform similar functions in the food web as the metazoans (Sanders, 1991; Sherr and Sherr, 1994; Arndt *et al.*, 2000).

Phytoplankton absorbs about 3 percent of the light shining on the ocean. By comparison, plants on land absorb about 15 percent of the available sunlight. This discrepancy is caused by the ocean itself, which absorbs sunlight in varying degrees. This competition for vital light resources is a limiting factor for the rate of primary production in aquatic ecosystems (Denny, 2008). Phytoplankton is consumed by herbivorous animal microorganisms called zooplankton. Populations of zooplankton provide nourishment for secondary consumers such as fish, whales and crustaceans. Without plankton, smaller fish and crustaceans would be without a food source and would die, causing a linear effect of death and extinction among bigger fish and mammals. Plankton takes in carbon dioxide and gives off oxygen during the process of respiration, supplying half of the Earth's oxygen, affecting the survival of aquatic and land food web (Divico, 2009).

2.2.3. Manures and plankton production

A common approach for increasing fish production in ponds is the direct application of fertilizer, which enhances production of plankton, a natural food item for fish (Chakrabarti and Jana, 1998). Pond fertilization practice using animal wastes are widely used in many countries to sustain productivity at low cost (Gupta and Noble, 2001; Majumder *et al.*, 2002). Upon decomposition, organic manures release inorganic nutrients that stimulate plankton growth at the base trophic level of aquatic production cycle. The number of phytoplankton in fertilized pond was recorded as more than 10 times higher than the unfertilized ponds (Boyd, 1982). The contribution of different groups of plankton population also differed with respect to the manures (Dhawan and Toor, 1989). Fertilization (both inorganic and organic) has of great implications in increasing primary productivity that usually follows in greater zooplankton production in ponds (Boyd, 1982; Shandhu *et al.*, 1985) though the abundance and composition of zooplankton are strikingly different.

In India, cow dung is the most common organic manure applied to fish ponds (Singh and Sharma, 1999). Organic matter in cow manure accelerates the

development of large bacterial population as a result of decomposition (Buschiel, 1983). Hassan (1990) observed that zooplankton biomass varied from 0.12 to 9.48 mg l⁻¹ in cow manure treated ponds, where naupli were the dominant group (59.3%) among zooplankton, followed by rotifers (24.8%), copepods (11.9%), and cladocerans (4.0%). Grag and Bhatnagar (1999) reported the effects of five (5000, 10,000; 15,000; 20,000; 24,000; kg ha⁻¹ yr⁻¹) different doses of organic fertilizer on the pond productivity in terms of plankton production and fish biomass in fresh water fish ponds. Highest plankton population, zooplankton, fish biomass and specific growth rate (2.3% bodyweight day⁻¹) were observed in ponds which were treated with fertilizer at the rate of 15,000 kg ha⁻¹ yr⁻¹.

Among the manures, chicken manure is preferred because of its ready solubility and high level of phosphorous concentrations (Knud- Hansen *et al.*, 1991). Soluble organic matter supplied to ponds by using manure stimulates phytoplankton growth (Sevillega *et al.*, 2001) and increases biomass of zooplankton and benthic organisms (Atay and Demir, 1998). Poultry manure gave the quickest best results for plankton production among cow, poultry, goat, sheep, pig and horse manures (David, 1969). Fang *et al.* (1986) carried out an experiment with chicken and pig manure in ponds and they reported that chicken manure was suitable for plankton production. Dinesh *et al.* (1986) reported that poultry manure is the best among the commonly used organic manures in India. Dhawan and Toor (1989) reported that total phytoplankton were significantly higher in the ponds treated with poultry droppings alone and in combination with cow dung than in the ponds with cow dung alone and in combination with supplementary diet, indicating the fertilization superiority of poultry manure over cow manure. Rosy (1993) compared the effect of cow and chicken manure on the production of plankton and observed four groups of phytoplankton such as Cyanophyceae, Bacillariophyceae, Chlorophyceae, and Euglenophyceae and four groups of zooplankton such as Rotifera, Copepoda, Cladocera and Nauplius in her study. Banerjee (1979) and Bhanot *et al.* (1991) reported that organic fertilizer especially poultry manure treated ponds gave a comparatively higher production of zooplankton. Yadav and Grag (1992) who found that the mean fish production, net primary productivity, plankton population and nutrients were greater in the ponds treated with organic fertilizer at the rate of 1500 kg ha⁻¹ yr⁻¹ and given

supplementary feed on alternative days than in ponds treated with organic fertilizer at the rate of 10000 kg ha⁻¹yr⁻¹ but with daily feeding.

Ovie and Adepoju (1995), were successful in mass culturing zooplankton predominated by *Moina* sp. (90% and 97.2%, by composition and biomass respectively) using pig manure in outdoor concrete tanks sufficient for feeding fish larvae and fry for the entire rearing period. Total phytoplankton population growth in the ponds treated with poultry manure alone has been higher due to the presence of sufficient PO₄-P and NO₃-N release from the manure in water (Varghese and Shanker, 1981; Sood, 1984). Jana and Chakrabarti (1993) revealed that the differences in offspring production of Cladocerans were directly correlated with increasing levels of NH₃-N. Frequent application of low doses of manure resulted in significantly higher number and biomass of *Daphnia* (Jana and Chakrabarti, 1997).

2.3. Seasonal diversity of plankton

Planktonic communities are sensitive indicators of trophic nature of a water body (Nyaggard, 1949). The seasonal occurrence and species composition in plankton production is directly or indirectly influenced by the physico-chemical factors of the water Bhowmik *et al.* (1993). In temperate latitudes the driving force and mechanisms of seasonal changes are related to variations in the physical, chemical and biotic environments, e.g. changes in solar irradiance and nutrient levels. However, in tropical latitudes the seasonal succession of phytoplankton species depends on ambient nutrient levels more than on other environmental factors. Minimal seasonal variation in day length and heat income does not prevent remarkable phytoplankton seasonal cycles in the tropics (Sirikhae *et al.*, 2004).

The zooplankton in the surface water of a fresh water lake are those which are caught in a fine meshed net towed slowly through the water column, and consist mainly of protozoans, rotifers, cladocerans, copepods and a great variety of larval forms (Odum, 1971; Clesceri *et al.*, 1998). Zooplankters inhabiting a shallow freshwater lake respond quickly to environmental changes, and hence their species composition and frequency of seasonal abundance fluctuate according to the changing status of the water mass in which they are found (Gannon and Stemberger, 1978; Carmichael, 1981; Chattopadhyay and Banerjee, 2007). The net zooplankton species increased their abundance during summer (April- May),

probably corresponding to the water quality, decaying vegetation, increased levels of organic matter in the sediment and higher abundance of bacteria in the lake during this time (Jacoby and Greenwood, 1989; Srivastava *et al.*, 1990; Coman *et al.*, 2003). In contrast, the abundance of net zooplankton species decreased in winter (November- January), probably corresponding to low water temperature and high alkalinity (pH 7.6-9.8) of the water (Chattopadhyay and Banerjee, 2007).

The diurnal, seasonal, and interannual patterns in zooplankton and micronecton species composition in the subtropical Atlantic exhibit peak abundances during the spring bloom (Feb.- Mar.) but there is a considerable variation between species within a taxon. Pronounced vertical migration occurs in many species. Species diversity within several major taxa is lowest in the winter and highest in spring and summer. Diversity is also significantly higher at night due to the presence of vertical migrators. Diurnal, seasonal, and interannual difference in species abundances are evident even upto the genus level (Steinberg *et al.*, 2003). Seasonal cycle of phytoplankton in Northern temperate oceans exhibit highest phytoplankton growth in the spring when there is plenty of light and nutrients. A secondary peak in phytoplankton biomass occurs in the autumn (Spokes, 2003).

2.4. Dose and frequency of manuring

Optimal manuring rate is the highest amount of organic matter that can be utilized in a pond ecosystem without showing any adverse effect on fish growth and water quality. Using regression analysis, Edwards *et al.* (1996) indicated that a more efficient use would be a daily input of a maximum of 1 kg dry matter (DM) per 200 m² pond. The buffalo manure conversion efficiency would almost double from 1.0 to 1.9% with a recommended reduced loading rate from 5 to 2 kg DM with further increase in fish yield.

The results from different studies pertaining to the conversion values per unit of input indicated an optimal manuring rate of about 5g m⁻² day⁻¹ carbon in ponds treated with higher doses. This is equivalent to 100 kg DM of manure ha⁻¹ day⁻¹, which may be accepted as a standard manuring rate in Europe (Olah, 1986). In Thailand, manuring rate exceeding 20 g DM m⁻² day⁻¹ caused water quality deterioration in terms of erratic diurnal dissolved oxygen fluctuations and high concentrations of ammonia and nitrate (Villacorta, 1989).

There is wide variability with dosage and frequency of manuring. With differences in source of manure, test species and climatic differences different authors have designed their studies with wide variations in their findings (Table 4).

Table 4. Dosages and frequencies of manuring under different studies

Type of manure	Dose	Frequency	Reference
Mixed fertilizer (Pig dung, Cow manure, SSP, Urea.)	105-6757g tank ⁻¹	Weekly in a twofold manner	Bhakta <i>et al.</i> , 2006
Cow dung	@0.10g N ₂ /100g wet fish wt.	Daily	Javed <i>et al.</i> , 1992
Cow dung	@ 0.1g and 0.15g N/100g wet fish wt.	Daily	Fatima <i>et al.</i> , 2003
Cow dung (Fresh and dry)	@0.1gN/100g wet fish body wt.	Daily	Shumaila <i>et al.</i> , 2003
Pig manure, Cow manure, chicken manure	@ 3% in dry wt. of the total wt. of the stocked fish.	Daily	Baotong <i>et al.</i> , 1983
Cow dung + Pig dung + Poultry excreta	@70kg ha ⁻¹ , 45kg ha ⁻¹ , 35kg ha ⁻¹ .	Daily	Singh and Sharma, 1999
Pig manure	18 and 36 ton ha ⁻¹	Yearly or weekly	Dhawan and Kaur, 1997
Pigeon droppings, Goat dung, Cow dung	After liming @ 500kg ha ⁻¹ and @ 10,000kg ha ⁻¹ .	Three installment	Patra and Roy, 1988
Cow dung and Poultry excreta	@ 0.13kg m ⁻³ , 0.26kg m ⁻³ , 0.39kg m ⁻³	Every 10 days	Jha <i>et al.</i> , 2004

2.5. Manuring and productivity

The efficient usage of fertilizer may sustain a high level of primary production; fish production is highly dependent on the availability of the fish to efficiently utilize the natural food available in the pond. This level of efficiency will greatly depend on the composition of fish species stocked and their relative densities. Rappaport *et al.* (1977) observed that higher extents of phytoplankton

and chironomid larvae in organically manured fish pond. Animal manure is often used in semi intensive system systems to improve the primary production of the ponds and fish growth (Boyd, 1982; Colman and Edwards, 1987; Schneeberger and Lin, 1988; Miska, 1988; Knud Hansen *et al.*, 1993; Edwards *et al.*, 1997). Poultry and Cattle manures have been tried with *Oreochromis niloticus* and *O. shiranus* in ponds and produced good results (Gupta *et al.*, 1992; Knud Hansen *et al.*, 1993; Kamanga and Kunder, 1998).

In India, Alikunhi *et al.* (1955) manured the nursery ponds with cow dung at the rate of 11,208 to 22,417 kg ha⁻¹. They concluded that heavy manuring with cow dung colours the water dark brown and while during the first 8-10 days of manuring, the phytoplankton content of the water is remarkably poor, there after the water teems with zooplankton, particularly rotifers, cladocerans and copepods, the crop of animalcules lasting from 7- 10 days. The average production of plankton in ponds manured @11,208 kg ha⁻¹ is reported to be more than in those manured @16,812 kg ha⁻¹. The manure is to be applied 15-20 days before the anticipated date of spawn release. Benerjee *et al.* (1979) observed that poultry droppings along with cow dung resulted in faster growth rate of *C. carpio* spawn than cow dung alone.

2.6. Fish production potentials of different manures

A net yield of 2928.54 kg ha⁻¹ yr⁻¹ of major carps under polyculture conditions with adding cow dung at the rate of 0.10 g nitrogen (from cow dung) per 100g of wet fish weight daily (Javed *et al.*, 1992). Saha *et al.* (1980) reported that cow manure application in major carp nursery ponds yield 50-60% more fish than the untreated ponds. The use of cow manure resulted in an increase of gross fish production from 0.18 to 1.8 g m⁻¹ day⁻¹ in about 40 days (Costa and Keemibiahetty, 1993).

Doria and Leonhardt (1993) estimated the increase in weight and length from May to December in 189 carps reared in semi-intensive polyculture with *Collossoma macropomum*, *Piaractus mesopotamicus* and *Prochilodus scrofa* in a 900 m² earthen tanks fertilized with poultry litter 100 g m⁻² fortnightly. Fish were given a pelleted feed with 28% crude protein 5 and 1.5% of total biomass of the tanks in warm and cold months, respectively. Mean weight increase from 8.2 to 598.6 g and mean length from 7.6 to 30.94 cm. Mean daily gain in weight and length was 4.86 g and 0.018 cm, respectively. Ghosh *et al.* (1994) reported that

the growth of Java punti (*Puntius javanicus*) when reared alone and catla (*Catla catla*), mrigal (*Cirrhinus mrigala*) and Java punti reared together in the rice field was superior when organic fertilizer was applied either alone or in combination with an inorganic fertilizer. Biogas-plant effluent supplied at 0.15% (W/V) concentration level at 3 days interval with no supplementary feeding resulted in maximum weight gain of 0.67 g fish⁻¹day⁻¹ of *Oreochromis mossambicus* with a total production of 4826 kg ha⁻¹ in 125 days (Balasubramanian and Bai, 1996).

The effects of 5,000; 10,000; 10,000; 15,000; 20,000; 24,000 kg ha⁻¹yr⁻¹ doses of organic manure on pond productivity in term of plankton production and fish biomass exhibited highest plankton population, zooplankton, fish biomass and specific growth rate (2.3% bodyweight day⁻¹) in ponds which were treated with fertilizer at the rate of 15,000 kg ha⁻¹yr⁻¹ (Grag and Bhatnagar, 1999). Mahboob and Sheri (1997) studied the growth performance of six fish species under the influence of artificial feed, broiler manure, buffalo manure and N: P: K (25: 25: 0). Broiler manure and N: P: K (25: 25: 0) fertilization remained the best treatment for maximum fish production of 9400 and 7300 kg pond⁻¹year⁻¹. A mixture of organic and inorganic fertilizers in the ratio of 3:1 (cow dung: phosphate) was quite effective in increasing pond production when applied at a rate of 500 kg ha⁻¹ (Hora and Pillay, 1962). According to Pulin and Shehadeh (1980) organic matter of cow manure added at the rate of 3-4% standing fish biomass, gave a fish yield of 20 kg ha⁻¹ day⁻¹. Better growth of a fish with higher rate of manure application has also been reported by Hickling (1962) and Hassan (1989).

Production potentials of manures from different sources varied widely primarily because of the variability in dosage and test fishes (Table 5). Again, such variability has been influenced because of the differences in stocking rate and stocking size of the test fishes under variable test conditions.

Table 5. Fish yield potential of different manures

Manure	Dose	Cultured sp.	Stocking	Yield	Referen ce
Mixed type (Chicken, Pig, Cattle)	500kg ha ⁻¹ week ⁻¹ ; 1200kg ha ⁻¹ week ⁻¹	Juvenile of <i>T. rendali</i>	2 no. of fish m ⁻²	314.8kg ha ⁻¹ , 583kg ha ⁻¹ , 608kg ha ⁻¹	Kangombe, 2006.
Cow manure	@ 0.1g and 0.15g N/100g wet fish wt.	IMC	4:3:3	2238.80k g/ha/yr and 2265.21k	Sughra <i>et al.</i> , 2003
Cow dung (Fresh and dry)	@ 0.1gN/100g wet fish body wt.	<i>Labeo rohita</i> , <i>Catla catla</i> , <i>C. mrigala</i>	4:3:3	1127.23k g/ha/yr , 1358.38k g/ha/yr	Afzal <i>et al.</i> , 2003
Cow dung	@0.10g N ₂ /100g wet fish wt	IMC	4:3:3	2928.54 & 767.29kg	Javed <i>et al.</i> , 1992
Cow dung + Poultry manure	@ 0.13kg/m ³ , 0.26kg/m ³ , 0.39kg/m ³	Koi carp(<i>C. carpio</i> var. koi)	0.2fish/l (400fish/tank)	7.38 to 9.17 gm	Jha <i>et al.</i> , 2004.
Cow dung + Pig dung + Poultry excreta	@70kg/ha, 45kg/ha, 35kg/ha	<i>L. rohita</i> fingerlings	6000no./ha	2663.50, 2219.789 kg/ha/yr	Singh and Sharma, 1999.
Pig manure	18 and 36 ton/ha	Carp polyculture	2 fish/m ² of different fish species	2630.49, 2210.34 kg/ha/yr	Dhawan and Kaur, 1997

Cow and poultry manure	@ 0.26kg/m ³	Koi carp(<i>C. carpio</i> var. koi)	0.3 fish/l.	3.14 to 9.64 gm	Jha <i>et al.</i> , 2008
Pig	@2.0g/m ² /day	Polyculture	8500fish/ha	0.184g/m ² /day	Sharma and Olah, 1986
Cow manure	@1.2g/m ² /day	Polyculture	5,000 no fish/ha	0.106g/m ² /day	Schroeder, 1974
Cow	@5g/m ² /day	Polyculture	18,000 fish/ha	0.326 g/m ² /day	Moav <i>et al.</i> , 1977
Cow	@5g/m ² /day	Polyculture	16,000 fish/ha	0.300 g/m ² /day	Schroeder and Hepher, 1979
Chicken	@5g/m ² /day	Polyculture	17,500 fish/ha	0.310 g/m ² /day	Olah, 1986

2.7. Limitations of organic manure

The use of organic manure in aquaculture is an ancient practice and, despite its drawbacks, continues to be used by aqua culturist as an efficient and economical means of increasing production. The indiscriminate use of these manures in fish ponds, instead of improving the pond productivity, may also lead to pollution. One of the major problems in the use of organic manure is the extreme variability of composition. Rapid decomposition of the manure and the increased bacterial population can results in oxygen depletion and fish mortality. Organic matter in cow manure accelerates the development of large bacterial population as a result of decomposition (Buschiel, 1983).

Over manuring may also promote incidence of disease (Pillay, 1995). Pond fertilization using high amounts of animal wastes are known to have caused noticeable harm to the environment (Quines, 1988), by proliferating the growth of pathogenic bacteria like *Aeromonas* sp. and *Pseudomonas* sp. (Hojovec, 1977; Sugita *et al.*, 1985; Jinyi *et al.*, 1987). Fresh water fish in Indian ponds commonly suffer from bacterial diseases such as various kinds of skin ulcerations, albinoderma, erythroderma, furunculosis, and vertical scale disease, primarily caused by *Aeromonas* sp. and *Pseudomonas* sp. (Das, 2003). The microbiological

quality of fish pond water should be considered as the criterion for assessment of organically manured pond water. Buras *et al.* (1985) found that critical concentration of standard plate count bacteria to be $5 \times 10^4 \text{ ml}^{-1}$, beyond which microbes appeared in the fish meat.

Organic manuring also leads to severe depletion of dissolved oxygen, high biological and chemical oxygen demand, and high ammonia levels (Boyd, 1982), leading to stress in cultured fish (Parker, 1996).

Public health concerns related to helminthes requiring fish or other aquatic organisms as intermediate hosts in organic manured ponds have been well documented (Larsson, 1994; Santosh, 1994; Polprasert, 1996; Egna and Boyd, 1997). It seems apparent that organic manure, if used, should be applied with caution in view of the above facts.

The foregoing review on the subject of organic manuring in aquaculture clearly indicated the lack of conformity so its advantages and disadvantages are concerned. Though, several studies have been made in different countries with variable sources of manures under aquaculture conditions with different test fishes, the results are not homogenous and reproducible. This is because of the variability of chemical composition of the manures of diverse origin and variable cultivable conditions. Therefore, more studies are necessary particularly with regards to the dosage and frequency of locally available manures from the farm animals.

Chapter III

MATERIALS AND METHODS

3. Materials and methods

The present study to investigate the effects of manuring schedule upon the physicochemical, biological, microbial population and above all the growth responses of common carp (*Cyprinus carpio*) and rohu (*Labeo rohita*) has been conducted in outdoor experimental tanks.

3.1. Preparations of experimental tanks

Twenty one outdoor cylindrical experimental tanks (180 l) were selected for the present investigation. After thorough washing and sun drying, the tanks were provided with agricultural soil base of 15 cm. They were then filled with ground water (pH 7.5), randomly grouped into seven batches in triplicate and kept undisturbed for 10 days for conditioning.

3.2. Application of manure

Cow manure was selected for the present experiment as it is widely being used in composite farming of carps in India and is readily available. The first two batches of the experimental tanks were designated for weekly, the third and fourth batches for fortnightly, and the fifth and sixth batches for monthly application of manure, whereas, the remaining seventh batch without manure application served as control. The conventional rate of 10,000 kg/ ha/month cow manure as usually practiced in preparation of fish ponds in India was selected as the dosage for the initial application. Therefore, the actual amount of manure needed for monthly application has been divided into two and four split doses in the treatments with fortnightly and weekly manuring schedule keeping the absolute amount of manure in all the three treatments equal (Table 6.). Afterwards, during the culture period the dosage became half in the subsequent months as usually practiced by the fish farmers.

Table 6. Amount of manure applied in different treatments

Frequency of application	Actual amount required (g/ cistern)
Preparatory dose	
Weekly	80
Fortnightly	160
Monthly	320
Maintenance dose	
Weekly	40
Fortnightly	80
Monthly	160

3.3. Stocking of fish

Fingerlings of common carp (*Cyprinus carpio*) and rohu (*Labeo rohita*) (1:1) were stocked @ 10 fingerlings/cistern ten days after first instalment of manure application in one batch each of the two batches in all the three manuring schedules (WF, FF, MF). The remaining batches without fish in weekly manuring (W), fortnightly manuring (F) and monthly manuring (M) served as control. The last batch without manuring was also stocked with fish at same density which served as another control set. The fish was kept in the tanks for a period of 120 days. No supplementary feed was applied during this period to avoid interaction between feed and manure.

3.4. Water replenishment

A fixed level of water was maintained in the experimental tanks by periodic addition of ground water to compensate the losses due to evaporation and sampling.

3.5. Collection of Sample

3.5.1. Water sample

Water samples were collected at 15 days interval from each of the tanks at a fixed hour of the day (8:00 a.m.) by completely dipping the collection bottle at 15 cm depth for physico-chemical analyses. During collection of water samples, cautions were taken so as to prevent air bubbling, which might influence water quality parameters such as dissolved oxygen.

3.5.2. Soil sample

Soil samples from each of the cisterns were collected by using a mini hand grab sampler. They were air-dried, pulverized with pestle and mortar and sieved through 150 µm mesh sieve and stored in labeled polythene packets for analyses.

