

**STUDIES ON THE ECOLOGICAL ASPECTS
AND THE MICROBIAL ACTIVITY OF
RICE-FISH ROTATIONAL FARMING SYSTEM
IN THE WETLANDS OF KUTTANAD,
KERALA**

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Chapter 1

INTRODUCTION

Aquaculture is one of the world's fastest-growing food producing sectors, providing an important supplement to and substitute for stagnating yields from wild fish stocks. The importance of aquaculture for future food security was acknowledged by the 1996 World Food Summit, which agreed "to promote the development of environmentally sound and sustainable aquaculture well integrated into rural, agricultural and coastal development." Over the last decade, aquaculture production increased at an average compounded growth rate of nearly 11 per cent per annum. By 1996, total annual production of cultural fish, molluscs, crustaceans and aquatic plants reached a record of 34.12 million tonnes. Of special importance is the fact that more than 85 per cent of total aquaculture and food production came from developing countries, and in particular from low income food deficit countries (LIFDCs). Production within this group is concentrated in Asian countries, with China being by far the largest producer.

Annual aquaculture production is projected to exceed 40 million tonnes by 2010. Much of this increase is expected to come from the farming of fish and crustaceans in ponds, enhanced production in small and medium sized water bodies and integrated fish and crustacean farming, primarily with rice but also with vegetables and other crops as well as livestock. Efficiency in the use of water (particularly freshwater) and land resources is becoming a crucial factor in sustaining high growth rates. In many areas where aquaculture has rapidly expanded over the last decade, there is growing pressure on limited land and water

resources, and planning for integrated fisheries and agricultural development is therefore of the utmost importance.

Integrated farming involving crop and fish, aimed at increasing production through maximum utilisation of land and water is now being practised in many of the south-east Asian countries. This is an economically attractive and ecologically viable strategy most suited for the wetland ecosystems.

In many countries, aquaculture has been considered as part of the overall farming systems, as the wastes and by-products of agriculture could be utilised for manuring ponds and feeding fishes and the waste of fish accumulated in the pond bottom as fine silt, recycled back to the land for crops. It was reported that 50 kg of fish, produced enough pond humus to fertilise 670 m² of cropland. So also the grass cultivated in the crop land and the pond bunds form food for fishes like grass carp, which is known to convert 60-70 kg of grass and vegetable tops into 1 kg of flesh. Although a large number of crops could be integrated with fish, the rice-fish combination is the most promising one and the one having greater potential for development.

Continued production of livestock, fishery and poultry along with rice has been recognised as a revolutionary concept to increase production in several countries. Rearing of fish in rice fields is known to improve the soil conditions leading to increase in the rice yield. Rice-fish rotation was also proved to be effective in suppressing weeds, pests and diseases. With the popularisation of aquaculture as an integrated activity with rice, several of the 'padasekharams' formerly remained uncultivated for several years were brought to farming with enhanced profitability.

Synchronous or simultaneous system has been observed in many countries like China, Malaysia, Indonesia, Japan and in a smaller scale in India. The

species of fishes cultured commonly in rice fields under the system of synchronous culture are *Cyprinus carpio*, *Oreochromis mosambicus*, *Trichogestes pectoralis*, *Channa striatus* and *Clarias batrachus*. The application of pesticides is a major obstacle to fish culture in rice fields.

Rice fish culture is an age-old practice in India. The country has a resource of 2-3 million hectares of deepwater rice plots in the fresh water sectors. Production of fish on rice lands as a viable option for increasing farm cash and protein levels has begun to attract many Asian government and policy makers.

The alternate or rotational system of rice-cum fish culture is gaining importance. Rotation of crops in the same field has many advantages and rotation of rice and fish is no exception owing to the fact that the package of practices of both can be followed without any compromise. It allows the use of machinery and to a certain extent insecticides and pesticides for rice production and allows greater water depth for fish culture. This system is practicable only in such wetland ecosystem like 'Kole' and kayal lands of Kuttanad having adequate water level of about 1 metre.

About 10,000 ha being utilised in West Bengal, using the fields for growing rice in the rainy season and for prawn farming during the summer seasons. In Kerala about 5700 ha of 'Pokkali' fields are presently utilised for their rotational cropping, growing saline resistant pokkali variety of rice during the rainy season and prawns during the dry summer months between November and April.