3.5.3. Plankton sample

A conical plankton net made of bolting silk cloth (no. 21 with 77 meshes per square centimeter) was used to collect the plankton sample. About 5 l of water from each of the cisterns was collected from randomly selected locations with the help of a 500 ml beaker and pooled together for filtering. The filtered sample of plankton was preserved in 4% formalin solution and stored in labeled vials for subsequent quantitative and qualitative analysis (APHA, 1995).

3.6. Analyses of samples

3.6.1. Water quality

3.6.1.1. Temperature

Surface water temperature was measured using a centigrade thermometer on spot and expressed as °C (APHA, 1995).

3.6.1.2. pH

pH of water samples was recorded by a digital pH meter (ADCO) on spot.

3.6.1.3. Dissolved oxygen (DO)

For estimation of dissolved oxygen content of water Winkler's method was followed (APHA, 1995).

3.6.1.4. Total alkalinity

Total alkalinity of water samples was estimated using phenolphthalein and methyl orange as indicator and N/50 H₂SO₄ as titrant (APHA, 1995).

3.6.1.5. Ammonium- nitrogen (NH₄-N)

After proper filtration of the sample, phenol solution, sodium nitropruside solution and oxidizing solution were added to the sample. The samples were then wrapped with paper and kept at room temperature (22-27 °C) in subdued light for at least 1 hour. A blue colour appeared which was stable for 24 hrs. The ammonia concentration of the samples was directly estimated through a double beam UV-vis-Spectrophotometer (CECIL CE-4002) at 543 nm wavelengths (APHA, 1995).

3.6.1.6. Nitrite nitrogen (NO₂-N)

The water sample was filtered through Whatman filter paper No. 1 and 50 ml of filtered water sample was added with 1 ml of sulphanilamide reagent. After 3 minutes, 1ml of aromatic amine reagent was added and shaken thoroughly. The absorbance value at 543 nm against distilled water blank was recorded (APHA, 1995).



3.6.1.7. Orthophosphate (PO₄ - P)

The orthophosphate level of water was determined colorimetrically (UV-vis-Spectrophotometer (CECIL CE-4002) at 690 nm following the stannous chloride method (APHA, 1995).

3.6.1.8. Biochemical oxygen demand (BOD)

Biochemical oxygen demand was estimated by standard methods of (APHA, 1995). The water sample was collected from each cistern on the sampling day and initial D.O. value was estimated by Winkler's method. Other water samples from each cistern were kept in the B.O.D. incubator for 24 hours and final D.O. was estimated by the same method. BOD₁ value was calculated by subtracting final D.O. value from initial D.O. value and expressed as mg l⁻¹.

3.6.1.9. Primary production

The dark and light bottle technique described by Winberg (1963) was followed for the measurement of primary productivity of phytoplankton. Water samples were collected in 125 ml borosil glass bottle in triplicate from each cistern taking all necessary precautions during filling to prevent air bubble from remaining in the bottle. All the bottles were then exposed at the surface layer of water under normal light conditions for 6 hours. The oxygen content of all the dark and light bottles was monitored using modified Winkler's method. The calculation described by Vollenweider (1974) was used to measure the rate of primary production. The results of primary production in terms of oxygen were converted into mg carbon by multiplying with a factor 0.375 (Natarajan and Pathak, 1983).

3.6.2. Soil quality

3.6.2.1. pH

The pH was determined with a digital pH meter (ADCO) using 1:2 suspensions of soil and water (Jackson, 1967).

3.6.2.2. Organic carbon

For estimation of organic carbon, air-dried powdered sediment sample (500 mg) was digested with 1 N $K_2Cr_2O_7$ (20 ml) and concentrated H_2SO_4 (20 ml) and kept for 30 minutes at dark. The digested sample was then diluted with 150 ml distilled water and 10 ml ortho-phosphoric acid and 1 ml diphenyl amine indicator was added. It was then titrated against 0.5 N ferrous ammonium sulphate (Mohr's salt) until brilliant green colour appeared (Walkley and Black, 1934).

3.6.2.3. Available phosphorus

Available phosphorus was determined using 1:20 soil to Olsen's extractant (0.5 $NaHCO_3$ adjusted to pH 8.5) (Olsen *et al.*, 1954) followed by Dickman and Bray's (1940) chlorostannous reduced molybdophosphoric blue colour method in hypochloric acid system as described by Jackson (1967).

3.6.3. Analyses of plankton

Formaldehyde preserved plankton samples were analysed by 'Drop Count Method' (APHA, 1995) under a binocular microscope.

3.6.4. Microbiological parameters

3.6.4.1. Total aerobic heterotrophic bacteria (AHB)

Aliquots of tenfold dilution from 10^{-1} to 10^{-3} for water samples were made in sterile distilled water. The aerobic heterotrophic bacteria were enumerated in nutrient agar by serial dilution of the sample, followed by the conventional spread plate method (APHA, 1995). The bacteriological media was obtained from Himedia Laboratories Ltd. Mumbai, India. After inoculation, the Petri dishes containing the culture media were incubated at $37^\circ C$ for 48 hrs. The

population of bacteria was expressed in terms of cfu/ml. Each dilution of the sample was plated in triplicate and arithmetical mean of the 3 counts was used in the present study.

3.6.4.2. Cellulose decomposing bacteria (CDB)

Similar to HB, aliquots of tenfold dilution from 10^{-1} to 10^{-3} for water samples were made in sterile distilled water. Conventional spread plate technique under aerobic conditions was used to enumerate viable counts of cellulose decomposing bacteria, following the methods described by Rodina (1972) and Austin (1990) at an incubation temperature of 37°C for two- three days. Each dilution of the sample was plated in triplicate and arithmetical mean of 3 counts was used in the present study.

For each Petri dish, 15cm^3 of CMC agar, made with 0.5 g Carboxymethyl cellulose (a soluble form of cellulose); 0.1 g NaNO_3 ; 0.1 g K_2HPO_4 ; 0.1 g KCl ; 0.05 g MgSO_4 ; 0.05g yeast extract; 0.1 g glucose in 100 ml of water. The medium was solidified using 1.7 % w/v agar (Apun, 1995).

3.6.5. Fish growth

Fish growth was recorded at 30 days intervals from each cistern. Half of the stocked fish were caught randomly with a hand net and their length (cm) and weight (g) increments were recorded for estimation of average weight gain, specific growth rate (SGR). They were then released again as quickly as possible for further growth. The following estimates were done as:

Average length gain = (Final length - Initial length)

Average weight gain = (Final weight - Initial weight)

Body weight gain (%) = $\text{Final wt.} - \text{Initial wt.} / \text{Initial wt.} \times 100$

Specific growth rate (SGR) = $100 \times [\ln. (W_t) - \ln. (W_0) / \text{days}]$

3.6.6. Statistical analyses

All the data were statistically analyzed. One way analysis of variance was applied to determine the significance of difference among the treatments. This was followed by LSD test to compare the difference between any pair of treatment combinations. Correlation-coefficient test was applied for determining the relationship between selective biological and physico-chemical parameters.

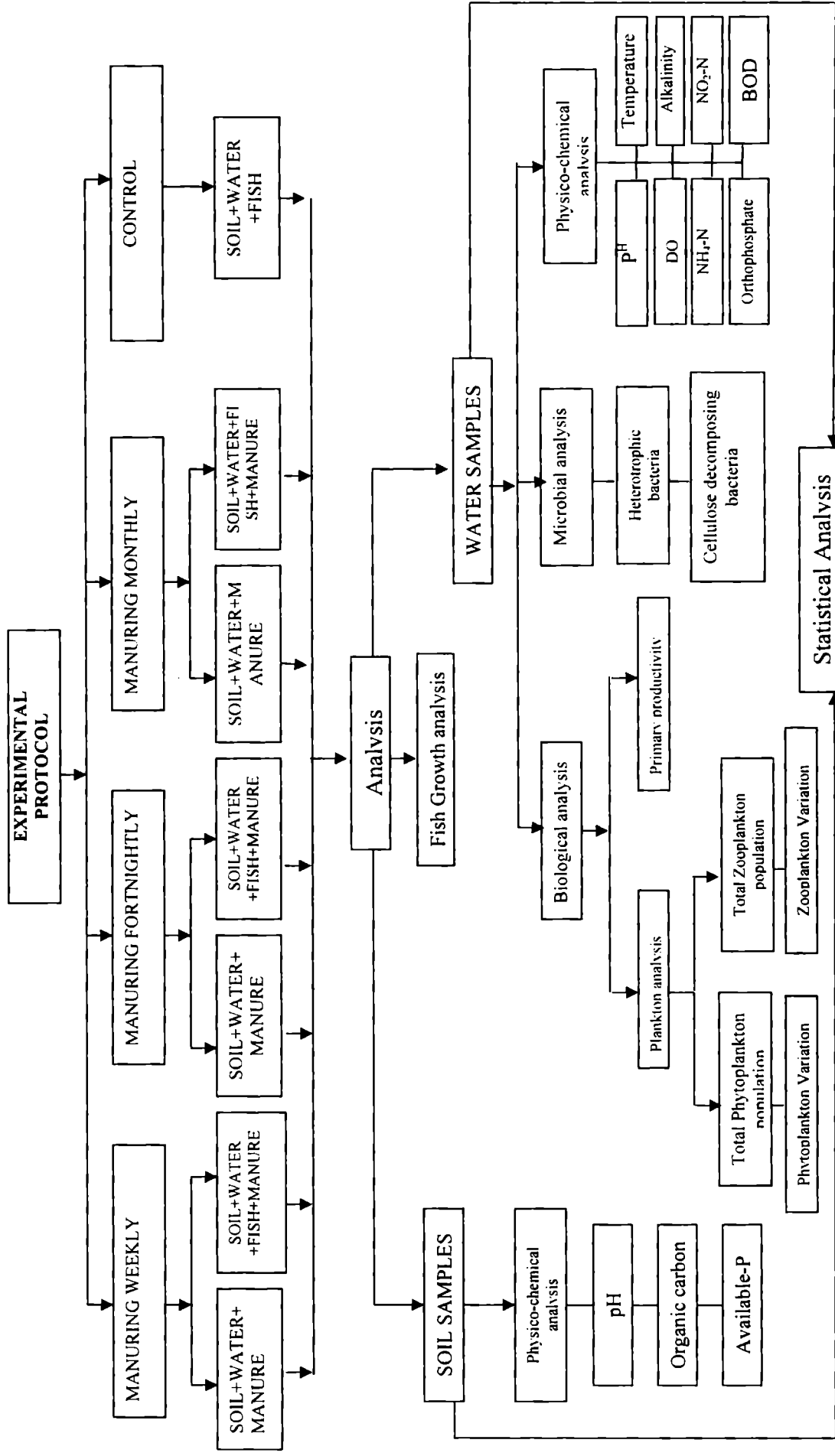


Fig. 1. Experimental protocol followed in the present study

Chapter IV

EXPERIMENTAL RESULTS

4.1. Water quality

4.1.1. Physico-chemical parameters

4.1.2. Temperature

Water temperature ranged between (30 – 33 °C) during the period of study with little variation among the treatments.

4.1.3. pH

Water pH did not differ much among the treatments and the values ranged from 7.8 to 7.2. Also, treatment difference remained insignificant ($P > 0.05$).

4.1.4. Dissolved oxygen (DO)

Dissolved oxygen concentration of water, in general, tended to increase over time in any of the treatments employed. The treatments without fish exhibited higher presence (4.16 – 8.23 %) of dissolved oxygen in comparison to their respective counterparts with fish. Again among the treatments with fish dissolved oxygen concentration was maximum (6.13 mg l⁻¹) in weekly manuring compared to fortnightly (5.75 mg l⁻¹) and monthly (5.71 mg l⁻¹) manuring schedule. The lowest (5.55 mg l⁻¹) concentration of dissolved oxygen was observed in control (**Fig.2**).

Overall treatment difference was highly significant ($F = 3.870$, $P < 0.01$) during the course of investigation. LSD test revealed significance between most of the treatment combinations excepting either between FF and WF or between FF and MF.

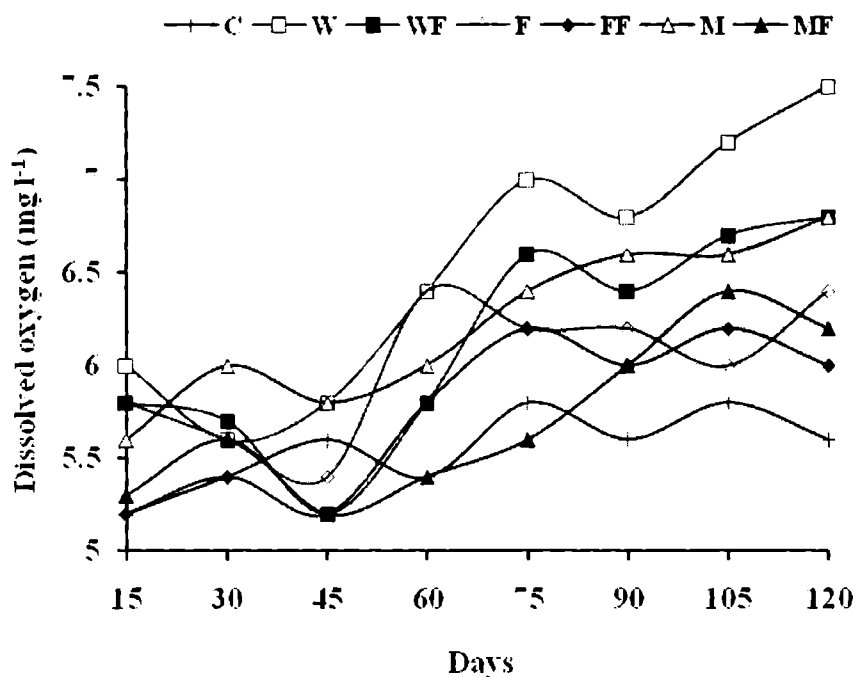


Fig.2: Temporal changes of dissolved oxygen concentration of water in different treatments employed.

4.1.5. Alkalinity

In general, alkalinity of water exhibited declining trend in all the treatments irrespective of the manuring schedule (**Fig.3**). However, the magnitude of decrease was maximum (56.86%) in FF followed by C (56.66%), F (54.71%), WF (53.06%), W (45.58%), M (32.20%), and MF (25%).

The overall treatment difference remained highly significant ($F = 3.273$; $P < 0.01$) up to day 75 after which it became insignificant ($P > 0.05$). Again, differences between any of the possible combination of treatments (LSD) randomly remained insignificant ($P > 0.05$).

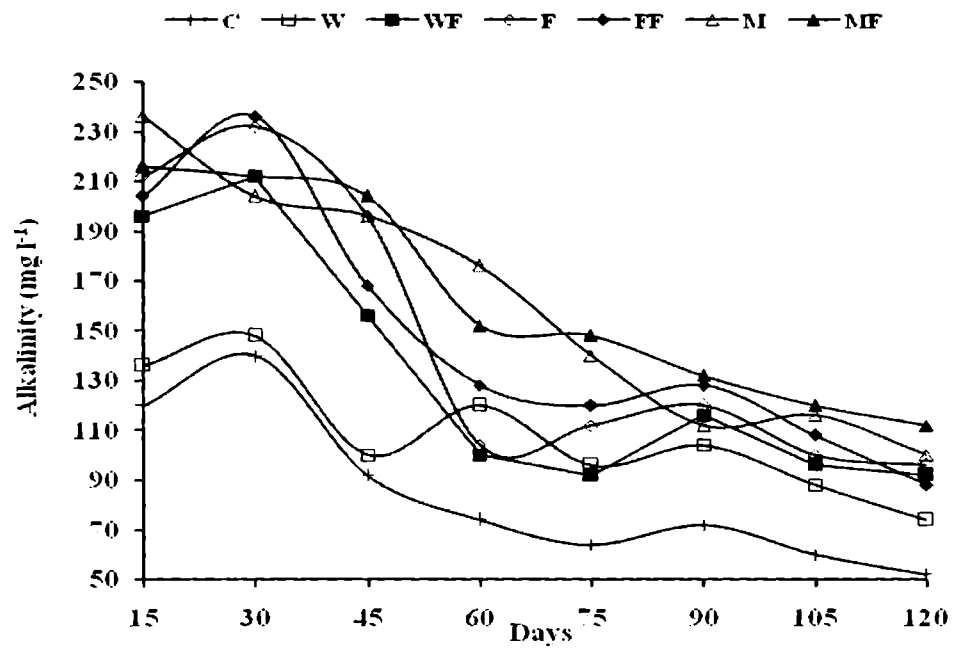


Fig.3: Temporal changes of total alkalinity of water in different treatments employed.

4.1.6. Biochemical oxygen demand (BOD)

Biochemical oxygen demand tended to increase in all the treatments excepting the control (Fig. 4). However, the systems without fish in any of the manuring schedules exhibited higher values than their respective counter parts with fish. The maximum value (1.61 mg l^{-1}) was observed in W and minimum (0.58 mg l^{-1}) in control.

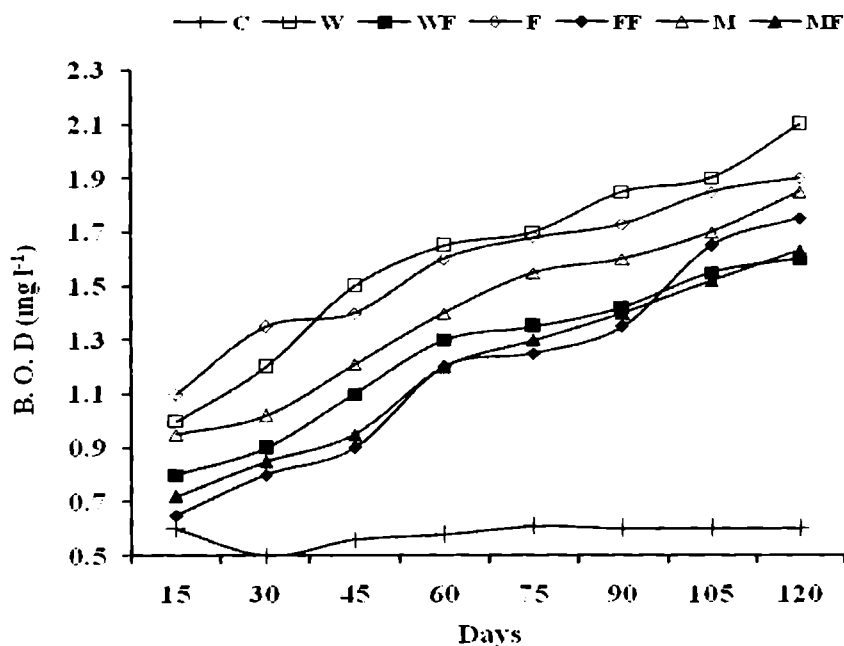


Fig.4: Temporal changes of biochemical oxygen demand of water under different treatments employed.

Overall treatment difference remained always significant ($F = 10.06$; $P < 0.001$), but differences between FF and MF with fish exhibited insignificance ($P > 0.05$) in some cases (LSD).

4.1.7. Nutrient parameters

4.1.7.1. Ammonium nitrogen

An increasing trend in the values of $\text{NH}_4 - \text{N}$ was observed in all the treatments. Higher values of $\text{NH}_4 - \text{N}$ in the treatments with fish in comparison to their counterparts without fish in any of the manuring schedules were conspicuous (Fig.5).

Again, overall mean value was maximum (0.203 mg l^{-1}) in MF followed by FF (0.179 mg l^{-1}) and lowest in WF (0.126 mg l^{-1}). Treatment differences exhibited high level of significance ($F = 9.1466$; $P < 0.001$). However, differences between M and MF, M and FF, F and FF or between W and WF exhibited insignificance ($P > 0.05$) in some cases.

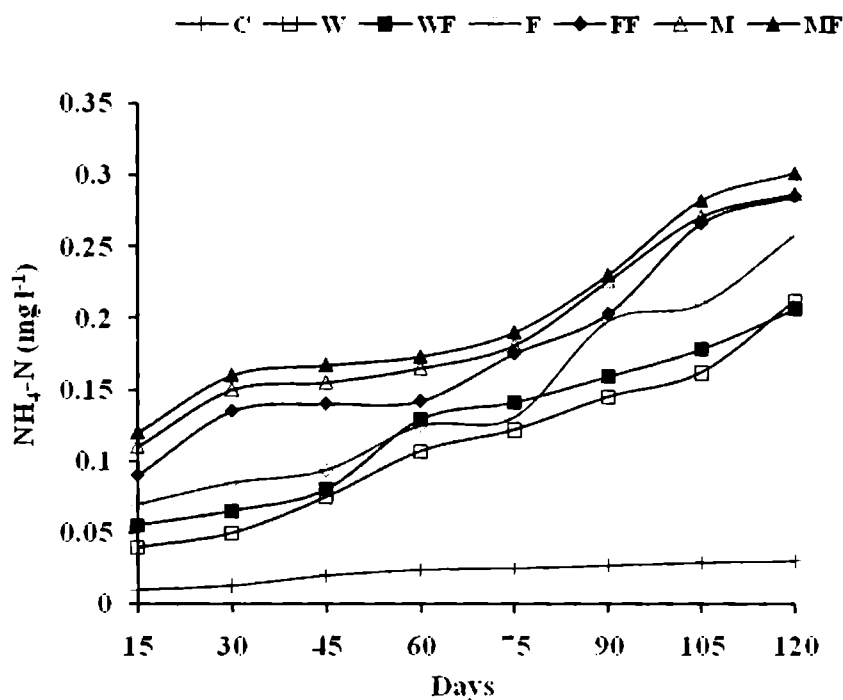


Fig.5: Temporal changes in the ammonium nitrogen concentration of water under different treatments employed.

4.1.7.2. Nitrite nitrogen (NO₂-N)

Nitrite nitrogen increased sharply over time in any condition excepting control (Fig.6). The maximum mean value (0.031 mg l⁻¹) was observed in FF, followed by MF (0.031 mg l⁻¹); M (0.027 mg l⁻¹); F (0.026 mg l⁻¹); W (0.024 mg l⁻¹); WF (0.021 mg l⁻¹); C (0.004 mg l⁻¹).

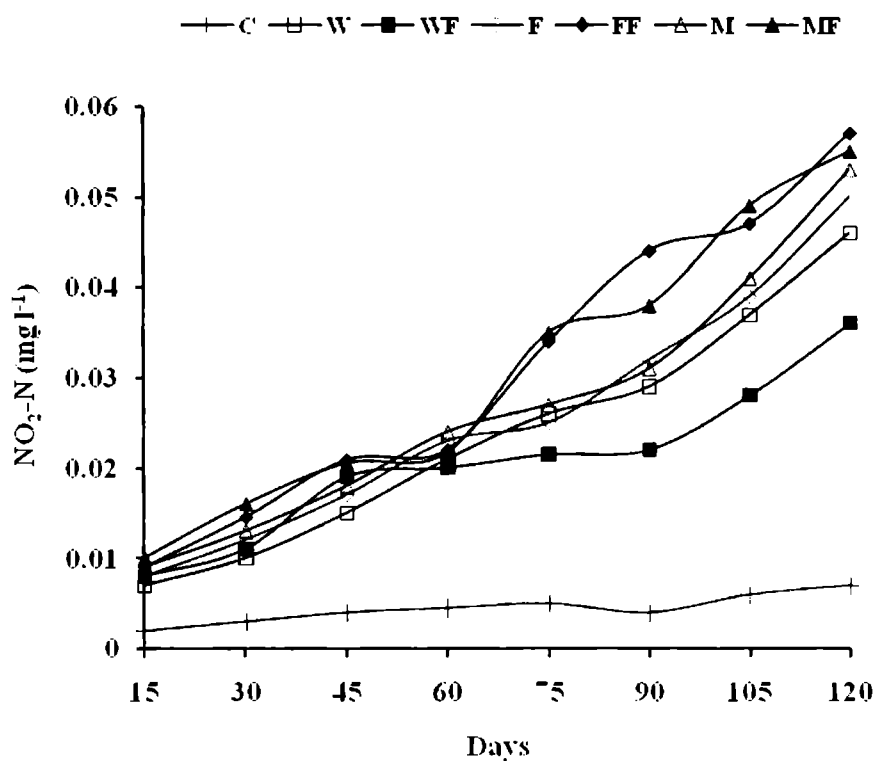


Fig.6: Temporal changes in the nitrite nitrogen concentration of water in different treatments employed.