Aquaculture has emerged as a promising industry in many of the developing countries. But the application of wrong technology or overexploitation of natural resources have only short-term gains. Environment-

friendly rice-fish rotational farming fitting to the overall agricultural system is now accepted as a sound alternative to capital intensive hi-tech aquaculture. However, it is essential to develop a threshold grow at strategy for aquaculture integration, making rotational farming of rice mandatory, whereby the waste generated by aquaculture is assimilated in rice farming and vice versa. Apart from increased productivity and economic efficiency, this method is supposed to help in maintaining the ecological balance or promotes ecological sustainability, because of the reduced application of pesticides in rice farming in rice-fish rotational system. Microbes play a very important role in the cycling of matters in the natural environment. In rice-fish-rotational farming, animal manure are frequently used and the organic matters are firstly decomposed by aquatic microbes, especially myriads of aquatic bacteria; and mineralised into inorganic nutrient salts before being taken in by the phytoplankton and zooplankton fed by fishes. Aquatic bacteria play a very important role in fish farming (Guo Xianzhen *et al.*, 1994). There were certain correlations between the load of bacteria in fishpond and several environmental factors monitored. The bacterial communities in both pond water and sediments were of diversified physiological groups which can break down sorts of organic matters. Detailed studies should focus on anaerobic bacteria, which may be functioning in under layers of sediments. More studies should relate comparison of pond management with microbial growth and look into whether and how microbial growth activities in fishponds could be manipulated and enhanced by management practices.

Agriculture constitutes the single largest sector of the economy of the State of Kerala contributing over 37 per cent of the State domestic product. Over 70 per cent of the workforce depends directly or indirectly on agriculture.

The Kuttanad region lying in the Indian peninsula encompassing an area of 1,500 sq. km., lying largely 0.6 to 2.2 m below mean sea level is a highly complex ecosystem, unique in its topography and ecology. It is the deltaic formation of four river systems, viz. Meenachil, Pampa, Manimala and Achancoil, together with the low lying areas in and around Vembanad lake, the largest estuarine system on the west coast of India. The region is water logged almost around the year and is subject to flood submergence during monsoon and saltwater ingression during summer.

A prolonged rainy season extending from May to November and a lean period from December to April are characteristics of the weather. The south-west monsoon contributes over 60 per cent of the rainfall in the region. The existence of warm water and humid environmental conditions are congenial for aquaculture.

The rice fields of Kuttanad, Kerala, comprising the deltaic wetland areas adjoining the Vembanad Lake was used to support and contribute substantially to inland fish production in the state. The Vembanad Lake, situated in the south-west coast of India, and connected to the sea through the Cochin backwater is well known for its fishing resource and as the nursery ground for the commercially important crustaceans. Adjoining the lower reaches of the lake are the vast agricultural lands known as 'Kuttanad' which serve as the granary of Kerala.

The Vembanad Lake is subjected to the flood waters emptied by the river systems and also by the sea water entering the lake on account of tidal action. The Vembanad Lake and the connected backwater systems exert considerable influence on the socio-economics of the surrounding areas as the living resources available in the lake play an important role for the people living on its banks.

One of the major hazards to the cultivation of rice in the agricultural fields lying adjacent to Vembanad Lake is the incursion of saline water through tidal flow, especially during the summer period. To prevent salt water incursion and to promote a double crop of rice in about 50,000 ha of low lying fields in the area, 1463 metre long barrage rising 92 cm above the level of high tide was constructed at Thanneermukkom in the Vembanad Lake. Designed as a bridge cum regulator with facilities for allowing navigation, it became the second biggest salt water barrage in the country.

All the cultivated wetlands of Kuttanad are known as 'punja' lying below the mean sea level. According to variations in chemical, biological and morphological characteristics, the soil in the region is divided into three groups (a) the kayal (b) Karappadam and (c) kari. The kayal soil which has been reclaimed from the lake beds is slightly acidic (pH 5.5-6.5), with the texture varying from silt loam to silty clay loam. The chemical characteristics shows organic carbon content 1.24%, total nitrogen 0.085%, P_2O_5 0.058%, K_2O 0.107%, CaO 0.349% and MgO 0.286%.

The karappadam soil, developed along the rivers as flood plain deposits is poorly drained, and is moderately acid pH 4.5-5.5, its surface soil being clay loam, fairly rich in organic matter 4.08% nitrogen, 6.30%.