Overall, treatment difference upto day 60 remained insignificant ($P > 0.05$) after which differences became highly significant ($F = 3.7785$; $P < 0.01$). LSD test revealed insignificant differences ($P > 0.05$) either between FF and MF, W and F or between F and M in most cases.

4.1.7.3 Orthophosphate

Orthophosphate concentration of water in all the treatments tended to increase overtime but the treatments with fish exhibited higher values of orthophosphate than the respective treatment without fish. In the weekly manuring system the increase of orthophosphate level of water remained steadier. Whereas, in fortnightly and monthly manuring system more zigzag pattern was observed (Fig.7).

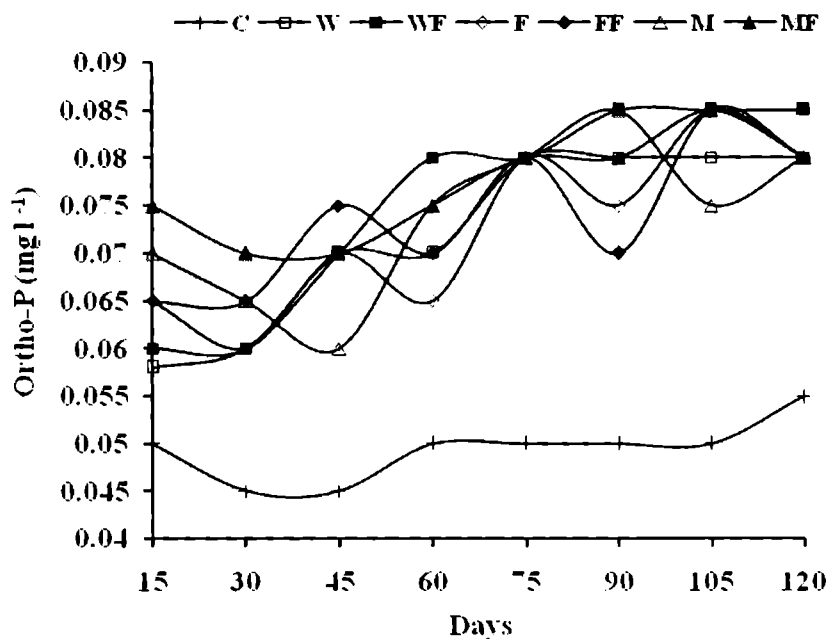


Fig.7: Temporal changes in the orthophosphate concentration of water in different treatments employed.

The maximum value was obtained in MF ($.077 \text{ mg l}^{-1}$) followed by WF ($.075 \text{ mg l}^{-1}$), FF ($.074 \text{ mg l}^{-1}$) and lowest in control ($.049 \text{ mg l}^{-1}$). Difference among the treatment remained insignificant ($P > 0.05$).

4.1.8. Biological parameters

4.1.8.1. Gross primary productivity (GPP)

The temporal change of GPP indicated a steady rise in all the treatments (Fig.8) with a sharp fall at termination. The overall mean value ($271.87 \text{ mg C m}^{-2} \text{ hr}^{-1}$) was observed in W followed by WF ($206.25 \text{ mg C m}^{-2} \text{ hr}^{-1}$), F ($198.675 \text{ mg C m}^{-2} \text{ hr}^{-1}$), M ($198.075 \text{ mg C m}^{-2} \text{ hr}^{-1}$), MF ($157.1563 \text{ mg C m}^{-2} \text{ hr}^{-1}$), FF ($141.575 \text{ mg C m}^{-2} \text{ hr}^{-1}$), and C ($93.75 \text{ mg C m}^{-2} \text{ hr}^{-1}$).

Treatment difference exhibited extremely higher level of significance ($F = 6.83$; $P < 0.001$). However, LSD test revealed insignificance ($P > 0.05$) either between F and M or between FF and MF in most of the dates of observation.

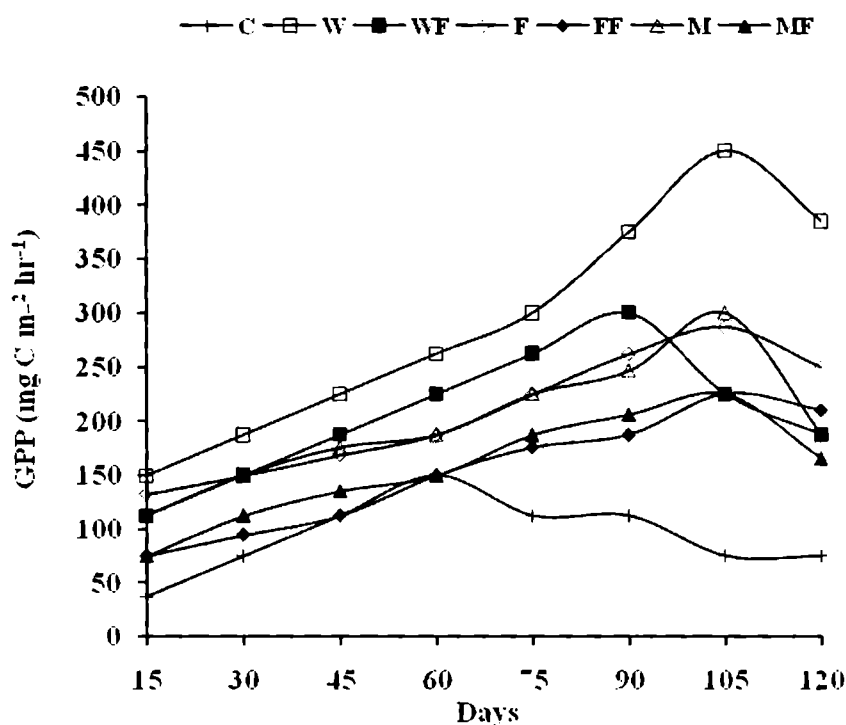


Fig.8: Temporal variation of gross primary production of water under different treatments employed.

4.1.8.2. Plankton analysis

4.1.8.2.1. Total phytoplankton

Total phytoplankton population tended to increase in all the treatments upto day 90 after which a gradual decline was observed (Fig.9). The population in W always remained distinctly higher and the overall mean was (23.19%) higher than the rest of the treatments. Moreover, the systems without fish in comparison to their counterparts with fish exhibited significantly higher values ($P < 0.05$).

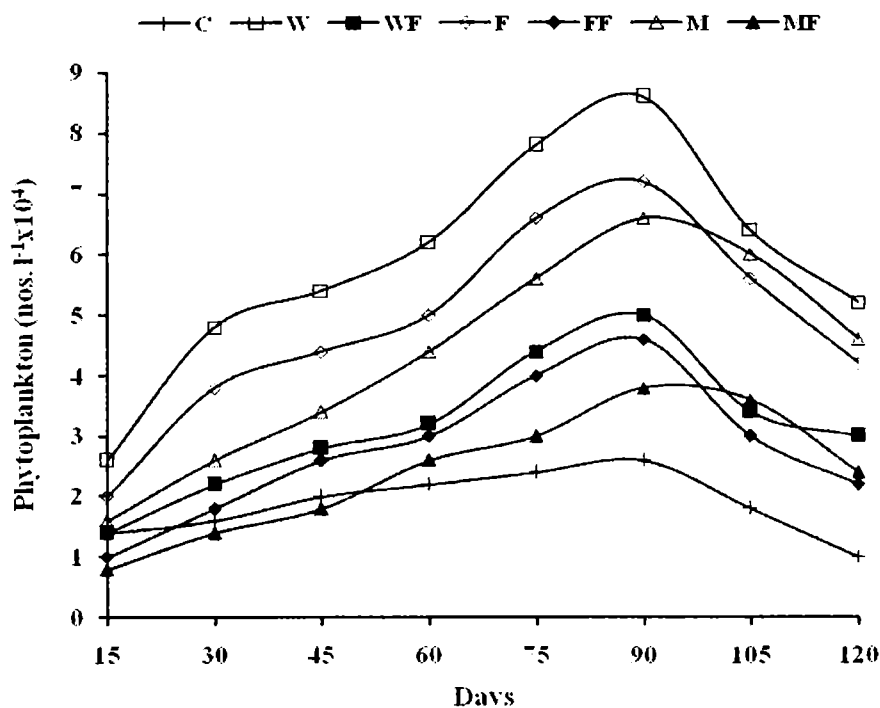


Fig.9: Temporal variation of total phytoplankton in different system employed.

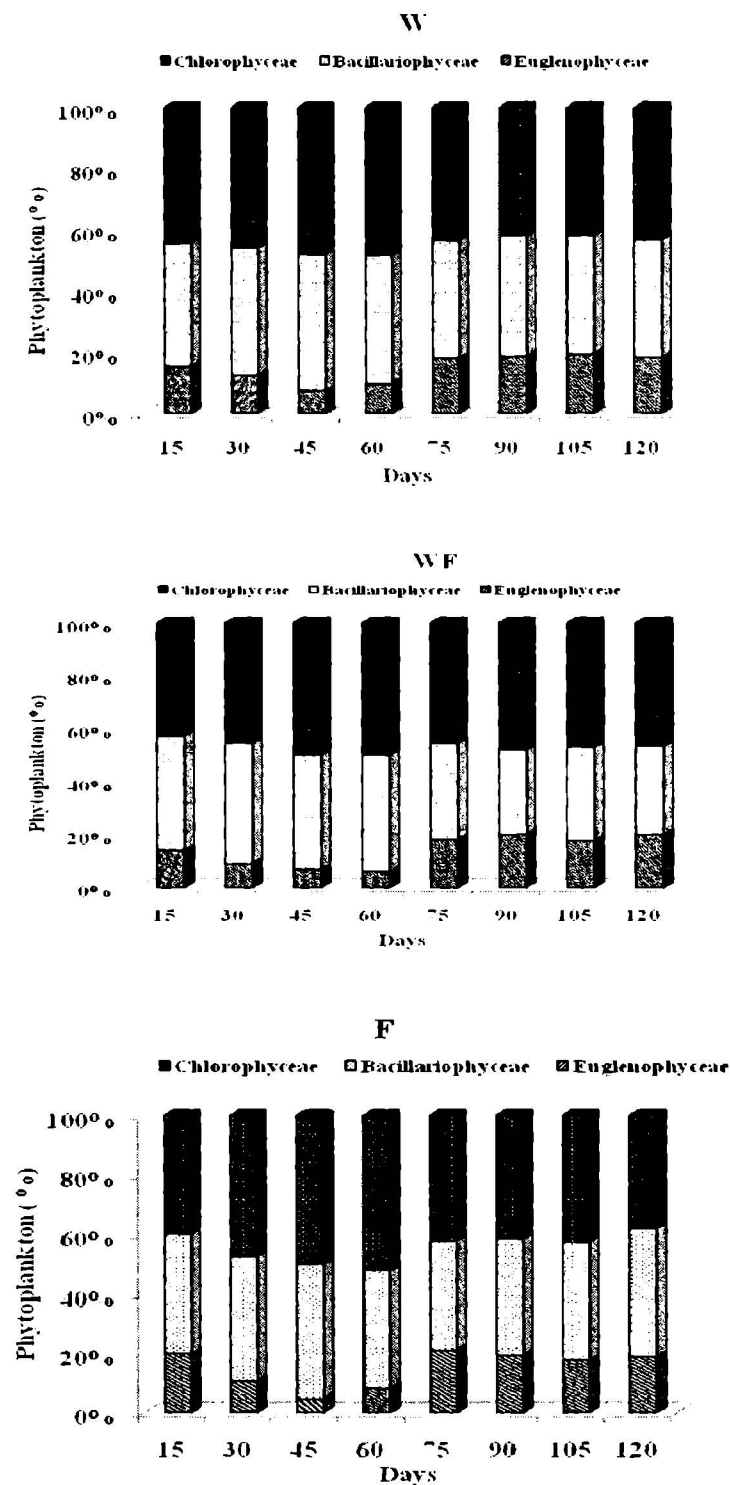
The overall treatment difference remained highly significant ($F= 8.86$; $P < 0.001$). Differences either between MF and FF or between WF and FF exhibited insignificance (LSD) in some dates of observation ($P > 0.05$).

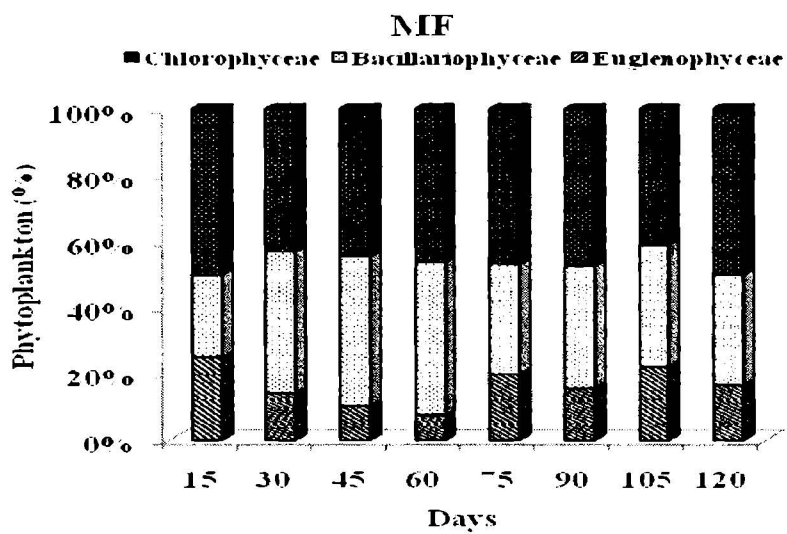
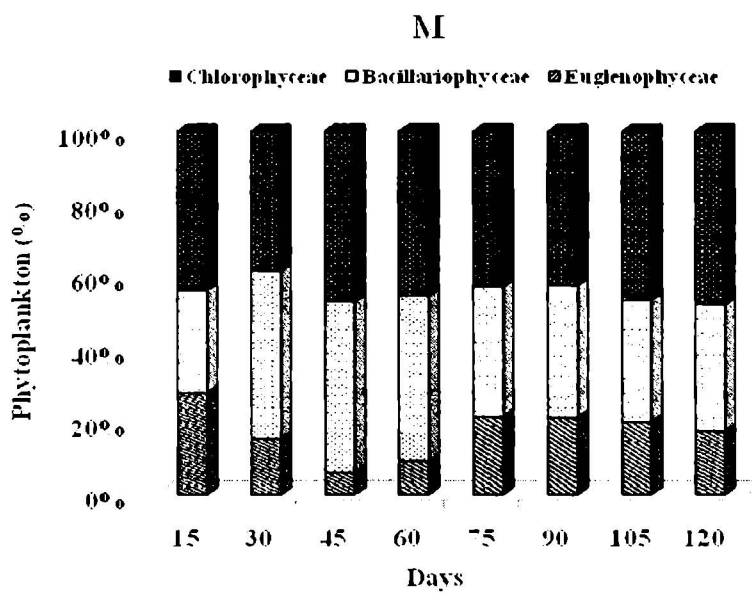
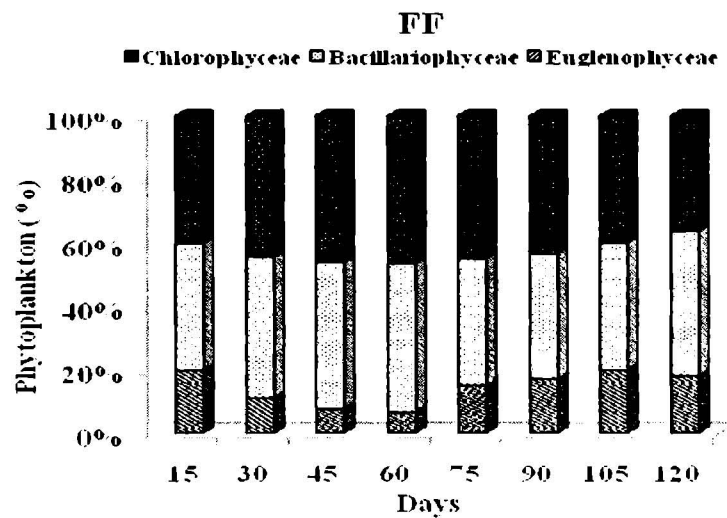
4.1.8.2.2. Population composition of phytoplankton

Phytoplankton populations in the treatments were composed by the members of Chlorophyceae (*Chlorella* sp., *Spirogyra* sp., *Pediastrum* sp.), Bacillariophyceae (*Cyclotella* sp., *Navicula* sp., *Synedra* sp.) and Euglenophyceae (*Euglena* sp., *Phacus* sp.)

Phytoplankton population in any of the treatments without fish was represented primarily by Chlorophyceae (44.31- 44.73%) whereas, such contribution by Chlorophyceae in the treatment with fish ranged from (42.21- 46.94 %). On the other hand, the contribution of Bacillariophyceae varied from (37.45- 42.17 %) and (38.29- 40.62 %) in treatments with fish and without fish respectively. Phytoplankton population in any of the treatments was least

contributed by Euglenophyceae and the values ranged between (14.07 – 17.17%) (Fig. 10).





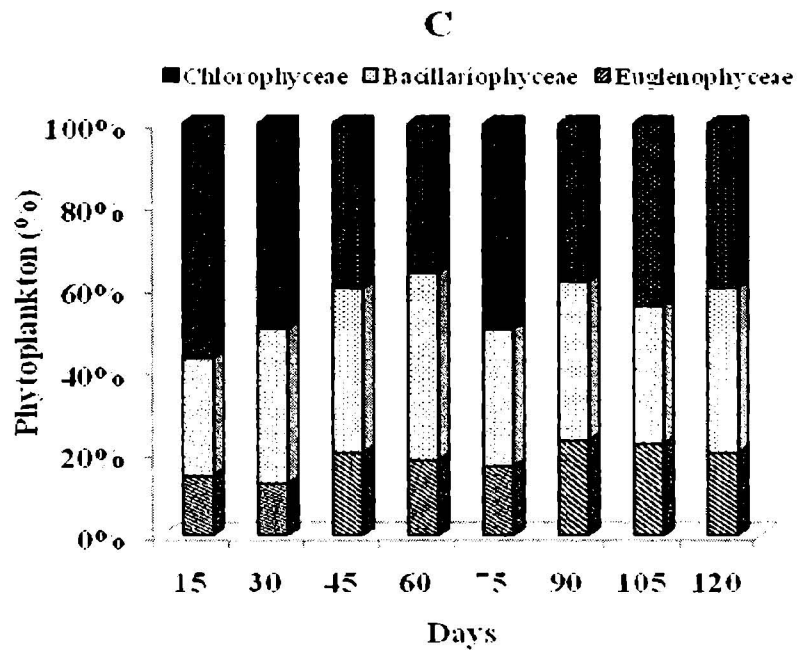


Fig.10: Distribution (%) of different groups of phytoplankton in different systems employed.

The temporal trend of relative contribution by Chlorophyceae and Bacillariophyceae towards the total phytoplankton population remained more or less steady in the treatment without fish, whereas, such contribution of Bacillariophyceae in the treatment with fish gradually declined irrespective of the manuring schedule (Fig.11).

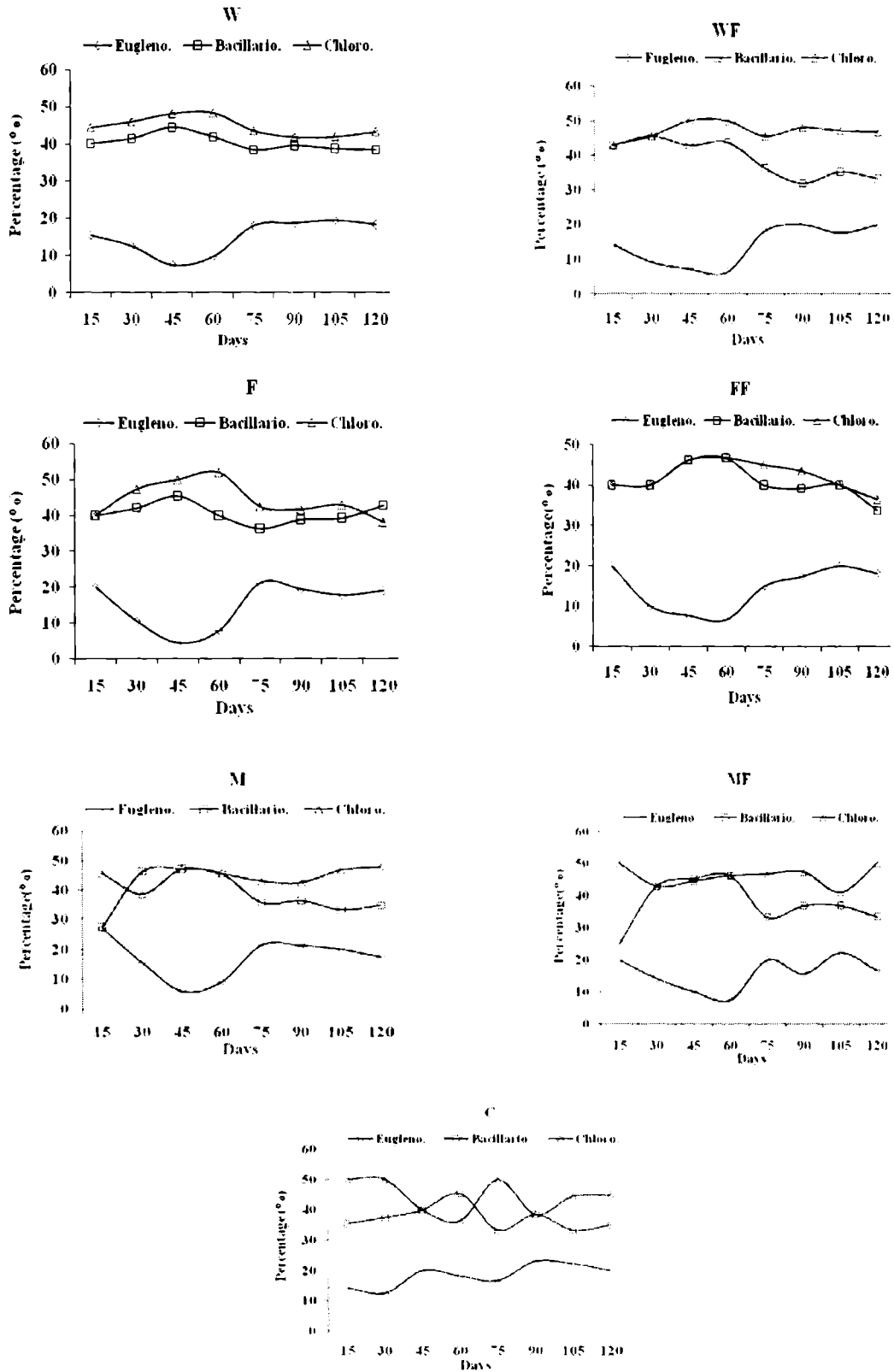


Fig.11: Temporal trends of different groups of phytoplankton in different systems employed.

The temporal trend in the percent contribution of Euglenophyceae towards total phytoplankton population clearly indicated a gradual decline up to day 45- 60 in any of the treatments employed, after which an increase in the percent contribution was observed. An increase of 18.53 – 40.05 % in the population of Euglenophyceae in the treatments with weekly manuring schedule with or without fish was observed. Likewise, the relative contribution of Bacillariophyceae noticeably increased (26.47 – 33.32 %) in the treatments with monthly manuring either with or without fish.

4.1.8.2.2. Total Zooplankton

The temporal trend of zooplankton population exhibited more or less identical response to that of phytoplankton. Also, the relative response in the treatments with fish and without fish in any of the manuring schedule showed similar response to that of phytoplankton. The average mean value in the systems without fish remained higher (17.47% to 20.96 %) than their counterparts with fish (Fig.12).

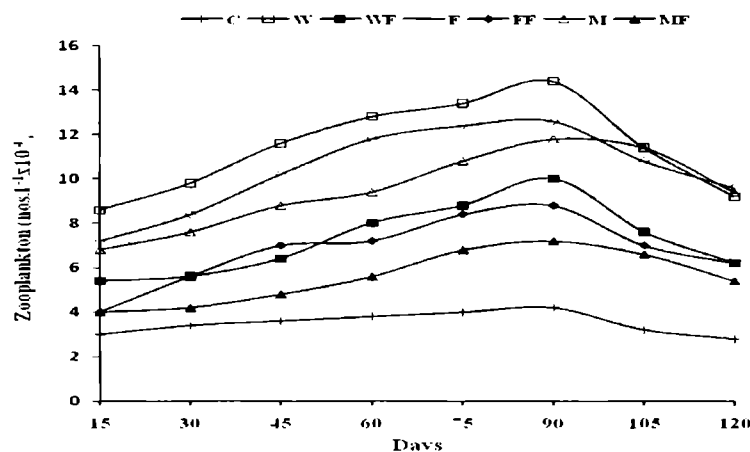


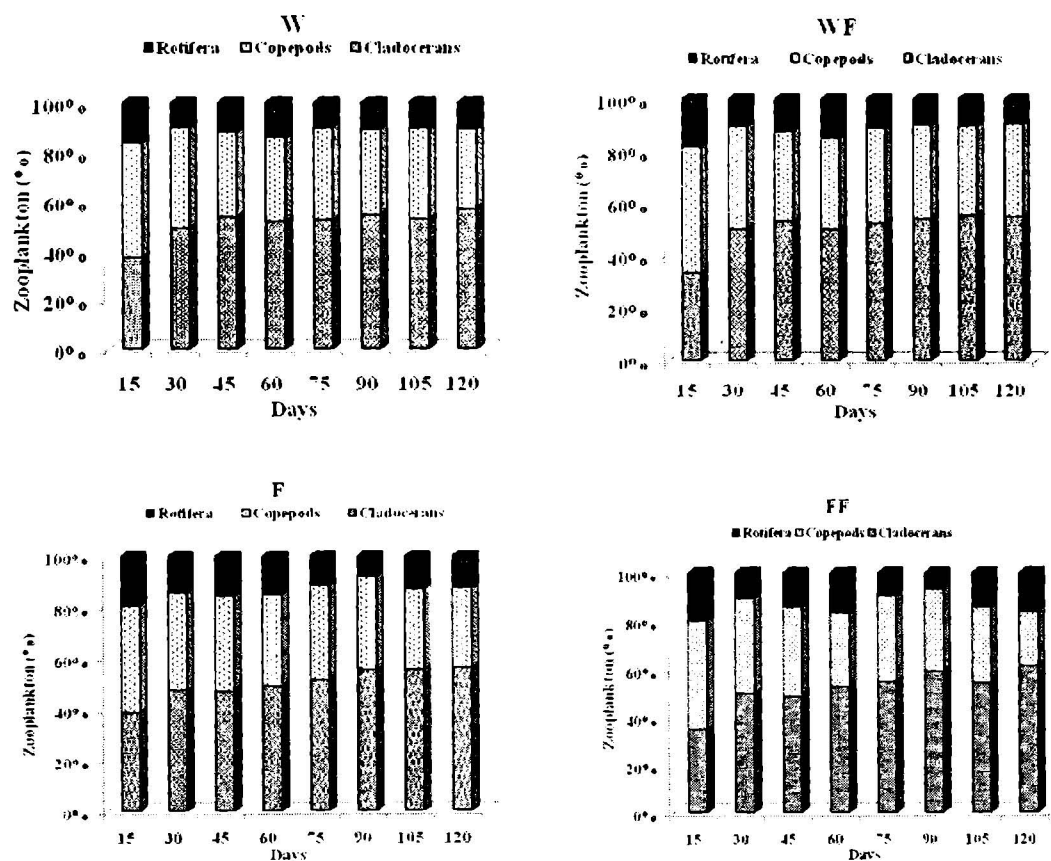
Fig.12: Temporal variation of total zooplankton in different system employed.

The overall treatment difference was highly significant ($F = 24.6961$; $P < 0.001$) but the level of significance decreased as the investigation period approached to termination. Therefore, LSD test revealed insignificant differences between any combinations of the treatments.

4.1.8.2.2. Zooplankton population composition

Zooplankton populations in the treatments were composed by the members of Cladocera (*Daphnia* sp., *Moina* sp.), Copepoda (*Cyclops* sp., *Diaptomus* sp.) and Rotifera (*Brachionus* sp., *Keratella* sp., *Asplanchna* sp.)

Among different groups of zooplankton, relative contribution of Cladocerans increased in all the treatments. However, such increase was more pronounced in the system with fish (64 – 72 %) compared with the system without fish (34-52%). On the contrary, the relative contribution of Copepods and Rotifers declined and for copepods the magnitude of such increase was (20 – 56 %) in the system with fish compared to (17- 30 %) without fish. Likewise, the rate of increase in the percent contribution of rotifer in the system with fish was (19 – 63 %) compared to (33 – 40 %) in the system without fish (Fig.13, 14).



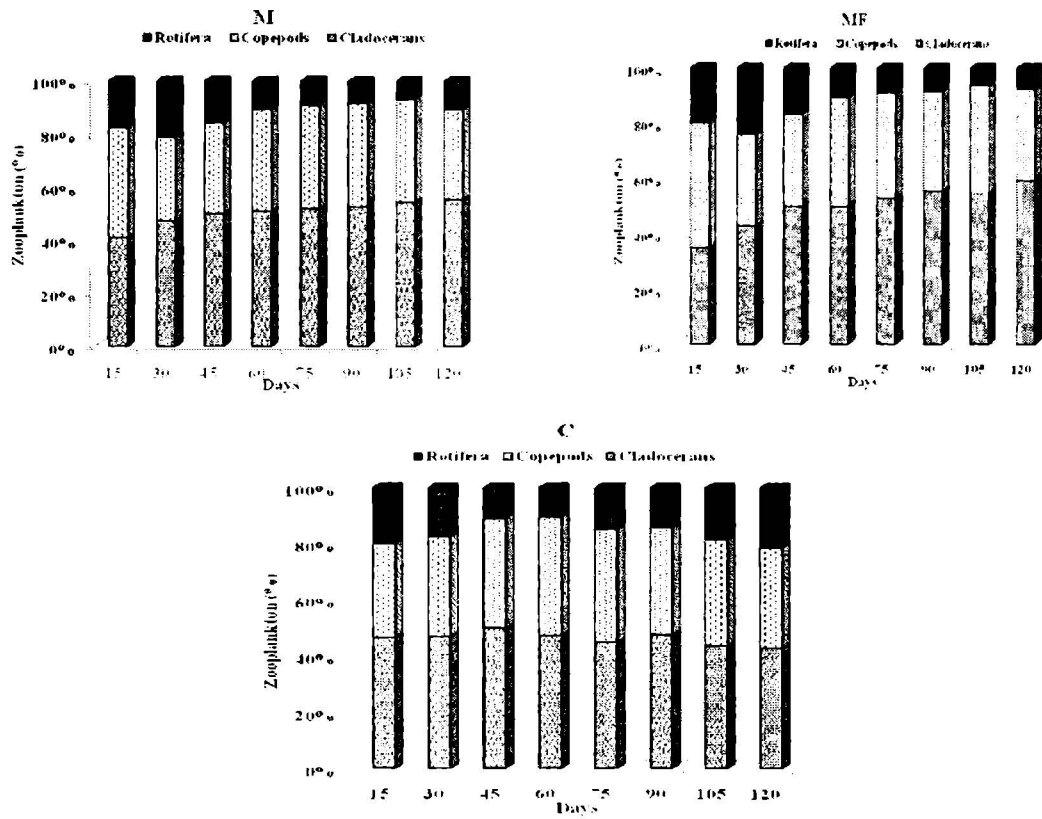
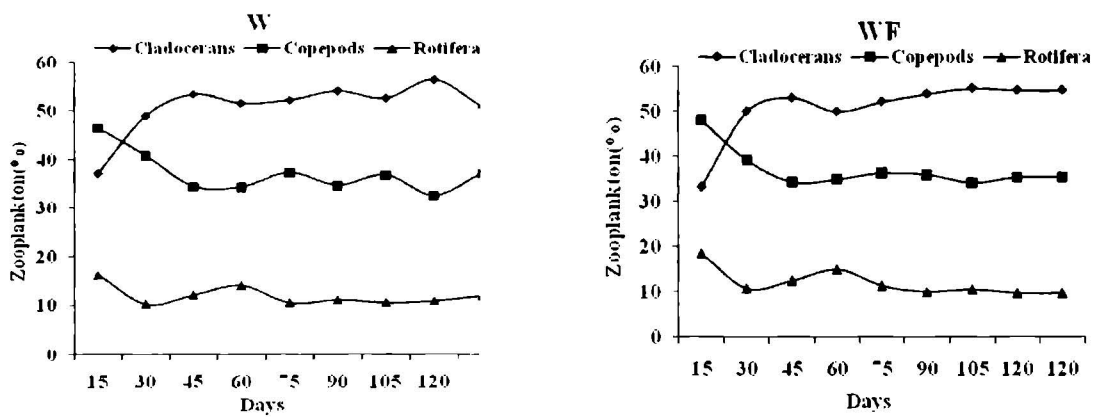


Fig.13: Distribution (%) of different groups of zooplankton in different system employed.



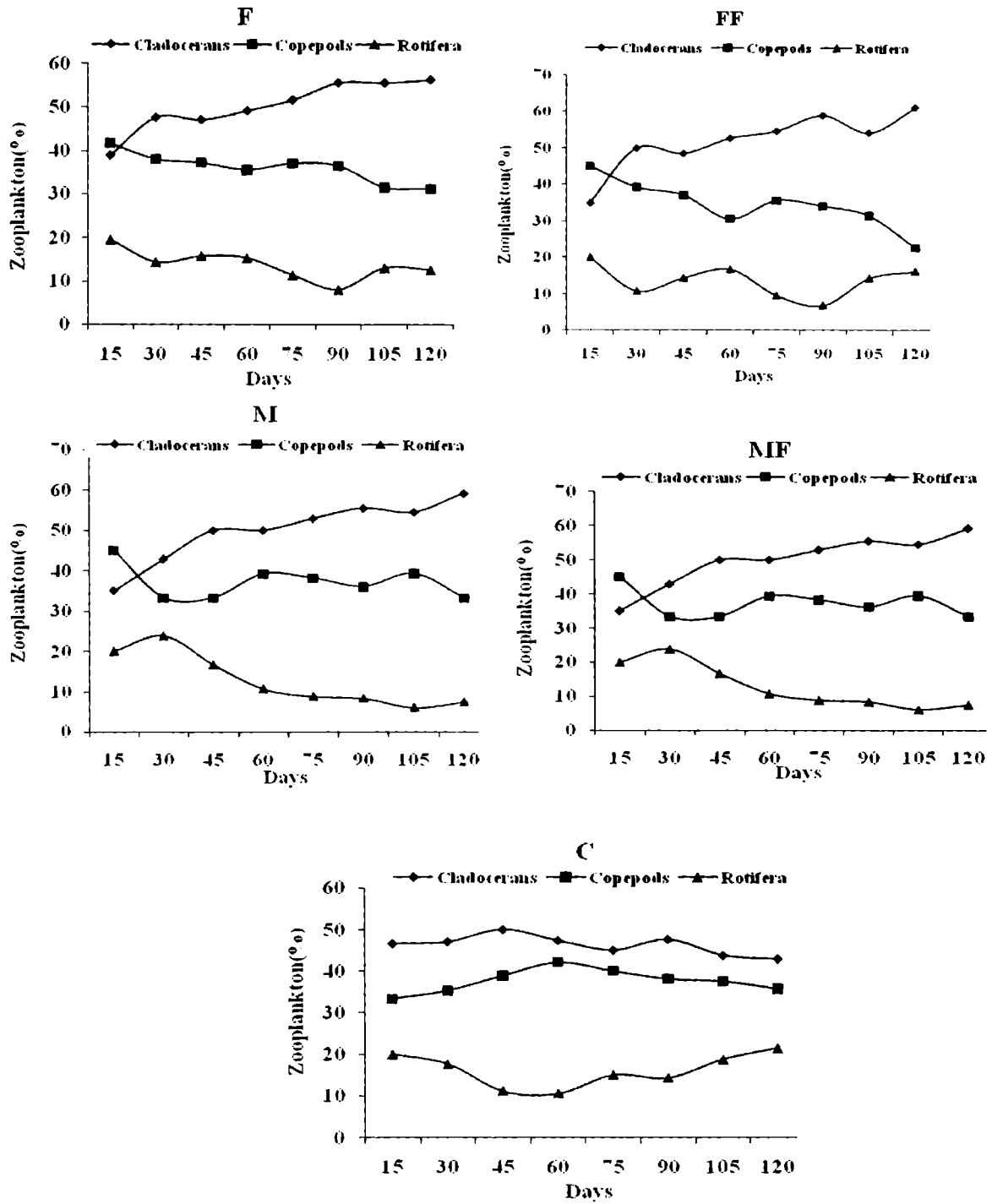


Fig.14: Temporal trends of different groups of zooplankton in different systems employed.

4.1.8.3. Total plankton

The temporal trend in the total plankton population exhibited similar trend to that of either total phytoplankton or total zooplankton (Fig.15). The treatment without fish exhibited higher presence of total plankton (17.27 % to 21.546 %) compared to the treatments with fish.

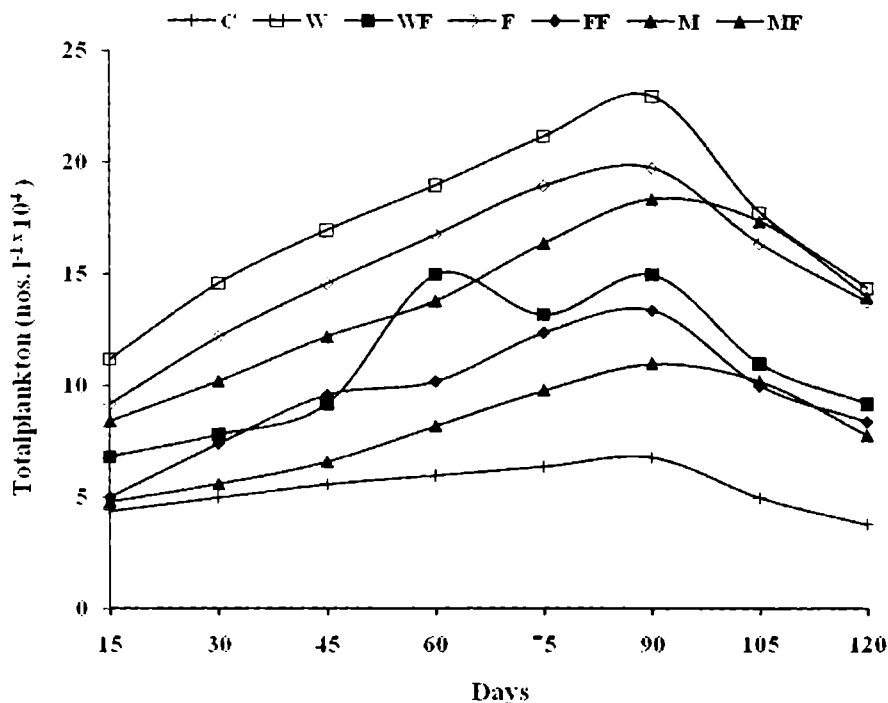


Fig.15: Temporal variation of total plankton in different systems employed.

Though, overall treatment difference remained highly significant ($F = 15.84$; $P < 0.001$), differences between treatments with fish or without fish became insignificant (LSD) during the terminal phase of the experimental period.

4.1.8.4. Shannon diversity index

4.1.8.4.1. Phytoplankton

Diversity of phytoplankton tended to increase over time in all the treatments with minimum values always in control (Fig.16).

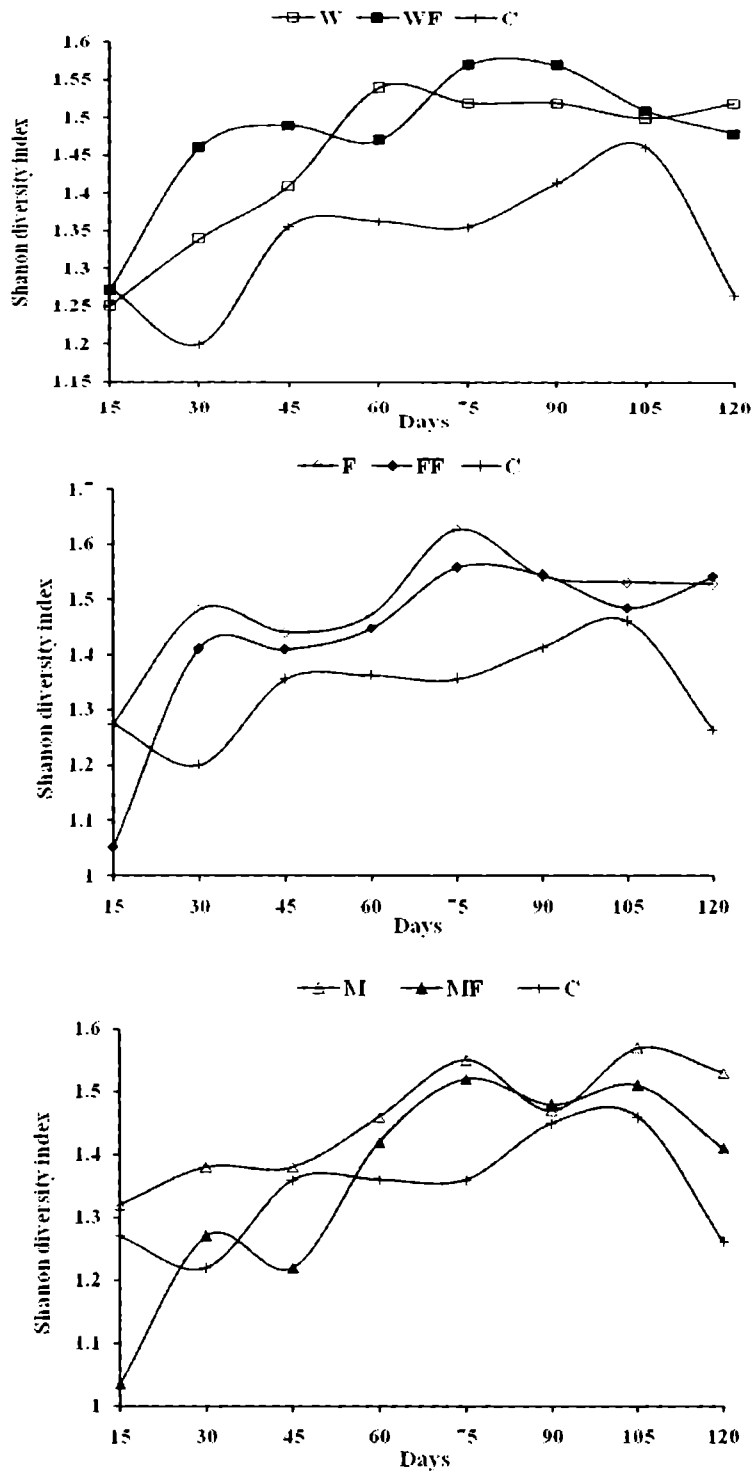


Fig.16: Shanon diversity index of phytoplankton in different treatments employed.

The mean value (1.48) in WF was higher than W (1.45) such trend was reversed in the fortnightly and monthly manuring schedule where the system with fish exhibited higher values (1.49 and 1.46 respectively) compared to their counterparts without fish (1.43 and 1.36 respectively).

4.1.8.4.1. Zooplankton

Shannon diversity index of zooplankton ranged between (1.52 – 1.72) during the period of the study in all the treatments. The temporal trend in the values of diversity index exhibited more or less stationary trend in the system under weekly manuring schedule (Fig. 17).

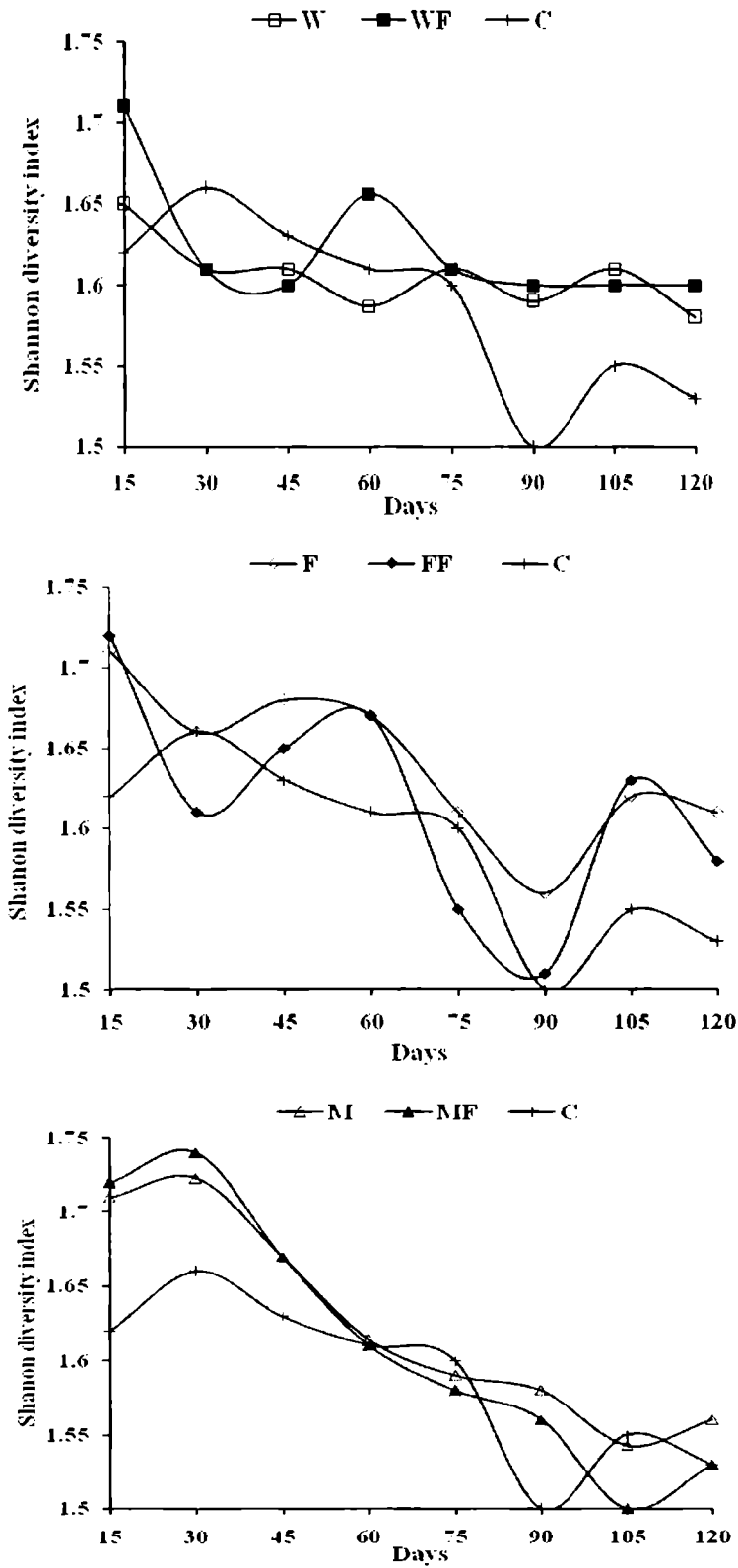


Fig.17: Shanon diversity index of zooplankton in different treatments employed.