The kari soil, (peaty soil) of the swampy area is deep black in colour, has a high proportion of organic matter and is highly acidic (pH 3-4.5). Under inundated conditions, acidity is less intense. The soil is either silty clay or clay in texture, the organic carbon 3.14% and nitrogen 0.23%.

A scientific mix of fish species comprising filter feeders, herbivores and omnivores will be polystocked under a mixed stocking regime in the

padsekharams. The padasekhara samithi will be free to choose the species depending on local market demands.

The general species mix and stocking model suggested comprise surface feeders (a) 25% preferably catla; column feeders (a) 30% i.e. rohu and bottom feeders (a) 45% i.e. mrygal or common carp. In the suggested first model where the animal manure is abundantly available, the filter feeding carps or planktonivores are the dominant components - Filtering species 60% - catla and silver carp, (target species) omnivores (30%) and herbivore (10%)- Rohu, common carp, Mrigal and Grass carp (Secondary species). In the suggested second model where there is weed infested fields, the macrovegetation feeders will be included at a dominant ratio-Herbivores (50%)- grass carp (Target species), Filtering (20%) and omnivorous (30%)- Rohu, catla, silver carp, mrigal and common carp. In the suggested third model the omnivores were stocked as target species 50% common carp/Rohu/ giant prawn and fitting species 50%- catla, silver carp and grass carp (secondary species). The stocking density advised is 4000-6000 number per ha.

The net fish production is directly proportional to the microbial activity in water and sediments which in turn is accelerated by manuring. Periodic application of organic manures has been shown to increase fish yields substantially. In order to augment productivity, prior to stocking of fish, the field should be manured with an organic manure, preferably cow dung, at the rate of 5 tonnes per ha or poultry droppings at the rate of 800 kg per ha. Sixty to seventy per cent of the whole dose will be applied as basal. When filter feeding fishes are dominant, manure addition will be done frequently in small doses. As the carp species stocked in the rice fields feed on natural food, use of supplementary feeds will be reduced to a minimum. Manuring alone will not be enough especially for

common carp and the grass carp which are active feed consumers. The feeding rate should not exceed 2-3 per cent of body weight and feeding place should be a fairly hard place in the padasekharam, necessarily a side facing the sun.

One of the major problems expected in Kuttanad ricefields in acidity, especially with the first rains, the pH drops to 4 to 4.5. Since the calcium content is low, periodic application of lime will be necessary. The study area selected for this project work is known as 'Anthonikkayal Padasekharam' a kayal land of 54 acres situated in the Arpookara panchayath, close to Vembanad lake. It is situated between Pennar river and Kaipuzha river. It is a joint venture of 33 farmers who are the owners of this 54 acres of land. Rice fish rotational farming was practised very profitably since 1996 in this padasekharam. Figure 1 shows the map of Kuttanad showing agro-ecological zone; Figure 2 shows pattern of flood incidence in Kuttanad and Figure 3 shows Riverine systems associated with the Kuttanad wetlands.

Integrated farming comprising crop and livestock has been sustainable over centuries. The system has been able to meet food needs of the society till the recent explosion of the population. In this system, animals are raised on agricultural wastes. The animal power is used for agricultural operation and the dung is used as manure and fuel. It may be possible to reach the same level of yield with proportionally less input in the integrated farming, and the yield would be inherently more sustainable because the waste of one enterprise becomes the input of another leaving almost no waste to pollute the environment or degrade the resonance base.

The integrated rice fish sequential or rotational farming system for low lying rice fields tested and developed by the Kerala Agricultural University at its Regional Research Station at Kumarakom and introduced in Kuttanad a few years

ago as demonstration trial in farmer's fields has become an instant success. As a result there has been even an increase, though marginal, in the area under rice in the low lying fields of Kottayam district between 1997-98 and 1998-99 from 13754 hectare to 14393 hectare.

Fish is one of the important items of food all over the world. Due to steady growth of population in India there is a need to bestow better to enrich our food basket by including diverse biological items. Fish is a fairly valuable item of human diet and is gaining great recognition. It is also an important source of protein, iron and Vitamin A. According to National Sample Survey the average consumption in Kerala is 15 kg per capita per annum which is more than the national average of 3 kg per capita per annum. In Kerala 95 per cent of the population consume fish. It is estimated that the total catch of fish was 6.48 lakh tonnes during 1998-99 in Kerala. Under the *Janakeeya Matsya Krishi* being implemented by the Kerala Government with popular involvement, 890 hectare brought under fish farming during 1998-99.