Such trends were somewhat different in fortnightly and monthly manuring schedule with or without fish. The values continued to decline up to day 90 in fortnightly manuring schedule, whereas in monthly manuring schedule such decline continued till the end. This trend is somewhat parallel to that of control. In comparing the relative values of diversity index it is conspicuous that diversity index was somewhat higher in the system with fish (1.64) compared to the treatment without fish (1.6). Such trend was reversed in both fortnightly and monthly manuring schedule of fish.

4.1.9. Microbiological parameters

4.1.9.1. Total aerobic heterotrophic bacteria (AHB)

Total AHB population in the treatments without fish exhibited increasing trend with higher values in W ($121.25 \text{ cfu} \times 10^3 \text{ ml}^{-1}$) followed by F ($88.25 \text{ cfu} \times 10^3 \text{ ml}^{-1}$), M ($79.75 \text{ cfu} \times 10^3 \text{ ml}^{-1}$) and control ($39.5 \text{ cfu} \times 10^3 \text{ ml}^{-1}$) (Fig.18).

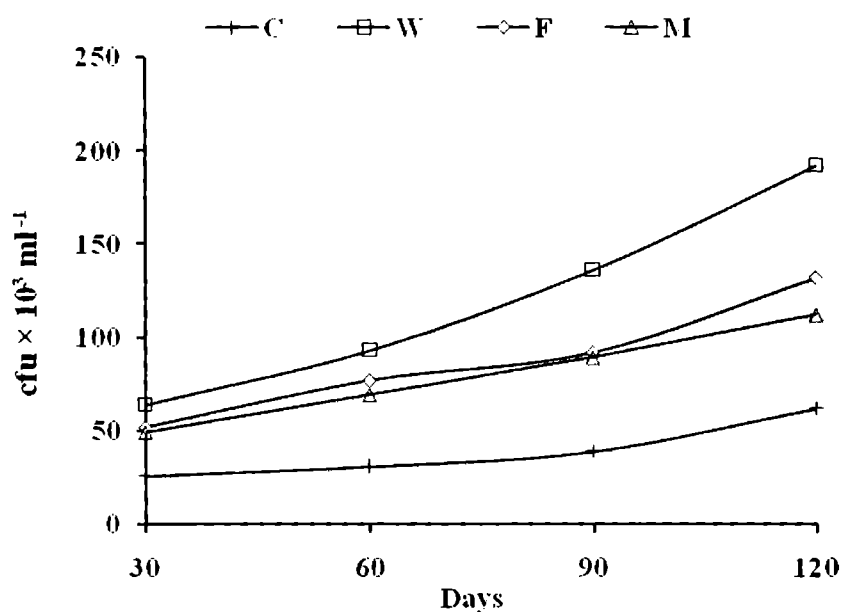


Fig.18: Temporal changes in the values of total heterotrophic bacteria under different system employed.

Overall treatment difference was significant ($F = 3.47$; $P < 0.05$) but differences between F and M or between W and F (LSD) exhibited insignificance ($P > 0.05$) during the initial phase of the investigation.

4.1.9.2. Cellulose decomposing bacteria (CDB)

Similar to AHB, CDB populations also tended to increase with the progress of the study (Fig.19). Population size of CDB remained always higher in W ($81.5 \text{ cfu} \times 10^3 \text{ ml}^{-1}$) followed by F ($66.25 \text{ cfu} \times 10^3 \text{ ml}^{-1}$), M ($49.75 \text{ cfu} \times 10^3 \text{ ml}^{-1}$) and control ($21 \text{ cfu} \times 10^3 \text{ ml}^{-1}$).

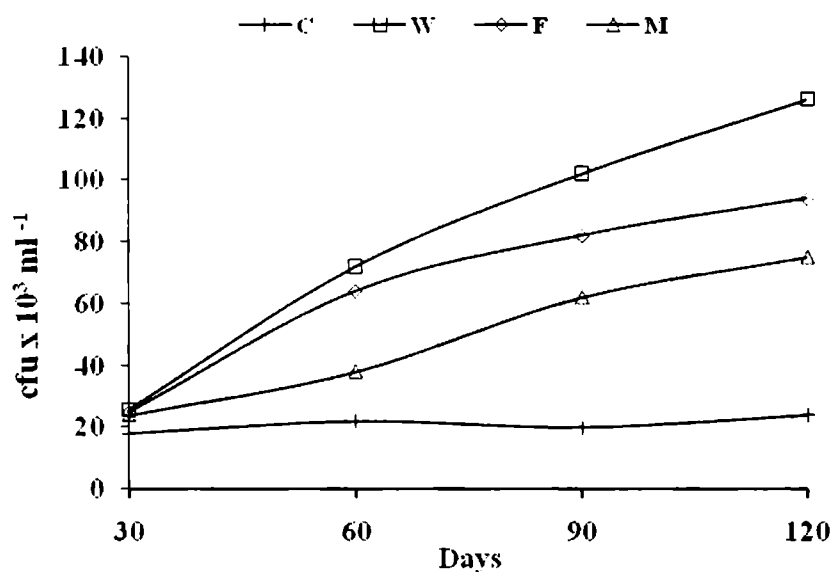
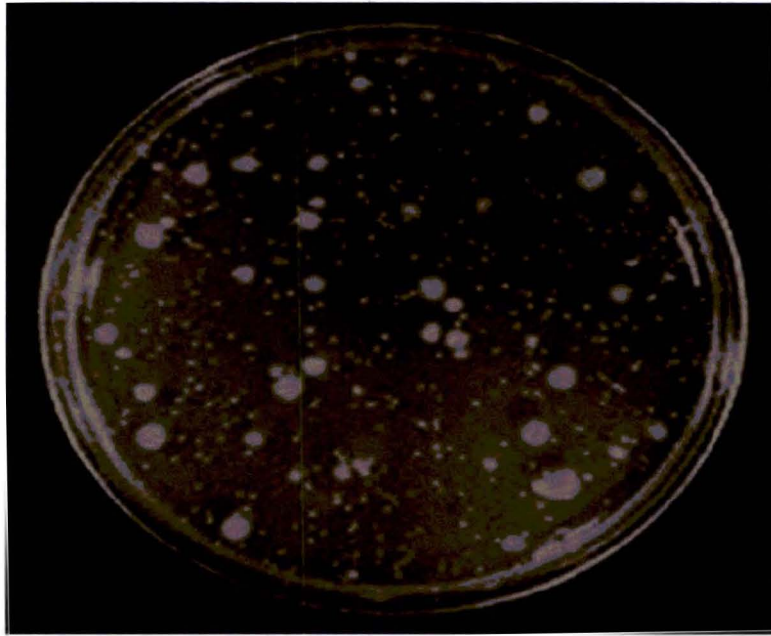
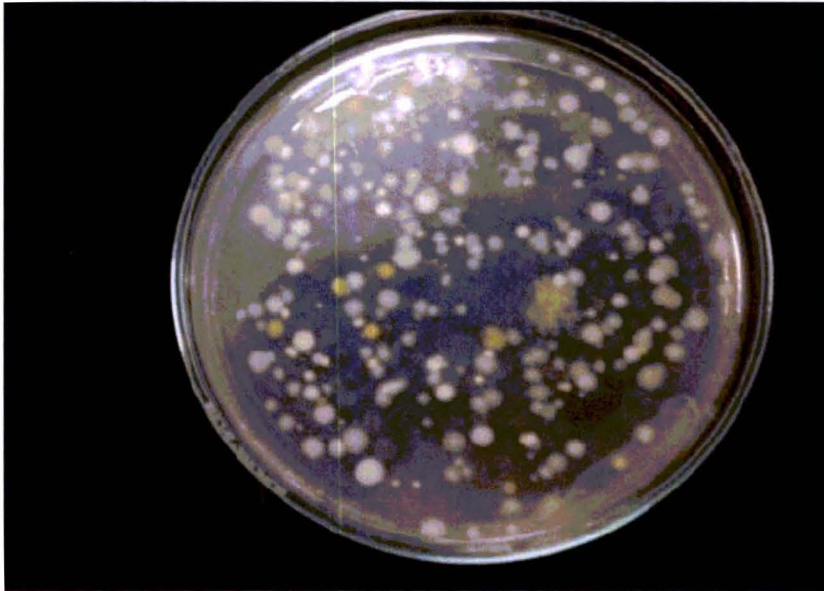


Fig.19: Temporal changes in the values of cellulose decomposing bacteria under different system employed.

Overall treatment difference ($F = 3.25$, $P < 0.05$) as well as differences between any combination of treatment means (LSD) remained significant ($P < 0.05$).



Cellulose decomposing bacterial colonies found in CMC agar plate



Total Aerobic Heterotrophic bacterial colonies found in nutrient agar plate

4.2. Soil quality

4.2.1. pH

The soil pH did not differ much among the treatments and ranged between (5.8 to 7.0) during the period of investigation.

4.2.2. Organic carbon

In general, an increasing trend in the values of organic carbon was observed in all the treatments and the overall mean value (1.56 mg g^{-1}) was highest in F and lowest in C (0.73 mg g^{-1}) (Fig.20).

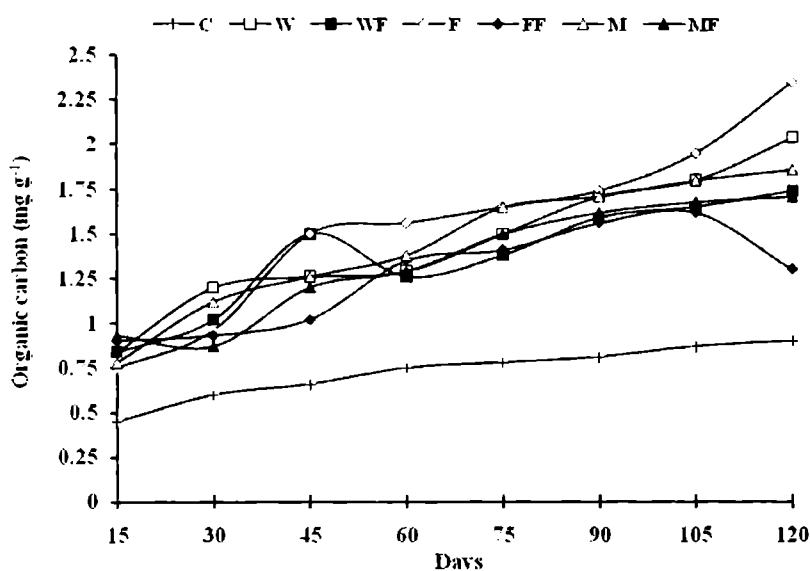


Fig.20: Temporal changes in the organic carbon of soil under different treatments employed.

The overall treatment difference exhibited high level significance ($F = 4.8436$; $P < 0.001$). However, treatment differences between every possible combination of treatments remained insignificant (LSD) ($P > 0.05$) in most of the dates of observation.

4.2.3. Available phosphorus

Though, an increasing trend was observed in all the treatments, the magnitude of increase was more pronounced after day 75 (**Fig.21**). The maximum mean value (1.90 mg g^{-1}) was observed in W followed by F (1.67 mg g^{-1}), M (1.57 mg g^{-1}), WF (1.40 mg g^{-1}), MF (1.29 mg g^{-1}), FF (1.28 mg g^{-1}), and C (0.51 mg g^{-1}).

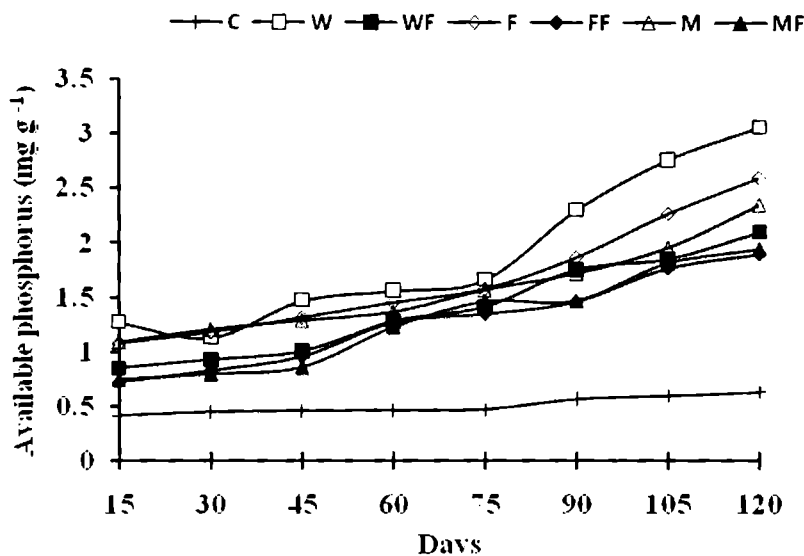


Fig.21: Temporal changes in the available phosphorus of soil under different treatments employed.

The overall treatment difference was significant ($F = 6.8118$; $P < 0.001$), but significance either between WF and FF, between WF and MF or between FF and MF remained insignificant ($P > 0.05$) in most cases (LSD).

4.3. Fish growth

4.3.1. Length of fish

As expected, length of any of the fish tended to increase over time (**Fig.22**) and the maximum length attained was in weekly manuring schedule (rohu- 16.5 cm, common carp-12.5 cm) and minimum in control (rohu- 10 cm, common carp- 8.4 cm).

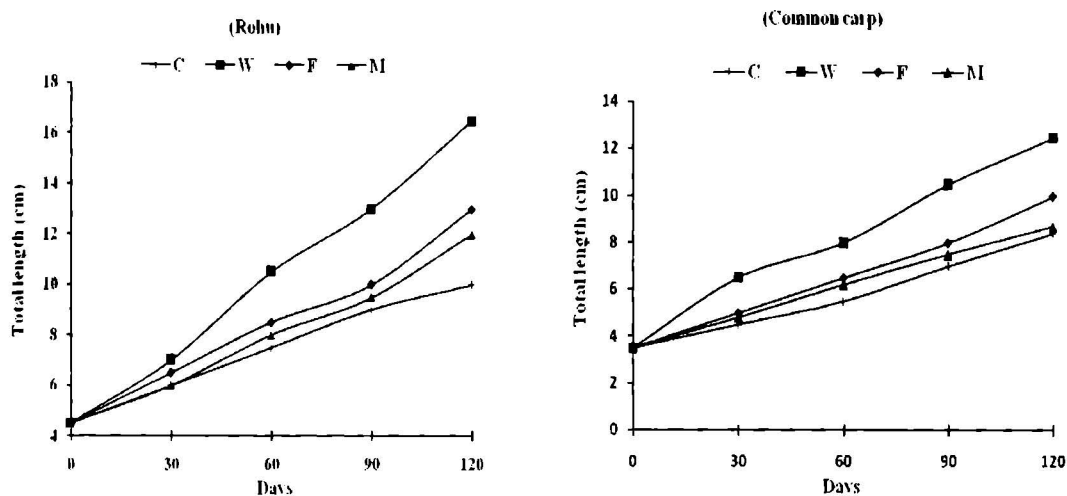


Fig. 22. Total length of the experimental fish (Rohu, Common carp) in different treatments employed.

4.3.2. Rohu (*Labeo rohita*)

4.3.2.1. Body weight

The body weight of rohu (*Labeo rohita*) tended to increase over time in any treatments; however, weekly manuring system exhibited maximum (35.5 g) growth followed by fortnightly (28.5g) and monthly (25.5g) application of manure. Such growth was minimum (13.65g) in control (Fig.23).

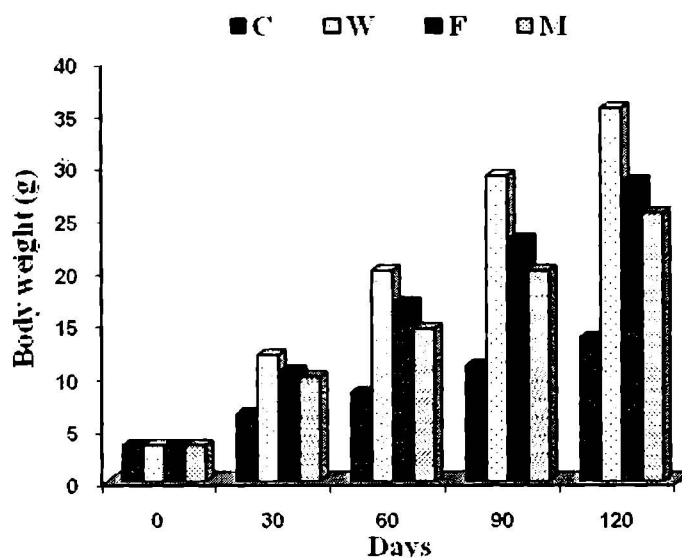


Fig.23: Temporal changes in the body weight of rohu (g) under different treatments employed.

4.3.2.2. Body weight gain

Temporal trend in the values of body weight gain of rohu (*Labeo rohita*) declined with time in any of manuring schedules (Fig.24). The mean value was highest (0.94g) in W followed by F (0.80g), M (0.70g), and C (0.425g).

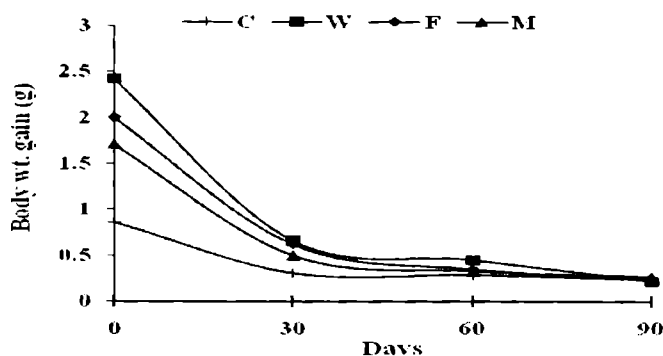


Fig.24: Temporal changes in the body weight gain (g) of rohu under different treatments employed.

4.3.2.3. Specific growth rate (SGR)

Likewise weight gain, specific growth rate declined gradually overtime in all the treatments. Again, the maximum rate was exhibited in W (1.93%) followed by F (1.74%), M (1.65%) and C (1.13%) (Fig.25).

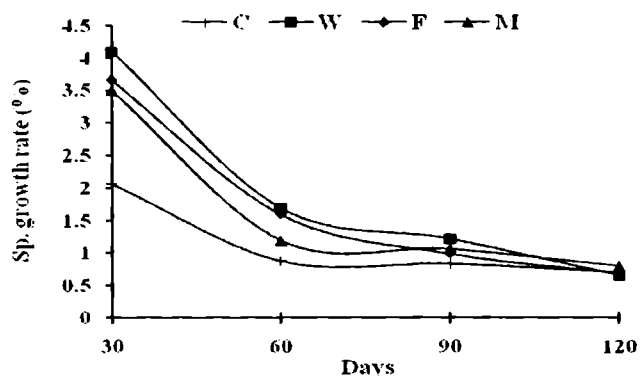


Fig.25: Temporal changes in the values of specific growth rate (%) of rohu under different treatments employed.

4.3.2.4. Net weight gain

Net weight gain of rohu in weekly application was maximum which was higher (91.42 %) than fortnightly (87.72 %) monthly (86.27 %) application of manure and control (74.35 %) (Fig. 26).

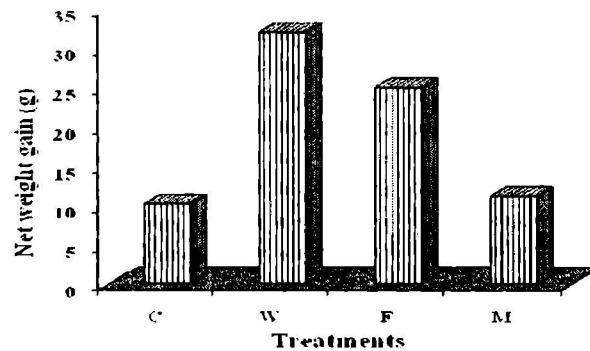


Fig.26: Temporal change in the values of net weight gain of rohu under different treatments employed.

4.3.3. Common carp (*Cyprinus carpio*)

4.3.3.1. Body weight

The body weight of common carp (*Cyprinus carpio*) tended to increase overtime in any treatments; however, weekly manuring system exhibited maximum (25.45g) growth all through followed by fortnightly (21.5g) and monthly (19.2g) application of manure. Such growth was minimum (12.5g) in control (Fig. 27).

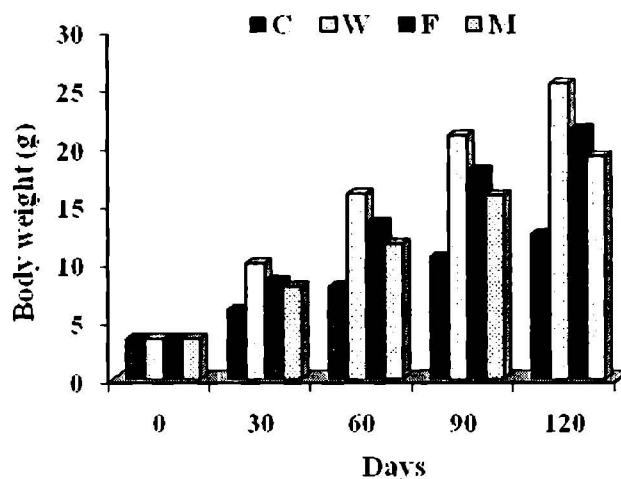


Fig. 27: Temporal changes in the body weight of common carp (g) under different treatments employed.

4.3.3.2. Body weight gain

Temporal trend in the values of body weight gain of common carp declined with time in any of manuring schedules (Fig. 28). The difference in body weight gain among the treatments was conspicuous upto day 60 after which it became insignificant. The mean value was highest (0.74g) in W followed by F (0.63g), M (0.58g), and C (0.38g).

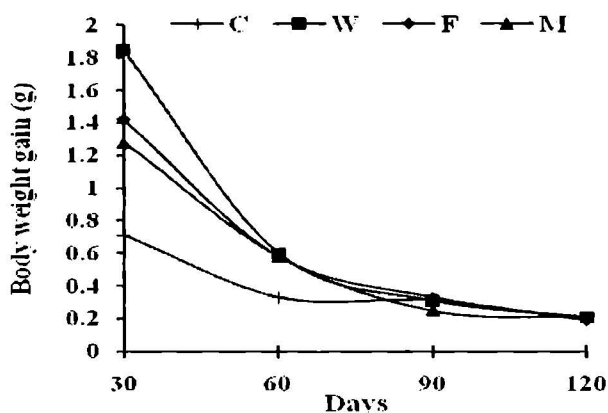


Fig.28: Temporal changes in the body weight gain (g) of common carp under different treatments employed.

4.3.3.3. Specific growth rate (S G R)

Likewise weight gain, specific growth rate of common carp declined gradually overtime in all the treatments. Again, the maximum rate was exhibited in W (1.65%) followed by F (1.51%), M (1.41%) and C (1.13%) (Fig.29).

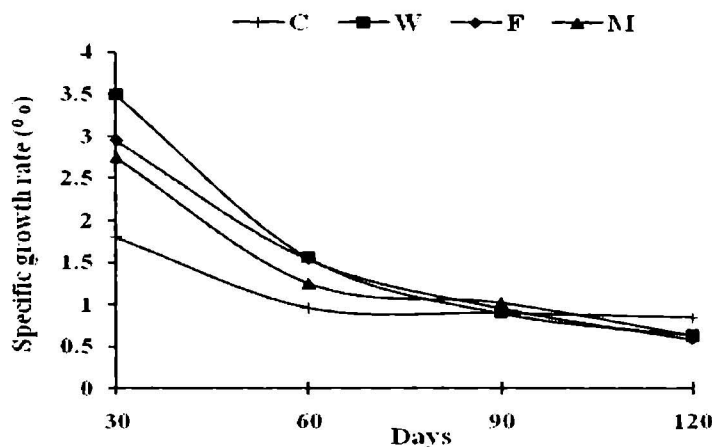


Fig.29: Temporal changes in the values of specific growth rate (%) of common carp under different treatments employed.

4.3.3.4. Net weight gain

Net weight gain in weekly application was maximum (Fig.30) which was higher (86.24 %) than fortnightly (83.72 %) monthly (81.77 %) application of manure and control (72 %).

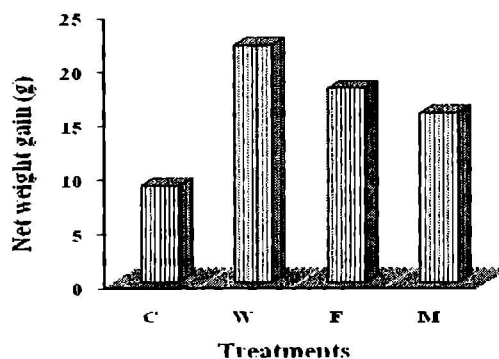


Fig. 30: Temporal change in the values of net weight gain of common carp under different treatments employed.

Chapter V

DISCUSSION

5. Discussion

The results of this study on varying manuring schedule with iso-nutrient input conditions in simulated fish culture systems conspicuously manifested upon the water quality variables as well as biological productivity. As loading of manure in bulk quantity at a time has a direct bearing firstly upon the dissolved oxygen profile (Boyd, 1982; Parker, 1986), the dissolved oxygen in the monthly manuring system with or without fish exhibited lowest value with corresponding higher values in splitted doses in fortnightly and weekly manuring systems. As there was grazing pressure upon the planktonic community and more respiratory demand in the treatments with fish, dissolved oxygen in the above systems was lower than their counterparts without fish any of the manuring schedule (Fig.2).

In contrast to dissolved oxygen, BOD values in all the treatments without fish exhibited higher values than their respective counterparts with fish (Fig.4). This is because of the higher respiratory demand of the larger population size of the planktons that has not been grazed upon in absence of fish.

Nutrient parameters of water like $\text{NH}_4\text{-N}$, $\text{NO}_2\text{-N}$ and $\text{PO}_4\text{-P}$ tended to increase over time in all the treatments. This is because of the more and more population build up of the heterotrophs (Fig.18 and Fig.19) responsible for mineralization. The role of heterotrophs in nutrient mineralization in organic matter decomposition is well documented (Jana and De, 1990; Jhingran, 1995; Cabello *et al.*, 2004). Boyd (1982) opined that organic loading leads to severe depletion of dissolved oxygen, high biological and chemical oxygen demand, and high ammonia levels. Moreover, nutrient levels in the treatments with fish exhibited conspicuously higher values irrespective of the manuring schedule. Bioturbation effect of the test fishes particularly common carp (*Cyprinus carpio*) might have played a crucial role in releasing nutrient from the bottom soil. Jana and Das (1992) conclusively demonstrated that bioturbation activity of the bottom dwelling fishes helps in releasing nutrients from the mud-water interface.

Because of comparatively steady supply of organic carbon with more frequencies in weekly manuring schedule, population of both total aerobic heterotrophic and cellulose decomposing bacteria remained always with higher densities rather than manuring in less frequencies with double and single times

loading in fortnightly and monthly applications. The overall relationship between organic carbon and total heterotrophic bacteria ($y = 60.21x^{1.536}$, $R^2 = 0.927$) and cellulose decomposing bacteria ($y = 36.878x^{1.716}$, $R^2 = 0.893$) in the present study was expressed highly positive correlated (**Fig.31 and Fig.32**). This corroborated the earlier views of Jana and De (1990) who stated that heterotrophic microorganisms, necessitating some organic sources of carbon in addition to inorganic forms for growth.

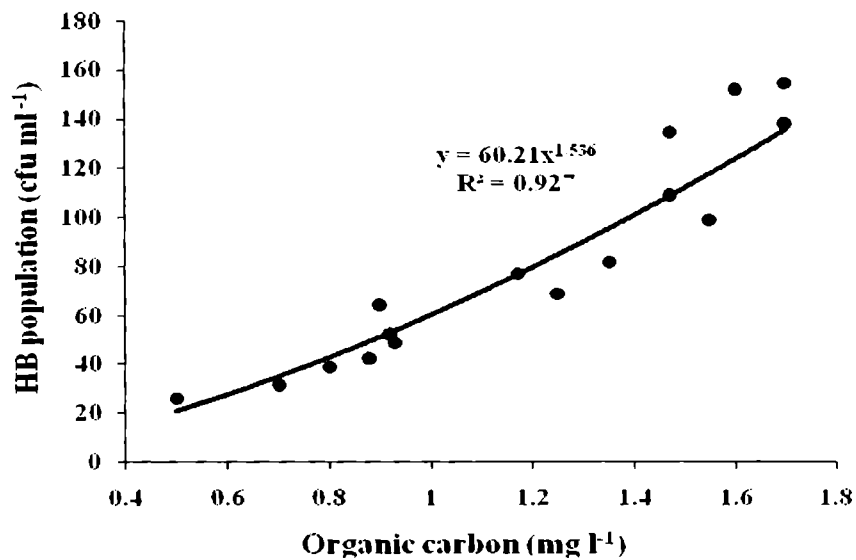


Fig.31. Relationship between organic carbon of water and total aerobic heterotrophic bacterial population

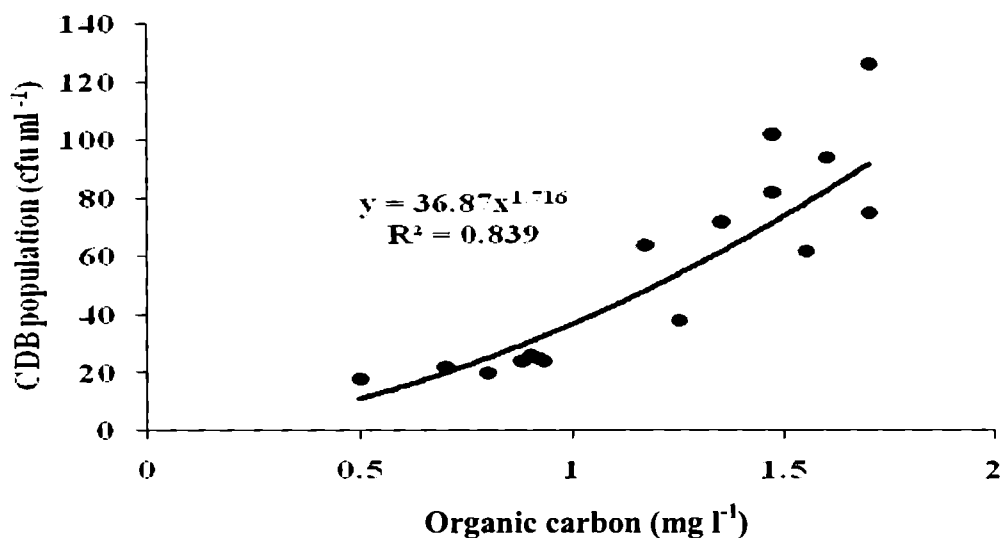


Fig.32. Relationship between organic carbon of water and cellulose decomposing bacterial population

Comparatively higher presence of heterotrophic bacterial population in weekly and fortnightly manuring systems perhaps resulted in more mineralization which resulted in consequently higher presence of nutrients in water. This is because the overall relationship between orthophosphate of water and total heterotrophic bacterial population (Fig.33) exhibited a direct relationship upto certain levels ($y = -676.47x^2 + 558.76x - 5.2119$; $R^2 = 0.4512$).

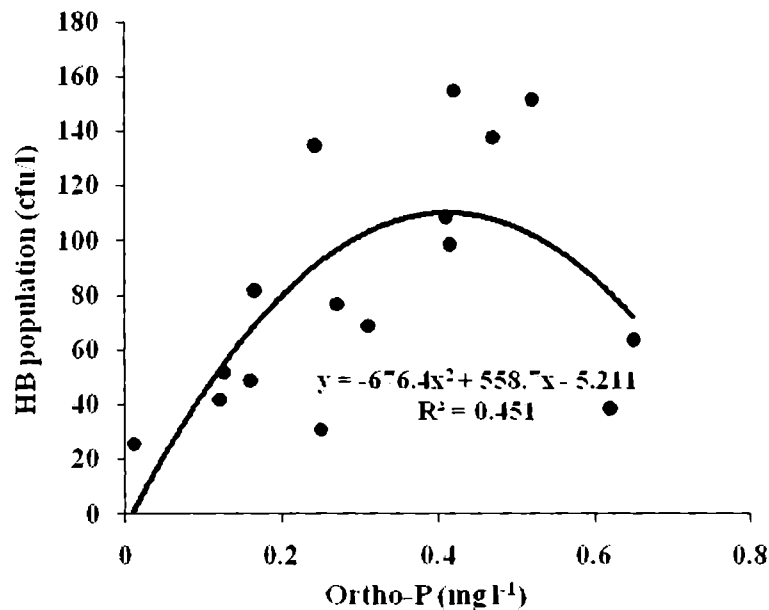


Fig.33. Relationship between orthophosphate of water and total heterotrophic bacterial population.

Weekly manuring systems exhibited higher presence of both phytoplankton and zooplankton as well than the other manuring schedules. This might be because of the more consistent levels of nutrients in the former. Again, higher presence of cladocerans in weekly manuring schedule by more than (8 – 18 %) than fortnightly and monthly manuring system might have contributed more in terms of fish yield. Wetzel, 1983; Kamanga and Kunda 1998; Jana and Chakrabarti 1993; have opined that cladocerans are the most group among the zooplanktons to the fish. The heterogeneity of the plankton populations (Fig.16; Fig.17) in the weekly manuring system indicated more sustainability of the system compared to fortnightly and monthly manuring treatments (Dash, 2001; Odum, 1971).

The maximum net weight gain of both the tested carps in weekly manuring system (Fig.26 and Fig.30) might have been contributed by the favourable water

quality in terms of both physico-chemical as well as biological parameters compared to the conventional monthly manuring system. Dissolved oxygen, organic carbon, available – P of bottom soil, plankton population, primary production as well as decomposing heterotrophic population in weekly manuring system remained higher by (1.48 -63.81%) in comparison to the monthly manuring treatment (Fig.34) which may directly favoured more growth of fish in the former.

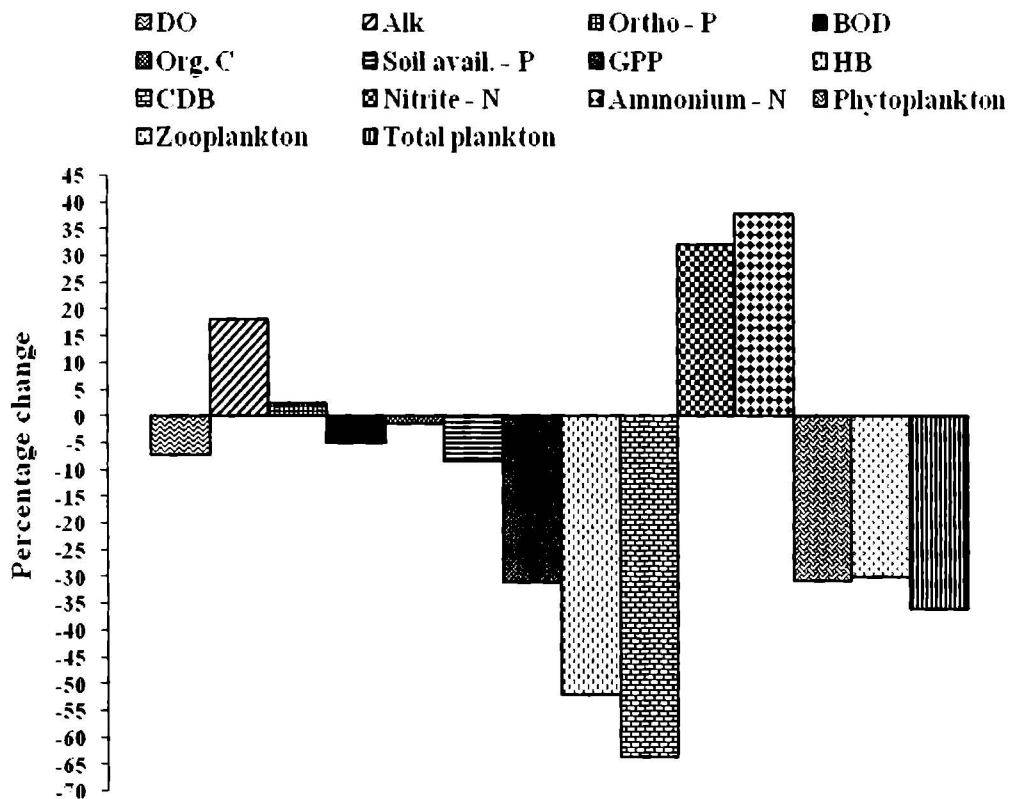


Fig.34: Change (%) of water quality variables in monthly manuring system compared to weekly manuring.

In contrast, the relatively less net gain attained in fortnightly manuring system might be because the more loading of manure at a time which have made the system marginally better in terms of water quality (0.65 – 33.16 %) than monthly manure application but inferior to weekly application of manure (Fig.35).

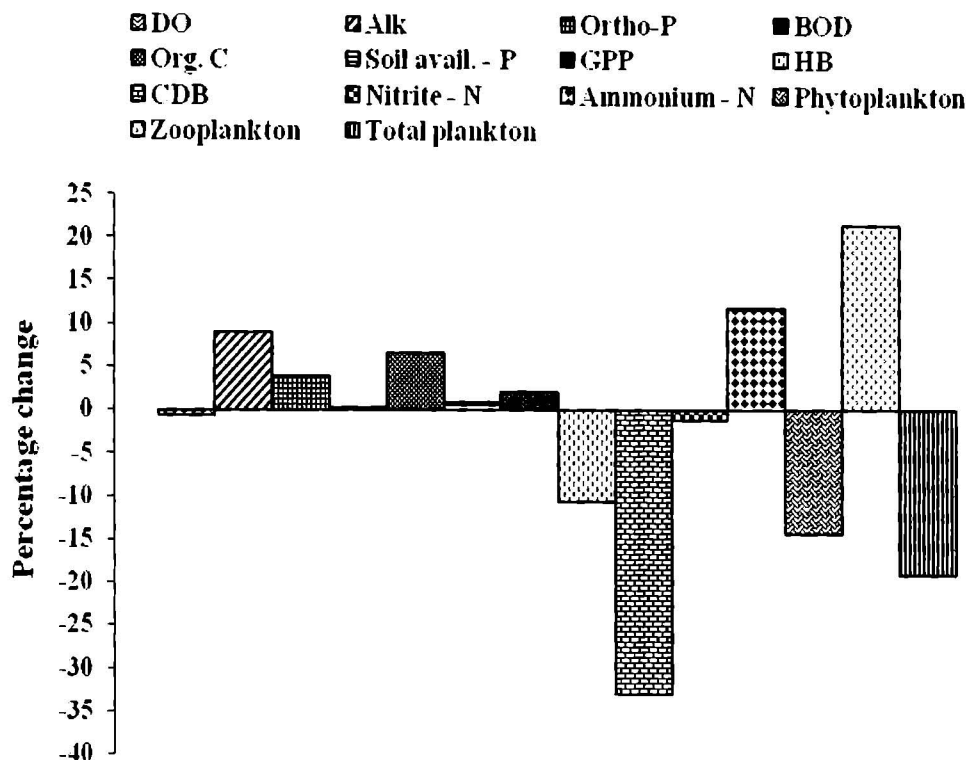


Fig.35: Change (%) of water quality variables in monthly manuring system compared to fortnightly manuring.

Again, the influence of these water quality parameters on growth and body weight of fish has been established in all the treatments irrespective of the variability in frequency of manuring in most cases (Table 7 and Table 8). The importance of physico-chemical and biological parameters like the above in determining the growth of fish has been well documented by several authors (Chakrabarti and Jana, 1991; Nath, Mandal, Tripathy and Karmakar, 1994).

Table 7. Correlation matrix among fish (*Rohu*) growth and selective physico chemical, biological and microbial parameters in different systems.

Control														
	Body wt.	Wt. gain	SGR	DO	Alkalinity	NH4-N	PO4-p	Soil org.C	Soil available	Phytoplankton	Zooplankton	Total plankton	BOD	GPP
Body wt		-.79 ^{ns}	-.8 ^a	.95 ^b	-.85 ^a	.95 ^b	.64 ^{ns}	.98 ^c	.96 ^b	.03 ^{ns}	.09 ^{ns}	.06 ^{ns}	.31 ^{ns}	.4 ^{ns}
Wt. gain			-.8 ^a	.89 ^a	-.86 ^a	.91 ^a	.94 ^b	.97 ^c	.97 ^c	-.3 ^{ns}	-.34 ^{ns}	-.49 ^{ns}	.83 ^a	-.19 ^{ns}
SGR				-.63 ^{ns}	.98 ^c	-.97 ^c	-.87 ^a	-.92 ^b	-.68 ^{ns}	-.13 ^{ns}	-.06 ^{ns}	-.01 ^{ns}	-.98 ^c	-.42 ^{ns}

Weekly														
	Body wt	Wt. gain	SGR	DO	Alkalinity	NH4-N	PO4-p	Soil org.C	Soil available P	Phytoplankton	Zooplankton	Total plankton	BOD	GPP
Body wt		-.88 ^a	.92 ^b	.78 ^{ns}	-.84 ^a	.979 ^c	.978 ^c	.995 ^c	.976 ^c	.736 ^{ns}	.53 ^{ns}	.51 ^{ns}	.97 ^c	.69 ^{ns}
Wt. gain			.99 ^c	-.74 ^{ns}	.979 ^c	-.92 ^b	-.97 ^c	-.88 ^a	-.86 ^a	-.62 ^{ns}	-.045 ^{ns}	-.57 ^{ns}	-.96 ^b	-.62 ^{ns}
SGR				-.8 ^a	-.96 ^b	-.95 ^b	-.99 ^c	-.92 ^b	-.9 ^a	-.59 ^{ns}	-.048 ^{ns}	-.048 ^{ns}	-.98 ^c	-.57 ^{ns}

a = level of significance 5%
 b = level of significance 1%
 c = level of significance .1%
 ns = non significant



Fortnightly														
	Body wt	Wt. gain	SGR	DO	Alkalinity	NH4-N	PO4-p	Soil org. C	Soil available P	Phytoplankton	Zooplankton	Total plankton	BOD	GPP
Body wt.		- .896 ^a	-.931 ^b	.966 ^b	-.876 ^a	.95 ^b	.88 ^a	.81 ^a	.977 ^c	.630 ^{ns}	.69 ^{ns}	.67 ^{ns}	.98 ^c	.98 ^c
Wt. gain			.99 ^c	-.98 ^c	.970 ^b	.68 ^{ns}	-.755 ^{ns}	-.89 ^a	-.89 ^a	-.89 ^a	-.56 ^{ns}	-.61 ^{ns}	-.89 ^a	-.95 ^b
SGR				-.99 ^c	.97 ^b	-.74 ^{ns}	-.79 ^{ns}	-.86 ^a	-.92 ^b	-.54 ^{ns}	-.57 ^{ns}	-.55 ^{ns}	-.92 ^b	-.97 ^b

Monthly														
	Body wt	Wt. gain	SGR	DO	Alkalinity	NH4-N	PO4-p	Soil org. C	Soil available P	Phytoplankton	Zooplankton	Total plankton	BOD	GPP
Body wt		-.83 ^a	-.82 ^a	.91 ^a	-.95 ^b	.97 ^b	.73 ^{ns}	.93 ^b	.96 ^b	.75 ^{ns}	.7 ^{ns}	.73 ^{ns}	.98 ^c	.86 ^a
Wt. gain			.99 ^c	-.5 ^{ns}	-.96 ^b	-.6 ^{ns}	-.92 ^b	-.93 ^b	-.85 ^a	-.78 ^{ns}	-.76 ^{ns}	-.077 ^{ns}	-.91 ^a	-.82 ^a
SGR				-.47 ^{ns}	.96 ^b	-.68 ^{ns}	-.91 ^a	-.92 ^b	-.85 ^a	-.74 ^{ns}	-.72 ^{ns}	-.73 ^{ns}	-.9 ^a	-.79 ^{ns}

a = level of significance 5%
 b = level of significance 1%
 c = level of significance .1%
 ns = non significant



Table 8. Correlation matrix among fish (*Common carp*) growth and selective physico chemical, biological and microbial parameters in different systems.