The rice-fish farming system is a low cost method of producing rice and at the same time the stocked fish provides an environment friendly way of controlling pests and grass and it provides nutrients for farm needs. This farming method promotes maximum utilisation of the farm resources and makes the farmer more self reliant and less dependent on outside farm inputs like chemical fertilizers and pesticides (Verlarde, 1996).

Integrated farming involving crop and fish aimed at increasing production through increase in utilisation of land and water is now being practised in many of the Padasekharams in Kuttanad. Rice-fish sequential farming enable raising of aquatic animals alternatively in one rice field to obtain aquatic products in addition to rice production. Yield of rice has been stated to increase 10-15 per cent through this method. This system has the advantages of low cost and better

economic returns. It is an economically attractive and ecologically viable strategy suited for the wetland ecosystems.

Case studies conducted on this new system of rice-fish farming have indicated highly attractive returns from both the fish crop and subsequent rice crop due to complementary effects of organic recycling of resources. The technology appears to be commercially attractive and ecologically viable. Popularization of this farming system in Kuttanad and other low lying rice belts of the state through adequate institutional support can, not only arrest the present unhealthy trend of area conversion from rice but also bring under plough vast areas kept fallow from years.

The broad objective of this project was to analyse the sustainability and ecofriendly aspects of rice-fish rotational farming which proved to be economically feasible in order to promote efficient utilisation of land and water resources available in the Kuttanad region of Kottayam district.

Although rice-fish rotational farming has been recognised as a potentially beneficial and profitable farming practice, it remains as an open field of multidisciplinary research and verification. The present project will help to popularise the technology with more scientific facts on its ecological and environmental dimensions and the microbial activity which refine the environmental quality, recycling and help to check the trend of indiscriminate use of agrochemicals and hazardous pesticides.

In the present investigatory project a thorough analysis has been made on the ecological efficiency and sustainability of rice fish rotational farming method, in comparison with mono culture of rice in both seasons in paddy cultivating

fields in Kuttanad. The rice-fish rotational farming in low land locations of Kerala were assessed for its sustainability, ecological advantages and disadvantages.

An earnest attempt has been made to emphasise and evaluate the microbial activity, role of both aerobic and anaerobic bacteria in recycling of nutrients, efficient conversion of raw materials and the enhancement of soil fertility, which reduces the use of agrochemicals and pesticides. Moreover, this study helped to correlate the farm management with microbial growth and look into whether and how microbial activities in rice-fish rotational farming system could be manipulated and enhanced by management practices.

No comprehensive studies have so far been conducted on the ecological aspects to assess the sustainability of rice-fish rotational farming systems in wetlands of Kuttanad. The role of microbes in efficient recycling process of nutrients, including waste degradation process and straw decomposition is significant and the microbial activity makes this method of farming 'sustainable,' and 'eco-friendly.' The rice-fish rotational farming system will be useful to the planners, policy makers, scientists and farmers to choke out suitable agricultural development projects for Kerala.

This report is divided into six chapters including the present one. The second chapter deals with review of related studies in the light of the present investigation. The third chapter deals with the methodology used for the generation of primary data and analytical tools and techniques employed. The results are presented in the fourth chapter, followed by the discussion of the findings in the fifth chapter. Chapter six summarises the findings, followed by references.



Plate 1: Thannermukkom Saltwater barrage

Chapter II

REVIEW OF LITERATURE

II.1 International status

The main objective of this chapter is to review the empirical and theoretical information available from similar and related studies. A comprehensive review of past studies could serve as a basis for delineating an ideal conceptual framework for the present project and relating its empirical findings with those of earlier investigation. Studies on different types of integrated farming, rice-fish sequential or rotational farming, ecological aspects and role of microbes in bioconversion in agriculture, aquaculture and integrated farming has also been reviewed.

Cagauan *et al.* (2000) reported from their case studies in Philippines that fish and the nitrogen fixing aquatic fern azolla and ducks integrated with rice farming can result in nutrient enhancement, pest control, feed supplementation and biological control. Halwart (1994) reported that the rice crop benefits from the presence of fish in terms of reduced pest incidence. Li,-Kangmin (1994) described that the rice fish culture in China is in the process of development from extensive culture to semi intensive culture, from monoculture to polyculture, and from self sufficient natural economy to commercial economy.