Control														
	Body wt	Wt. gain	SGR	DO	Alkalinity	NH4-N	PO4-p	Soil org. C	Soil available P	Phytoplankton	Zooplankton	Total plankton	BOD	GPP
Body wt		-0.89 ^a	-0.82 ^a	0.95 ^b	-0.86 ^a	0.96 ^b	0.64 ^{ns}	0.98 ^c	0.96 ^b	0.068 ^{ns}	0.132 ^{ns}	0.098 ^{ns}	0.34 ^{ns}	0.49 ^{ns}
Wt. gain			0.98 ^c	-0.69 ^{ns}	0.99 ^c	-0.99 ^c	-0.94 ^b	-0.96 ^b	-0.77 ^{ns}	0.01 ^{ns}	0.08 ^{ns}	0.05 ^{ns}	-0.97 ^b	0.01 ^{ns}
SGR				-0.64 ^{ns}	0.98 ^c	-0.97 ^b	-0.86 ^a	-0.91 ^b	-0.68 ^{ns}	-0.17 ^{ns}	-0.1 ^{ns}	-0.13 ^{ns}	-0.99 ^c	0.02 ^{ns}

Weekly														
	Body wt	Wt. gain	SGR	DO	Alkalinity	NH4-N	PO4-p	Soil org. C	Soil available P	Phytoplankton	Zooplankton	Total plankton	BOD	GPP
Body wt		-0.91 ^b	-0.94 ^b	0.85 ^a	-0.86 ^a	0.97 ^b	0.92 ^b	0.98 ^c	0.96 ^b	0.73 ^{ns}	0.53 ^{ns}	0.53 ^{ns}	0.98 ^c	0.69 ^{ns}
Wt. gain			0.99 ^c	-0.76 ^{ns}	0.96 ^b	-0.93 ^b	-0.99 ^c	-0.9 ^a	-0.88 ^a	-0.66 ^{ns}	-0.57 ^{ns}	-0.566 ^{ns}	-0.97 ^b	-0.65 ^{ns}
SGR				-0.81 ^a	0.94 ^b	-0.95 ^b	-0.99 ^c	-0.93 ^b	-0.91 ^b	-0.65 ^{ns}	-0.53 ^{ns}	-0.5 ^{ns}	-0.98 ^c	-0.63 ^{ns}

a = level of significance 5%
b = level of significance 1%
c = level of significance .1%
ns = non significant

Fortnightly														
	Body wt	Wt. gain	SGR	DO	Alkalinity	NH4-N	PO4-P	Soil org. C	Soil available P	Phytoplankton	Zooplankton	Total plankton	BOD	GPP
Body wt		-0.94 ^b	-0.97 ^b	0.97 ^b	-0.87 ^a	0.94 ^b	0.87 ^a	0.82 ^a	0.97 ^b	0.64 ^{ns}	0.71 ^{ns}	0.69 ^{ns}	0.98 ^c	0.99 ^c
Wt. gain			0.99 ^c	-0.99 ^c	0.98 ^c	-0.75 ^{ns}	-0.8 ^a	-0.86 ^a	-0.93 ^b	-0.52 ^{ns}	-0.56 ^{ns}	-0.54 ^{ns}	-0.93 ^b	-0.97 ^b
SGR				-0.98 ^c	0.97 ^b	-0.81 ^a	-0.84 ^a	-0.83 ^a	-0.95 ^b	-0.48 ^{ns}	-0.52 ^{ns}	-0.5 ^{ns}	-0.95 ^b	-0.99 ^c

Monthly														
	Body wt	Wt. gain	SGR	DO	Alkalinity	NH4-N	PO4-p	Soil org. C	Soil available P	Phytoplankton	Zooplankton	Total plankton	BOD	GPP
Body wt		-0.93 ^b	-0.91 ^a	0.899 ^a	-0.96 ^b	0.96 ^b	0.74 ^{ns}	0.94 ^b	0.96 ^b	0.78 ^{ns}	0.73 ^{ns}	0.76 ^{ns}	0.98 ^c	0.88 ^a
Wt. gain			0.98 ^c	-0.65 ^{ns}	0.98 ^c	-0.78 ^{ns}	-0.98 ^c	-0.98 ^c	-0.91 ^a	-0.79 ^{ns}	-0.78 ^{ns}	-0.78 ^{ns}	-0.95 ^b	-0.87 ^a
SGR				-0.58 ^{ns}	0.99 ^c	-0.78 ^{ns}	-0.94 ^b	-0.96 ^b	-0.92 ^b	-0.7 ^{ns}	-0.68 ^{ns}	-0.69 ^{ns}	-0.95 ^b	-0.78 ^{ns}

a = level of significance 5%
 b = level of significance 1%
 c = level of significance .1%
 ns = non significant



Chapter VI

SUMMARY

6. Summary

The present work embodied in this thesis entitled *Effects of Manuring Schedule on Water Quality and Biological Productivity* has been divided into eight chapters viz. introduction, review of literatures, materials and methods, results, discussion, conclusion and literatures cited. With regards to the objectives of this short term course bound study, the results clearly manifested several interesting findings. These are:

- i) As loading of manure in bulk quantity at a time has a direct bearing firstly upon the dissolved oxygen profile, the dissolved oxygen in the monthly manuring system with or without fish exhibited lowest value with corresponding higher values in splitted doses in fortnightly and weekly manuring systems.
- ii) As there was grazing pressure upon the planktonic community and more respiratory demand in the treatments with fish, phytoplankton population and dissolved oxygen in such treatments was comparatively lower than their counterparts without fish any of the manuring schedule
- iii) BOD values in all the treatments without fish exhibited higher values than their respective counterparts with fish because of the higher respiratory demand of the larger population size of the planktons that has not been grazed upon in absence of any effective grazer.
- iv) Nutrient parameters of water increased over time because of more and more population build up of the heterotrophs responsible for mineralization in any of the manuring schedule.
- v) Moreover, nutrient levels in the treatments with fish exhibited conspicuously higher values because of the bioturbation activity of the



test fishes particularly common carp (*Cyprinus carpio*). This has might have played a crucial role in releasing nutrient from the bottom soil.

- vi) Comparatively steady supply of organic carbon in weekly manuring schedule resulted in higher densities of both total aerobic heterotrophic and cellulose decomposing bacterial population in comparison to manuring in less frequencies viz. fortnightly and monthly applications. The overall relationship between organic carbon and total heterotrophic bacteria ($y = 60.21x^{1.536}$, $R^2 = 0.927$) and cellulose decomposing bacteria ($y = 36.878x^{1.716}$, $R^2 = 0.893$) in the present study was highly positive correlated.
- vii) Comparatively higher presence of heterotrophic bacterial population in weekly and fortnightly manuring systems might have resulted in more mineralization which effected in higher presence of nutrients in water. The overall relationship between orthophosphate of water and total heterotrophic bacterial population exhibited a direct relationship upto certain levels ($y = -676.47x^2 + 558.76x - 5.2119$; $R^2 = 0.4512$).
- viii) Weekly manuring resulted in higher presence of planktonic population. This might be because of the more consistent levels of nutrients in the former. Again, higher presence of Cladocerans in weekly manuring schedule by more than (8 – 18 %) than fortnightly and monthly manuring system might have contributed more in terms of fish yield.
- ix) The more heterogeneity of the plankton populations as expressed in Shannon diversity indices in weekly manuring system indicated more stability of the system compared to fortnightly and monthly manuring treatments.
- x) The maximum net weight gain of both the tested carps in weekly manuring system might have been contributed by the favourable water quality in terms of both physico-chemical as well as biological

parameters compared to the conventional monthly manuring system. Dissolved oxygen, organic carbon, available – P of bottom soil, plankton population, primary production as well as decomposing heterotrophic population in weekly manuring system remained higher by (1.48 -63.81%) in comparison to the monthly manuring treatment which may directly favoured more growth of fish in the former.

- xi) The influence of water quality parameters on growth and body weight of fish has been established in all the treatments irrespective of the variability in frequency of manuring in most cases.

Chapter VII

CONCLUSION

7. Conclusion

The findings of the present study warranted more detailed and long term study with regards to formulation of fish pond manuring schedule. As the present work is very short term and has been conducted in small simulated fish culture conditions, the study has some inherent limitations. Therefore, such studies must be replicated in actual pond culture systems in field conditions. Moreover, such studies with variable manure inputs from different husbandry sources and with varying compositions of cultivable fishes be conducted before coming to a definite conclusion. The present worker sincerely feels future research on this area should be directed with this views.



Chapter VIII

REFERENCES

8. Literatures Cited

- Ahmed, G. U., Hossin, M. A. R., Wahab, M. A. and Rahaman, K. M. A. 1997. Effect of fertilizers on soil and water quality parameters and growth of carp (*Labeo rohita* Hamilton) fry. *Prog. Agricul.* 8 (1and 2): 111-114.
- Ahmed, S. H. and A. K. Singh. 1989. Correlation between antibiotic factors of water and zooplantonic communities of a tank in Patna, Bihar, p 119-121. In *Proc. Nat. Sem. On Forty Years of Freshwater Aquaculture in India*, 7-9 November 1989, Central Institute of Freshwater Aquaculture, Bhubaneswar.
- Ajwa , H. A. and Tabatabai, M.A. 1994. Decomposition of different organic materials in soils. *Biol. Fertil. Soils* 18:175-182.
- Akand, M. A. 1986. Effect of inorganic fertilizers on water quality and fish production in carp ponds. *Bangladesh J. Fish.*, 9: 47-53.
- Amir Ullah, M. D. 1989. Nutrient release characteristics of duck manure for Nile Tilapia production. AIT Thesis no AE-89-43 M. S. Thesis, Asian Institute of Technology, Bangkok, Thailand.
- Anderson, J. M. 1987. Production and decomposition in aquatic ecosystem and implications for aquaculture. In *Detritus and Microbial Ecology in Aquaculture*, D. J. W. Moriarty and R. S. V. Pullin, eds., pp. 123-147. ICLARM Conference Proceedings 14, International Centre for Living Aquatic Resources Management, Manila, Phillipines.
- Anderson, J. M. and Ingram, J. S. I. 1993. Soil organic matter and organic carbon. J. M. Anderson and J. S. I. Ingram (Eds.), *Tropical soil biology and fertility*, CAB International, Wallingford: 62 – 66.
- Apun, K. 1995. Cellulose production. *Practical Biotechnology*. National centre for Biotechnology Education, Sarawak, Malaysia.
- AOAC (Association of Official Analytical Chemists). 1990. *Methods of Analysis*. 15th eds. AOAC, Washington. D. C, U. S. A.
- APHA (American Public Health Association). 1995. *Standard Methods for the Examination of Water and Wastewater*, 20th Edition. American Public Health Association, American Water Works Association, and Water Pollution Control Federation, Washington, 1040 pp.



- Arndt, H., Dietrich, D., Auer, B., Cleven, E. J., Grafenhan, T., Weitere, M., Mylnikov, A. P. 2000. Functional diversity of heterotrophic flagellates in aquatic ecosystems. In *The Flagellates*, Leadbeater, B. S. C., Green, J. C (eds). Taylor, and Francis: London; 240–268.
- Atay, D. and Demir, N. 1998. The effects of chicken manure on the phytoplankton primary production in carp ponds. *Acta Hydrobiologica*, 40: 215-225.
- Austin, B. 1990. *Methods in aquatic bacteriology*. John Wiley and Sons, New York, 425 pp.
- Azam, F., Fenchel, T., Field, J., Gray, J., Meyer-Reil, L. A., Thingstad, F. 1983. The ecological role of water-column microbes in the sea. *Marine Ecology Progress Series* 10: 257–263.
- Balasubramanian, P. R. and Bai, P. K. 1996. Studied the effect of bio gas plant as an organic fertilizer in monosex, monoculture of fish (*Oreochromis mossambicus*) Tamil Nadu, India. *Biosource Technol.*, 55: 119–24.
- Banerjee, R. K., Roy, P., Singit, G. S. and Dutta, B. R. 1979. Poultry droppings its manurial potentiality in aquaculture. *J. Inland Fish. Soc. India*. 11 (1): 94-108.
- Baotong, H., Tingting, W., Yingxue, F., Jiayi, D. and Xianzhen, G. 1983. Preliminary studies on the effects of three animal manure on the ecological conditions of pond water and fish growth. *Journal of Network of Aquaculture Centres in Asia*, Bangkok, Thailand. Vol. 9.
- Barat, S. and Jana, B. B. 1990. Density differences of heterotrophic bacteria of water between carnivorous catfish farming and polyculture system of herbivorous carps. In: Manna, G. K., Jana, B. B. (eds.), *Impacts of Environment on Animals and Aquaculture*. University of Kalyani, 207-214.
- Begum, M., Hossain, Y., Wahab, A., Faruque, Z., Ahmed, Alam, J., Shah, M. R. and Jasmine, S. 2007. Effects of iso nutrient fertilization on plankton production in earthen ponds of Bangladesh. *Pakistan Journal of Biological Sciences* 10 (8): 1221-1228.
- Beristain, B. T. 2005. Organic matter decomposition in simulated aquaculture ponds. Ph. D. thesis, Fish Culture and Fisheries Group, Department of Animal Science, Wageningen University, The Netherlands, 138 pp.

- Bhakta, J. N., Bandyopadhyay, P. K., Jana, B. B. 2006 Effect of Different Doses of Mixed Fertilizer on Some Biogeochemical Cycling Bacterial Population in Carp Culture Pond. *Turkish Journal of Fisheries and Aquatic Sciences* 6: 165-171.
- Bhanot, K., Basher, V.S., Bhattacharya, M., Ayyappan, S. and Panil, K.S. 1991. Composted domestic refuse as manure in carp ponds. *Proceedings of the National Symposium on New Horizons in Freshwater Aquaculture*, 23- 25 January 163- 165pp.
- Bhowmik, M. L., Sarkar, U. K., and Pandey, B. K. 1993. Plankton abundance and composition in sewage-fed fish ponds. *Inland Fish. Soc. India*. 25 (1): 23-29.
- Boyd, C. E. 1982. *Water quality management for pond fish culture*. Elsevier Science Publishers B. V., the Netherlands, 318pp.
- Boyd, C. E. 1990. *Water Quality for Ponds Aquaculture*. Alabama Agricultural Experiment Station, Auburn University, Auburn, A. L, U. S. A, 482 pp.
- Boyd, C. E. 1995. *Bottom Soils, Sediment, and Pond Aquaculture*. Chapman and Hall, New York, U. S. A, 348 pp.
- Boyd, C.E. 1995. Exchange of Dissolved Substances between Soil and Water. In: Boyd, C.E. (Ed.), *Bottom Soils, Sediment and Pond Aquaculture*. Chapman and Hall, New York, U. S. A, 348 pp.
- Brian, T. and Parker, D. 1991. "What Are Bacteria?" *World Book's Young Scientist*, 5, 128 pp.
- Broadbent, F. E., Jackman, R. H., McNicoll, J. 1964. Mineralization of carbon and nitrogen in some New Zealand allophanic soils. *Soil Sci.* 98:118 – 128.
- Bunnell, F. L., Tait, D. E. N., Flanagan, P. W. Van., Cleve, K. 1977. Microbial respiration and substrate weight loss. I. A. general model of the influence of abiotic variables. *Soil Biol, Biochem*, 9: 33-40.
- Buras, N., Duck, L., Niv. S. 1985. Reactions of fish to micro organisms in waste water. *Applied Environmental Microbiology*, 50: 989-995.
- Burnham, B. 2001. *The Whale Shark*.
- Buschiel, A. L. 1983. *Lehrehaus tropischer teichwirtschaft*, *Z. Fisch.*, 35: 181.

- Cabello, P., Roldán, M. D., Moreno-Vivián, C. 2004. Nitrate reduction and the nitrogen cycle in archaea. *Microbiology (Reading, Engl.)*150 (Pt 11): 3527–46.
- Carmichael, W., (ed.) 1981. *The water environment, Algal toxins and Health*. Plenum press, New York, N.Y.
- Chakrabarti, R. and Jana, B. B. 1998. Effects on growth and water quality of feeding exogenous plankton compared to use of manure in the culture of Mrigal, (*Cirrhinus mrigala*), and Rohu, (*Labeo rohita*) fry in tanks. *Journal of Applied Aquaculture*, 8: 87 – 95.
- Chattopadhyay, C. and Banerjee, T. C. 2007. Temporal changes in environmental characteristics and diversity of net-phytoplankton in a freshwater lake. *Turk. Bot.*, 31: 287 - 296.
- Chattopadhyay, G. N. and Mandal, L. N. 1980. Effect of different levels of water salinity on the decomposition of organic manures in a brackish water fish pond soil. *Hydrobiologia* 72: 287-292.
- Cheikyula, J. T., Ofojekwo, P. C. and Amali, E. I. 2001. Influence of varying manure concentrations on the productivity of *Moina* and *Cyclops* in duckweed (*Lemna minor*) culture. *Journal of Aquatic Sciences*, 16: 76-78.
- Chris, Whalen. 2010, *Lake Classification*. UWEX Extension and the Wisconsin Lakes Program.
- Clark, M. D., Gilmour, J.T. 1983. The effect of temperature on decomposition at optimum and saturated soil water contents. *Soil Sci. Soc. Am J*, 47:927-929.
- Clesceri, L. S., Green, A. E. and Eaton, A. D., (eds.) 1998. *Standard Methods for the Examination of Water and Wastewater*. 20th ed., Washington D.C., American Public Health Assoc., American Water Works Assoc., and Water Environment Fed., 2: 1-90, 4: 52-160, 10: 1-28.
- Colman, J. A. and Edwards, R. 1987. Feeding pathways and environmental constraints in waste-fed aquaculture: balance and optimization. In: *Detritus and Microbial Ecology in Aquaculture*. ICLARM Conference Proceeding, Vol.14 (ed. by D. J. W. Moriarty, and R. S. V. Pullin.), pp. 240-281. International Centre for Living Aquatic Resources Management, Bellagio.

- Coman, F. E., Connolly, R. M. and Preston, N. P. 2003. Zooplankton and epibenthic organisms in shrimp ponds: factors influencing assemblage dynamics. *Aqua. Res.*, 34: 359-371.
- Costa, H. H. and Keemibiahetty, C. N. 1993. An experimental study on the culture of fry of *Oreochromis mossambicus* in a peaty swamp in Sri Lanka, using cowdung as fertilizer. *Resources and Conservation*, 13: 247-54.
- Couteaux, M. M., Bottner, P., Berg, B. 1995. Litter decomposition climate and litter quality. *Trends Ecol. Evol.* 10: 63-66.
- Das, B. K. 2004. Bacterial diseases of fish and their control. In: Swain, P., Sahoo, P. K., Das, B. K. *Disease Diagnosis and Health Management of Freshwater Fish and Shellfish*. Bhubaneswar, Central Institute of Freshwater Aquaculture, 45-52.
- Das, S. K. and Jana, B. B. 1996. Pond fertilization through inorganic sources: An overview. *Indian Journal of Fisheries*, 43: 137-155.
- Das, S. K. and Jana, B. B. 2003. Pond Fertilization Regimen: State of the Art. *Journal of Applied Aquaculture* 13: 35- 66.
- Dash, M. C. 2001. *Fundamentals of ecology*. 2nd edition, published by TATAMC GRAW HALL, ISBN -0.07- 042147. 525pp.
- David, J. W. Moriarty., 10 December 1997. The role of microorganisms in aquaculture ponds. Elsevier Science B.V., the Netherlands.
- Debeljak, L. and Fasaic, K. 1985. Hydrochemical regime in common carp fingerling fish ponds under the conditions of organic and mineral fertilization. *Ekologia* 20: 37-46.
- Denny, M. W. 2008. *How the ocean works: an introduction to oceanography*, Princeton University press, pp 78-83
- Dhawan, A. and Kaur, S. 2002. Pig dung as pond manure: Effect on water quality, pond productivity and growth of carps in polyculture system. *Naga, The World Fish Centre Quarterly*, 25 (1): 11-14.
- Dhawan, A. and Toor, H. S. 1989. Impact of organic manures or supplementary diet on plankton production and growth and fecundity of Indian major carp, *Cirrhina mrigala* (Ham.), in fish ponds. *Biol. Wastes*, 29: 289- 297.

- Dickman, S. R. and Bray, R. H. 1940. Calorimetric determination of phosphorous. Ind. Eng. Chem. A. E., 12: 665- 668.
- Dinesh, K. R., Vargees, T. J. and Nandesha, M. C. 1986. Effects of a combination of poultry manure and varying doses of urea on growth and survival of cultured carps. In : J. L. Maclean, L. B. Dizon and L. V. Hosillos, (Eds.), Proceeding of First Asian Fisheries Forum. Asian Fish . Soc., Manila, Philippines. 565- 468pp.
- Doria, C. R. C. and Leonhardt, J. H. 1993. Analysis of growth of *Piaractus mesopotamicus* and *Clossoma macropomum* in semi-intensive polyculture with artificial feeding and organic fertilizer. Revista UNIMAR, 15: 211–22.
- Ducklow, H. W. 1991. The passage of carbon through microbial food webs: results from flow network models. Marine Microbial Food Webs 5:129–144.
- Dutta, O. K. and Goswami, P. K. 1988. J. Inland Fish Soc. 20 (1): 37-41.
- Edwards, P., H, Demaine., N. I. Taylor. and D, Turongruang. 1996. Sustainable aquaculture for small scale farmers: Need for a balanced model. Outlook on Agriculture 25 (1): 19-26.
- Edwards, P., Little, D. C. and Yakupitiyage, A. 1997. A comparison of traditional and modified artisanal aquaculture systems. Aquaculture Research 28: 777-788.
- Egna, S. and Boyd, C. E. 1997. Dynamics of pond Aquaculture. CRC press, Boca Raton, Florida.
- F. A. O. 1977. Freshwater fisheries and aquaculture in China. F. A. O Fish Tech. Paper No. 168: 84pp.
- Fang, Y., Guo, X., Wang, Y., Fang, X. and Z, Liu. 1986. Effect of different animal manures on the fish farming, proceedings of the First Asian Fisheries Forum, Manila, Philippines: 26-31 May 1986. 117-120 pp.
- Fatima, S., Ahmed, I., Kanwal, S. and Ateeq, U. 2003. Department of Zoology and Fisheries, University of Agriculture, Faisalabad–38040, Pakistan. Effect of Different Levels of Cow Dung on Growth Performance of Major Carps. International journal of agriculture & biology, 2: 194–195.