Studies conducted by Halwart (1994) in Philippines on the biological control potential of common carp *Cyprinus carpio* and Nile tilapia *Orochromis niloticus* has reported that although fish are not the single solution to insect pest problems in rice, they do contribute to limiting pest abundance and support the army of natural enemies of rice pests. Common carps are found to be effective bio

control agents against apple snail pomacea, the paddy pest in Philippines. Israel and Sevilleja (1995) reported that in Philippines rice fish culture leads to higher rice production compared to rice monoculture. Some ecological aspects of fish populations in tropical rice fields of Malaysia has been studied by Ali (1990) and reported a decline in individual weight of fishes, especially of herbivores, and was correlated to the abundance of the species and hence to food supply.

Khoo and Tan (1980) observed that introduction of herbivorous fish in rice-fields controlled weeds and reduced feeding cost. Sevilleja (1986) demonstrated that rice fish integrated farming yielded about 40 per cent more income as compared to monoculture of rice. Grass carps in rice fields when polystocked with other species were found to manure and fertilise pond water and generate natural food to filter feeders and omnivores (Yang *et al.*, 1994). Huang and Ming Xian (1984) studied the trophic levels in winter fallows of rice-fish system in China and postulated a model for computing production in this system. Sevilleja (1986) identified the need to verify the technology of rice-fish integration through farmer managed trials. A significant saving in fertiliser cost was demonstrated in rice production in fields previously utilised for fish production (Sevilleja and Lopez, 1986).

While observing the performance of individual fish species in rice-fish system, Li and Pan (1992) observed that fresh water cat fish grew much faster under monoculture system in rice fields. Moody (1992), however, observed that under rice-fish systems, *Cyprinus carpio* not only eradicated weeds and algae in the rice fields but also saved the cost on ploughing and harrowing. Yuan (1992) observed that grass carp was most effective in controlling the sheath blight disease of rice by directly eating sclerotes and hyphae germinating on sclerotia. Nie *et al.* (1992), traced the mutualism of rice and fish farming and concluded the grass carp

controlled weeds thoroughly as compared to hand weeding and herbicides. Fagi *et al.* (1994), postulated that under optimum stocking intensities in rice-fields, *Cyprinus carpio* enhanced availability of phosphorus to rice. Miltner *et al.* (1983), found that rice straw detritus were good feed supplements for prawns. Stahl (1979), however noted that decomposition of straw and stubbles served as detrital supplements to prawns. In their studies on the beneficial effects of fresh water prawn as a stocking component in rice-fish integrated situation. Guerrero *et al.* (1982), reported that when *Macrobrachium rosenbergii* was cultured along with rice, rice plants provided feeding surfaces essential for the species. According to Wang (1992), one of the most important farming models suited for rice-field, is azolla-rice-fish integration. Lightfoot *et al.* (1990), observed that integrated rice-fish system offered the possibilities of increasing rice yields by as much as 15 per cent while continuous monocropping of rice led to a decline in soil microbial biomass and fertility. Identifying the importance of fish in Asian rice-farming system, a network to popularise this practice has been mooted by IRRI and ICLARM (Lightfoot *et al.*, 1990). The observations of the Chinese scientists on the apparent advantages of rice-azolla-fish system as reflected in the increased grain yield, fish biomass, soil fertility and decreased incidence of pests, weeds and diseases have been highlighted by the Food and Agricultural Organization (FAO, 1988).

The common carp *Cyprinus carpio* appeared to be better suited to rice field environments of Philippines than Nile tilapia. Role of fish in pest control in rice farming has been studied by Yuan (1992) in China and reported that rice plant hoppers were reduced from a maximum of 104,000 to 70,776 per hectare. Rice leaf rollers decreased from 210,000 to 120,000 per hectare. Grass carp (*Ctenopharyngodon idella*) were particularly effective in controlling sheath blight.

Water quality parameters affecting fertility and productivity of rice-fish farming systems in Kerian, North Perak, were studied for 3 growing seasons from September 1985 to January 1987. Parameters were obtained for both sump ponds and rice fields. Temperature and dissolved oxygen were higher in the more exposed rice fields than in the sump ponds and both environments have slightly acidic pH. However, these parameters did not affect the native fish species, which have evolved to adapt to these extreme environments. Both the hardness and alkalinity levels were not low to affect phytoplankton production – liming increased temporarily the concentrations of the two parameters- Nitrate and Orthophosphate were rather low, in spite of frequent fertilizations at 56 kg/hectare urea and 1½kg/hectare NPK, chlorophyll concentrations were 33.6 plus or minus 5.9 and 45.2 plus or minus 13.5 mg/l respectively. Benthic populations fluctuated in response to fertilization and in general, the benthic population in the rice fields were higher than in the sump ponds, Ahyaudin (1992). Experiments conducted with grass carp (*Ctenopharyngodon idella*) in a rice-fish system in China showed that they increased rice yields generally by 10% or more. *C.idella* controlled weeds and harmful insects. By eating grass, they reduced the need for farmers labour for weeding. *C. idella* faeces also helped to fertilise the rice fields, Nie *et al.* (1992).

Fang Xiuzhen *et al.* (1994), in the studies of pond water and sediments of polyculture fishponds observed the correlation between the load of bacteria in fish pond and several environmental factors monitored. Bacteria of genus *Pseudomonas* were found commonly occurring in both pond water and sediments, and there were changes or replacement of dominating bacteria along with the seasons. The need for further studies on anaerobic bacteria functioning in underlayers of sediments, and studies on comparison of pond management with

microbial growth and studies on weather and how microbial activities in fish ponds could be manipulated and enhanced by management practices, is an area of which requires thorough investigation. Schematic representation of rice-fish agroecosystem is given in Figure 4.