- Gaedke, U., Hochstadter, S., Straile, D. 2002. Interplay between energy limitation and nutritional deficiency: empirical data and food web models. *Ecological Monographs* 72: 251–270.
- Gannon, J. E. and Stemberger, R. S. 1978. Zooplankton (especially crustaceans and rotifers) as indicators of water quality. *Trans. Amer. Micros. Soc.*, 97: 1-16.
- Garg, S.K. and Bhatnagar, A. 2000. Effect of fertilization frequency on pond productivity and fish biomass in still water ponds stocked with *Cirrhinus mrigala* (Ham.). *Aquaculture Research*, 31: 404 – 414.
- Gaur, A.C., Dargan, K. S. and Neelakantan, K. S. 1995. Organic manure. Publication and Information Division. Indian Council of Agricultural Research, New Delhi. India. 159pp.
- Gosh, B. C., R. Gosh., B. N. Mitra. and M. K. Jana. 1994. Influence of organic and inorganic fertilizers on the growth and nutrition of rice and fish in a dual culture system. *Agric. Sci.*, 122: 41–5.
- Grag, S. K. and Bhatnagar, A. 1999. Effect of different doses of organic fertilizer (cowdung) on pond productivity and fish biomass in still water ponds. *J. Applied Ichthyology*, 15: 10-8.
- Green, B.W. and Boyd, C. E. 1995. Chemical budgets for organically fertilized fish ponds in dry tropics. *Journal of World Aquaculture Society* 26, 284-296.
- Gupta, M. V., Ahamed, M., Bimbao, A., and Lightfoot, C. 1992. Socioeconomic impact and farmers' assessment of Nile Tilapia *Oreochromis niloticus* culture in Bangladesh. International ICLARM Technical Report 35, Center for Living Aquatic Resources Management, Manila, Philippines.
- Gupta, M.V. and Noble, F. 2001. Integrated chicken fish farming. M. Halwart, J. Gonsalves and M. Prein (Eds.), *Integrated agriculture – aquaculture : A primer*, FAO Fisheries Technical Paper 407, FAO, Rome: 49 – 53.
- Hasan, M. S. 1990. Development of fertilization strategy for culture with nitrogen and phosphorus supplementation of cattle manure. Ph.D.Thesis, AIT, Bangkok, Thailand, pp: 183
- Hassan, M. 1989. Effect of cow-dung manure fertilization of fish pond on the growth performance of three major carps viz., *Catla catla*, *Labeo rohita* and

- Cinhina mrigala*. M. Phil. Thesis (Zoology and Fisheries) Univ. of Agri., Faisalabad (Pakistan). 91p.
- Hickling, C. F. 1962. Fish Culture. Faber and Faber, London. 295 pp.
- Hojovec, J. 1977. Health effects from waste utilization. In: Taiganides EP. Animal Wastes . London: Applied Science Publishers Limited, 105-109.
- Hora, S. L. and T.V. R. Pillay. 1962. Hand-book on Fish Culture in Indo-PacificRegion. FAO Fish Biol. (14): 204 p.
- Hossain, M. Y., Begum, M. Ahmed, Z. F., Hoque, M. A. M., Karim, A. and Wahab, M. A. 2006. A study of the effects of iso-phosphorus fertilizers on plankton production in fish ponds. South Paci. Study. 26: 101-110.
- Hossain, M.Y., Jasmine, S., Ibrahim, A. H. M., Ahmed, Z. F., Ohtomi, J., Fulanda, B., Begum, M., Mamun, A., El- Kady, M. A. H. and Wahab, M. A. 2007. A preliminary observation on water quality and plankton of an earthen fish pond in Bangladesh: Recommendations for future studies. Pak. J. Biol. Sci.
- Hossain, Y., Begum, M., Ahmed, Z. F., Hoque, A., Karim, A. and Wahab, A. 2006. A Study on the effects of iso phosphorus fertilization on plankton production in fish ponds. South Pacific Studies Vol. 26. No.2.
- Jackson, M. L. 1967. Soil Chemical Analysis, Prentice Hall of India Pvt. Ltd. New Delhi: 498 pp.
- Jacoby, C. A. and Greenwood, J. G. 1989. Emergent zooplankton in Moreton Bay, Queensland, Australia: seasonal, lunar and diel patterns in emergence and distribution with respect to substrata. Marine Ecology Progress Series, 51:131-154.
- Jana, B. B. and Chakrabarti, L. 1997. Effect of manuring rate on in situ production of zooplankton, *Daphnia carinata*. Aquaculture, 156: 85-99.
- Jana, B. B. and Chakrabarti, R. 1993. Life table responses of zooplankton (*Moina micrura* Kurz and *Daphnia carinata* King) to manure application in a culture system. Aquaculture, 156: 85-99.
- Jana, B. B. and Das, S. K. 1992. The fertilizer value of phosphate rock in carp culture. Bamidgeh 44 (1): 13-23.

- Jana, B. B. and De, U. K. 1993. Management induced variability of the bacterioplankton in fish farming ponds. *Journal of Aquaculture in the Tropics*, 8: 131-140.
- Jana, B. B. and Patel, G. N. 1984. Spatial and seasonal variations of phosphate solubilizing bacteria in fish ponds of varying fish farming managements. *Archives für Hydrobiologie*, 10: 555-568.
- Jana, B. B. and Patel, G. N. 1985. Distribution pattern denitrifying bacteria in fish ponds of differing farming managements. *Archives für Hydrobiologie*, 103: 291-303.
- Jana, B. B. and Patel, G. N. 1990. Pattern and magnitude of nitrate reduction in fish ponds differing in management practices. *Aquacultura Hungarica (Szarvas)*, 6: 53-63.
- Jana, B. B. and Roy, S. K. 1986. Seasonal and spatial distribution pattern of nitrogen fixing bacteria in fish ponds under different management systems. *Hydrobiologia*, 137: 45-54.
- Jana, B. B. and Roy, S. K. 1985. Distribution patterns of protein mineralizing and ammonifying bacterial populations in fish-farming ponds under different management systems. *Aquaculture*, 44: 57-65.
- Jana, B. B., Chakrabarti, P., Biswas, J. K. and Ganguly, S. 2001. Biogeochemical cycling bacteria as indices of pond fertilization: Importance of C: N: P ratios of input fertilizers. *Journal of Applied Microbiology*, 90: 733-740.
- Jana, B. B., De, U. K. 1990. Spatial and seasonal distribution of heterotrophic bacteria in pond water and sediments under different management practices. *International Revue der Gesamten Hydrobiologie*, 75: 639-648.
- Javed, M., Hassan, M. and Sial, M. B. 1992. Fish pond fertilization. Effect of cow dung on the growth performance of major carps. *Pakistan J. Agri. Sci.* 29: 111-5.
- Javed, M., Sial, M. B. and Zafar, S. A. 1990. Fish pond fertilization, influence of broiler manure fertilization on the growth performance of major carps. *Pakistan J. Agri. Sci.* 27: 212-215.
- Jeremiah, K., Joseph, A. B. and Laura, C. H. 2006. Effect of using different types of organic animal manure on plankton abundance, and on growth and

- survival of *Tilapia rendalli* (Boulenger) in ponds. *Aquaculture Research*, 37, 136- 137.
- Jha, P., Barat, S., Chitta, R., Nayak. 2008. Fish Production, Water Quality and Bacteriological Parameters of Koi Carp Ponds Under Live-food and Manure Based Management Regimes. *Zoological Research*, 29(2):165-173.
- Jha, P., Barat, S., Lepcha, R. F. 2003. A comparative study of limnochemistry and primary productivity of some fish ponds in the northern districts of West Bengal, India. *Ecology, Environment and Conservation*, 9: 135-140.
- Jha, P., Barat, S., Nayak, C. R. 2006. A comparison of growth, survival rate and number of marketable koi carp produced under different management regimes in earthen ponds and concrete tanks. *Aquaculture International*, 14: 615-626.
- Jha, P., Barat, S., Sarkar, K. 2007. Comparative effect of live-food and manured treatments on water quality and production of ornamental carp, *Cyprinus carpio* var. *koi* L., during winter, summer, monsoon and post monsoon grow out experiments in concrete tanks. *Journal of Applied Ichthyology*, 23: 87-92.
- Jha, P., Sarkar, K., Barat, S. 2004. Effect of Different Application Rates of Cowdung and Poultry Excreta on water quality and growth of ornamental carp, *Cyprinus carpio* vr. *Koi*, in concrete tanks. *Turkish Journal of Fisheries and Aquatic Sciences* 4: 17-22.
- Jhingran, V. G. 1995. *Fish and Fisheries of India*. Hindustan Publishing Corporation New Delhi, India.
- Jinyi, D., Xianzhen, G., Xiuzhen, F., Meizhen, L. 1987. Preliminary studies on the effects of animal manure on bacterial disease of fish. NACA Working Paper No. 49. Bangkok: Network of Aquaculture Centres in Asia-Pacific.
- Jinyi, D., Xianzhen, G., Xiuzhen, F., Meizhen, L., Zhang, W. 1988. Preliminary studies on the effect of live stock manure application on bacterial fish disease and human hygiene. NACA Working Paper No. 69. Bangkok: Network of Aquaculture Centres in Asia-Pacific.
- Kamanga, L. and Kunda, F. 1998. The effect of different types of manure on zooplankton abundance and composition in relation to culture of

- Oreochromis shiranus* (L), In: First Regional Workshop on Aquaculture, Proceedings of the First Workshop on Aquaculture, held at Bunda College of Agriculture, Lilongwe, Malawi, 17-19 November 1997 (ed. by J. S. Likongwe, and E. Kaunda), and pp.45-56. University of Malawi, Lilongwe.
- Kestemont, P. 1995 *Aquaculture*, 129: 347-372.
- Knud- Hansen C.F. (1998). Pond Fertilization: Ecological Approach and Practical Application. Pond dynamics/Aquaculture Collaborative Research Support Program, Oregon State University, Carvallis, or U. S. A. 125pp.
- Knud- Hansen, C. F., Batterson, T. R. and McNabb, C. D., Harahat, I. S., Sumantadinata, K. and Eidman, H. M. 1991. Nitrogen input, primary productivity and fish yield in fertilized freshwater ponds in Indonesia. *Aquaculture*, 94:49-63.
- Knud- Hansen, C. F., Batterson, T. R. and McNabb, C.D. 1993. The role of chicken manure in production of Nile Tilapia, *Oreochromis niloticus*, *Aquaculture and Fisheries Management* 24, 483-493.
- Kowalenko, C. G., Ivarson, K. C., Cameron, D. R. 1978. Effect of moisture content, temperature, and nitrogen fertilization on carbon dioxide evolution from field soils. *Soil Biol. Biochem*, 10:417-423.
- Larson, B. 1994. The overviews on environment and aquaculture in the tropics and sub tropics. ALCOM Field Document No. 27, Food and Agriculture Organization of the United Nations, Rome, Italy.
- Lin, C.K., Green, D. R., B. W. and Veverica, K. L. 1997. Fertilization regimes. H. S. Egna, and C. E. Boyd (Eds.), *Dynamics of pond Aquaculture*, C. R. C Pres, New York: 73-107.
- Little, D. and Muir, J. 1987. A guide to integrated warm water aquaculture. Institute of Aquaculture, Stirling, Scotland, 238 pp.
- Mahboob, S. and Sheri, A.N. 1997. Growth performance of major carps and some Chinese carps under composite culture system with special reference to pond fertilization. *J. Aquaculture in Tropics*, 12: 201-7.
- Majumdar, S., Biswas, S., Barat, S. 2002. Abundance of ammonifying and heterotrophic bacterial populations in the water manured with cowdung and

- distillery sludge in outdoor model tanks. *Asian Journal of Microbiology, Biotechnology and Environmental Science*, 4: 229-233.
- Martyshev, F. G. 1983. *Pond Fisheries*. A. A. Balkema, Rotterdam, the Netherlands.
- Mei, Z., Shi, Z., Zhu, X. 1995. The studies on the nutritional content and the release of the fish pond mud. In: Zhu, X., Shi, Z. *The Studies of the Ecosystem in the Chinese Fish Ponds*. Sanghai: Sanghai Science and Technology Press, 29-36.
- Milstein, A., Alkon, A., Avnimelech, Y., Kochba, M., Hulata, G., Schroeder, G. 1991. Effects of manuring rate on ecology and fish performance in polyculture ponds. *Aquaculture* 96, 119-138.
- Milstein, A., Svirsky, F. 1996. Effect of fish species combinations on water chemistry and plankton composition in earthen fish ponds. *Aquaculture Res.* 27, 79-90.
- Milstein, A., Wahab, M.A., Rahman, M. M. 2002. The effect of common carp, *Cyprinus carpio* (L.) and mrigal, *Cirrhinus mrigala* (Hamilton) as bottom feeders in major Indian carp polycultures. *Aquacult. Res.* 33, 547-556.
- Moav, R., Wohlfarth, G.W., Schroeder, G.L., Hulata, G. and Barash, H. 1977. Intensive polyculture of fish in fresh water ponds. I. Substitution of expensive feeds by liquid cow manure. *Aquaculture*, 10: 25-43.
- Moriarty, D. J. W. 1987. Methodology for determining biomass and productivity of microorganisms in detrital food webs. In: Moriarty, D. J. W., Pullin, R. S. V. *Detritus and Microbial Ecology in Aquaculture*. Manila: International Centre for Living Aquatic Resources Management, 4-31.
- Msiska, O.V., 1988. Preliminary studies on the performance of *Oreochromis shiranus chilwae* in pond with respect to water quality and temperature. In: *The Second International Symposium on Tilapia in Aquaculture*. ICLARM.
- Muck, R. E. and Stunhuis, T. S. 1982. Nitrogen losses from manure storage. *Agricultural waste*, 4:41-54

- Natarajan, A. V. and Pathak, V. 1983. Pattern of energy flow in freshwater tropical and sub tropical impoundments. CIFRI, ICAR, Bull No- 36, Barrackpore, West Bengal, 1-27.
- Nath, D., Mandal, L. N., Tripathi, S. D., Karmakar, H. C. 1994. Correlation between fish production and physico-chemical parameters of water and soil in semi-intensive carp culture ponds of West Bengal, India. *Journal of the Inland Fisheries Society of India*, 26: 106-115.
- Nath, S. S. and Lannan, J. E. 1993. Dry matter nutrient relationships in manures and factors affecting nutrient availability from poultry manures. In: Egna, H, Mc Namara, M., Bouman, J. and Astin, N. (Editors), Tenth Annual Admin. Report, 1991-1992. PD/A CRSP, office of International research and development, Oregon State University, Carvallis, Oregon, pp, 110-119
- Nayak, P. K. and Mondal, B. K. 1990. Effect of cattle manure and supplementary feeding on water quality, growth and production of common carp in paddy-cum-fish culture. *J. Aqua. Trop.* 5 (2):117-122.
- Nyaggard, G. 1949, Danske, K., Vidensk, S. Biol. Skr. 7: 293 pp.
- Odum, E. P. 1971. *Fundamentals of Ecology*, 3rd edition, W. B. Saunders Company, Philadelphia, pp. 574.
- Olah, J. 1986. Carp production in manured ponds. pp. 293-303 In: R. Billard. and J. Marcel, eds. *Aquaculture of Cyprinids*, INRA, and Paris, France.
- Olah, J., Sinha, V. R. P., Ayyappan, S., Purushothaman, C. S. and Radheyshyam, S. 1986. Primary production and fish yields in fish ponds under different management practices. *Aquaculture*, 58: 111-122.
- Olsen, S. 1958. Phosphate absorption and isotopic index in lake muds. Experiment with P³²; Preliminary report. *Verhandlungen International Vereinigung Limnologie* 13: 915-922.
- Ovie, S. I. and Adepoju, F. 1995. Comparative growth of post larvae of *Clarias anguillaris* reared on Artemia, live and frozen zooplankton. *NIFFR Ann. Report*, pp: 51-56.
- Park, C. C. 2001. *The environment: principles and applications*. 660 pp.
- Parker, N. C. 1986. Stress and its implications in cultured fishes. In: Grimaldi, E., Rosenthal, H. *Trends and Problems in aquaculture development proceedings*

- of the second international conference on aqua farming. *Aquaculture* 84.
Verona: Fieredi Verona, 167-177.
- Patra, B. C. and Ray. A. K. 1988. *J. Inland Fish Soc.* 20(2): 61-63.
- Paul, E. A. and Clark, F. E. 1996. *Soil microbiology and biochemistry*. Academic press, San Diego.
- Peker, F. and Olah, J. 1990. Organic fertilization. In: R. Berka. and V. Hilge (eds.).
Proceeding of FAO- EI FAC symposium on productionenhancement in still
water pond culture, Prague, Czechoslovakia. pp. 116- 122.
- Persson, T., Baath, E., Clarholm, M., Lundkvist, H., Soderstrom, B. and Sohlenius,
B. 1980. Trophic structure, biomass dynamics and carbon metabolism of soil
organisms in Scots pine forest. *Ecological Bulletin*, 32: 419-462.
- Polprasert, C. 1996. *Organic Waste Recycling*. John Wiley and Sons, Chichester,
England.
- Pullin, R. S. V. and Z. H. Shehadeh. 1980. *In-tegrated Agriculture-Aquaculture
Farming System*, pp. 258. Manila, Philippines.
- Quines, O. D. 1988. Microorganisms: indicator of pollution in integrated
livestock-fish farming systems. *Environmental International*, 14: 531-534.
- Rappaport, U., Saring, S. and Y, Bejerano. 1977. Observations on the use
oforganic fertilizers in intensive fish farming at the Genoser station in
1976. *Bamidgeh*, 29: 57-70.
- Rath, R. K. 1993. *Freshwater Aquaculture*. 2nd Edition, Scientific Publishers,
India.
- Robert E. R., Miller, G. and Freeman, W. H. 2000. *Ecology*" Fourth edition.
- Robert, G. Wetzel. 1983. *Limnology*, 2nd Edition, Saunders college publishing.
- Rodina, A. G. 1972. *Methods in Aquatic Microbiology*. In: R. R. Colwell and M.
S. Zambruski, (Eds.) University Park Press. Baltimore, Butterwarths,
London: 461.
- Rosy, M. A. 1993. Comparison of cow and chicken manure on the production of
plankton and fish growth. M. Sc. Thesis. Department of Aquaculture and
Management, Faculty of Fisheries, Bangladesh Agricultural University,
Mymensingh, Bangladesh. 65 pp.

- Saha, K. C. S., Gupta, J. C. and Bhattacharya, A. N. 1980. Limiting factors controlling the production of Indian major carps fry in nursery ponds. Seminar on production of quality fish seed for fish culture. ICAR, 1-2.
- Sanders, R. 1991. Trophic strategies among heterotrophic flagellates. In *The Biology of Free-living Heterotrophic Flagellates*, Patterson, D. J., Larsen, J. (eds). Oxford; 21–38.
- Santosh, C. A. L. 1994. Prevention and control of food borne trematode infections in cultured fish. Food and Agricultural Organization, Aquaculture News letter 8: 11-15.
- Sayyappan, 2006. Handbook of Fisheries and Aquaculture. Indian Council of Agricultural Research, New Delhi.
- Schroeder, G. L. 1974. Use of fluid cowshed manure in fish ponds. *Bamidgeh*, 26(1): 84-96.
- Schroeder, G. L. 1987. Carbon pathways in aquatic detrital systems. In: Moriarty, D. J. W., Pullin, R. S. V., *Detritus and Microbial Ecology in Aquaculture*. Manila: International Centre for Living Aquatic Resources Management, 217-236.
- Sevilleja, R., Torres, J., Sollows, J. and Little, D. 2001. Using animal wastes in fish ponds. M, Halwart., J, Gonsalves. and M, Prein., (Eds.), *Integrated agriculture – aquaculture: A primer*, FAO Fisheries Technical Paper 407, FAO, Rome: 49-53.
- Shandhu, J. S., Toor, H. S. and Seghal, H. S. 1985. Zooplankton community in manured fish tanks. *Ann. Biol.*, 1: 94- 97.
- Sherr, E. B, Sherr, B. F. 1994. Bacterivory and herbivory: key roles of phagotrophic protists in pelagic food webs. *Microbial Ecology* 28: 223–235.
- Shumaila, Kanwal., Iftikhar, Ahmed., Muhammad, Afzal., Fatima, Sughra. and Khalid, Abbas. 2003. Comparison of Fresh and Dry Cowdung Manuring on Growth Performance of Major Carps. *International Journal of Agriculture & Biology*, 3–313–315.
- Singh, A. K. 1996. Investigation on the effect of pig manure on growth and survivability of Indian major carps and

- Singh, V. K. and Sharma, A. P. 1999. Comparative effect of three organic manures viz. cowdung, pigdung and poultry excreta on the growth of *Labeo rohita* (Ham.). Journal of the Inland Fisheries Society of India, 31: 1 – 5.
- Sirikhae, Pongswat., Sompong, Thammathaworn., Yuwadee, Peerapornpisal., Nathawut, Thanee. and Charuwan, Somsiri. 2004. Diversity of phytoplankton in the lake Rama IX Lake, a manmade lake, Pathumthani Province, Thailand. Science Asia. 30: 261-267.
- Sood, V. 1984. Studies on fecundity of exotic fish (*Cyprinus carpio*) in relation to feeding and ecological niches. M. Sc. Thesis, PAU, Ludhiana, India.
- Spokes, L. 2003. Seasonal cycle of phytoplankton growth. Environmental Sciences, University of East Anglia, Norwich - U.K.
- Steinberg, D. K., Markhaseva, E., Cope, J. S., Wilson, S. E., Madin, L. P. 2003. Diel, seasonal, and interannual patterns in zooplankton species composition in the subtropical Atlantic: A census of marine life. American Society of Limnology and Oceanography Aquatic Sciences.
- Stone, L., Berman, T., Bonner, R., Barry, S., Weeks, S. W. 1993. Lake Kinneret: a seasonal model for carbon flow through the pelagic biota. Limnology and Oceanography 38: 1680–1695.
- Sugita, H., Fushino, T., Oshima, K., Deguchi, Y. 1985. Microflora in the water and sediment of freshwater culture ponds. Bulletin of the Japanese Society for Scientific Fisheries, 51: 91-97.
- Swift, D. R. 1993. Aquaculture Training Manual, 2nd edn. Fishing News Books, GardenWalk Farnham, Surrey, U. K, 158 pp.
- Swift, M. J., Heal, O. W., Anderson, J. M. 1979, Decomposition in terrestrial ecosystem. University of California Press, Los Angeles, USA, 125pp.
- Varghese, T. J. and Shankar, K. M. 1981. A Review of Fertilization Experiments Conducted at the College of Fisheries, Mangalore. Proceedings of the seminar on some aspects of inland aquaculture in Karnataka. University of Agricultural Science, pp: 67-76.
- Velecha, V. and Bhatnagar, G. P. 1988. Seasonal changes of phytoplankton in relation to some physico-chemical factors in lower lake Bhopal. Geobios, 15, 170-173.

- Villacorta, L. G. 1989. Comparison of constant and Variable Loading Rates of Organic manure in Fish Culture. Master's Thesis, Asian Institute of Technology, Bangkok, Thailand.
- Visser, S. 1985; Role of the soil invertebrates in determining the composition of soil microbial communities. In: Fitter Alt (ed.) Ecological interactions in soil. Black well, Boston, pp 297- 317.
- Vitousek, P. M., Turner, D. R., Parton, W. J., Sandford, R. L. 1994. Litter decomposition on the Mauna Loa environmental matrix, Hawaii: patterns, mechanisms and models. Ecology 75: 418-429.
- Vollenweider, R. A. 1974. A manual on the methods of measuring primary production in aquatic environment. IBP handbook No. 12, 2nd Ed. Blackwell Scientific Publications, Oxford, London, : 225 pp.
- Walkley, A., and Black, I. A. 1934. An examination of the Degreffe method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci., 37: 29-38.
- Wienberg, G. G. 1963. Primary production of water bodies, U. S. Atom. Energy Comm. Div. Tech. Info. ABC- Tr: 5692 pp.
- Wohlfarth, G.W. and Hulata, G. (1987) Use of manure in Aquaculture. In: Detritus and Microbial Ecology in Aquaculture.
- Wohlfarth, G. W., Schroeder, G. L. 1979. Use of manure in fish farming- A review. Agricultural Wastes 1: 279.
- Yadav, N. K. and Garg, S. K. 1992. Relative efficiency of different doses of organic fertilizer and supplement feed utilization under intensive fish farming. Bioresource Tech., 42: 61-5.
- Zhu. G., Peng. Y., Li. B., Guo. J., Yang. Q., Wang. S. (2008). Biological removal of nitrogen from wastewater. Rev Environ Contam Toxicol 192: 159-95.
- Zoccarato, I., Benatti, G., Calli, S. L. and Bianchini, M. L. 1995. Aquaculture. 129: 387-390.