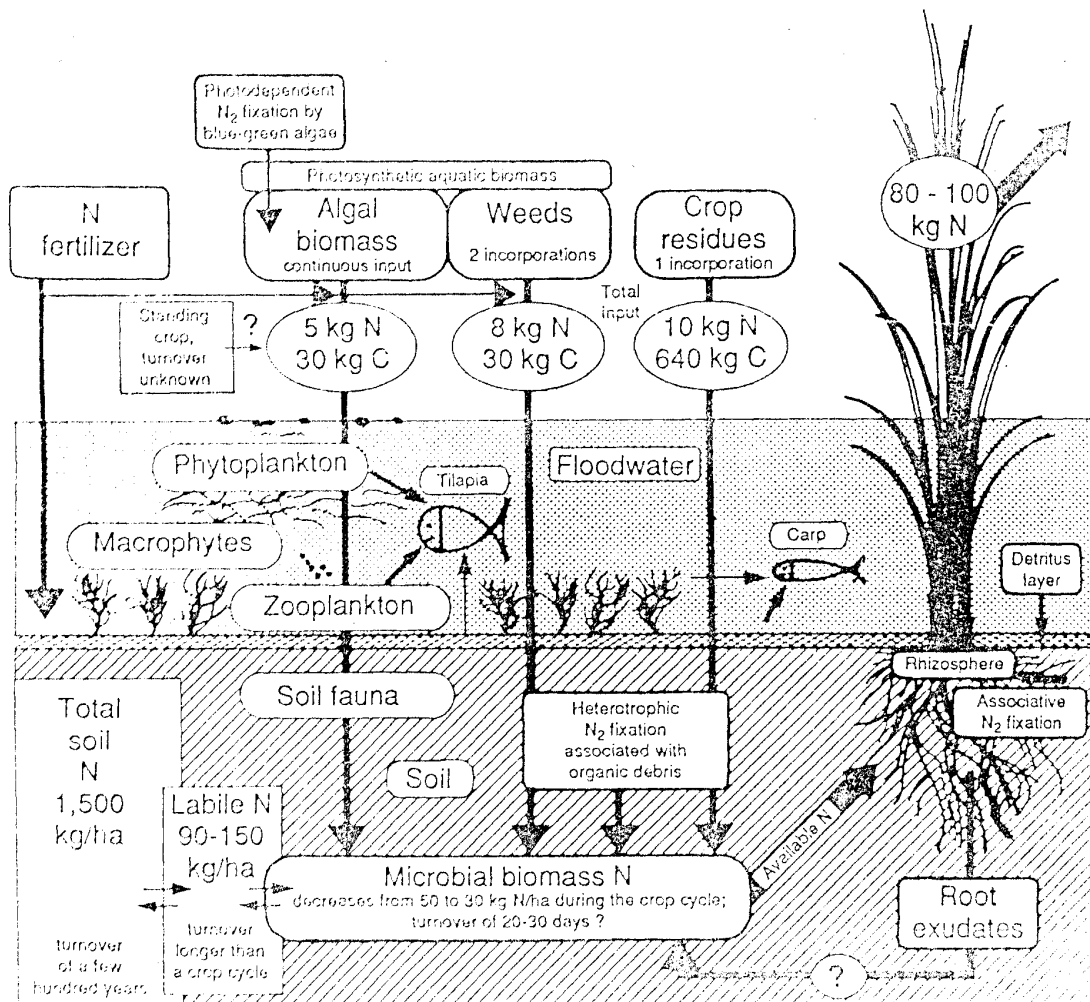


Figure 4 Schematic representation of the rice-fish agroecosystem with a conceptual representation of the origin of the nitrogen absorbed by rice, the role of the microbial biomass in providing available nitrogen to rice and the pathways involved in the replenishment of the microbial biomass. All figures are per hectare per crop.

Khoo and Tan (1980) in their study on integration of fish farming with agriculture in Malaysia estimated that fish farmer's income from fish culture constituted 22 to 60 per cent of farm income in single cropped area of rice and four to nineteen per cent in double cropped area. They concluded that fish formed a significant part of the total income of at least 60 per cent of tenant farmers interviewed. According to him efficient management was of utmost importance in increasing the profit margin.

Family farms, approximately 80% of farm households in Vietnam have their own small pond garden and canal for aquaculture. Integration of vegetable garden, pig and livestock is a traditional approach to family food production since 1960s (Aldon, 1997).

The potentials of the integrated farming technology for transforming existing traditional farming systems to become more sustainable in Ghana has been reported by Light foot *et al.* (1996). The integrated farming technology has become an appropriate method for replenishment of decimated fish populations in the rice fields with improvement of incomes, nutrition and environment for sustainable operations and resource management to support healthy human life in Bangladesh (Mazid and Hussain, 1996).

II.2 National status

The practice of utilisation of rice fields for sequential farming of fish and prawn is an age old practice in the pokkli rice fields of Kerala. These are brackish water fields adjoining the Vembanad lake. The practice is popularly known as 'Chemmeenketu' or prawn filtration. Here, in one and the same field, rice and prawn are farmed in a cyclical manner, the dietrial supplement of straw after the

rice crop forming the bulk of the food material for prawns. In these fields, rice is cultivated during the low saline phase (June-October) and shrimps reared during summer months (Nov-March) when salinity builds up and when the field is unsuitable for rice. In this system, the shrimp seeds naturally entering from the coastal sea are trapped and cultivated as a mutually beneficial and ecologically efficient farming model (Vannucci, 1986).

Studies conducted by the Kerala Agricultural University at the Regional Agricultural Research Station, Kumarakom indicated that in addition to rice production averaging three tons per hectare, fish yield ranging from 600 to 1000 kg. per hectare could be obtained by simultaneous farming of rice and fish. As compared to the practice of simultaneous farming which requires several modifications to the rice fields to protect the fish from the inherent risk of pesticide applications, rotational farming of rice and fish was shown to be more advantageous as it permitted better management practices for both rice and fish (Padmakumar *et al.*, 1990). In these investigations, where in Indian major carps, common carps and *Etropolis* and the giant fresh water prawn *Macrobrachium rosenbergi* were poly cultured, yield touched 1005 kg per hectare without any additional expenditure on feeding or manuring. From these observations it was inferred that rotational farming of rice and fish was a viable proposition for Kuttanad.

Ghosh and Chakrabarti (1990) reviewed the different works on farming of fish in rice fields in India and observed that monocrop rice fields under high monsoon precipitation and deep water rice fields are ideal zones for integrated farming. Mukopadhyaya *et al.* (1992) studied the relative advantages of rice fish integration in the deep water rice fields of West Bengal and reported fish yields ranging from 263-1215 kg per hectare. Tiwari (1993) observed that a framing

system involving flooded rice, poultry and fish had a high degree of complementarity. The integration of fish and the nitrogen fixing aquatic fern azolla show promise for increasing the production potential of the system.

Influence of organic and inorganic fertilization on the growth and nutrients of rice and fish in a dual culture system in Kharagpur, West Bengal, India has been studied by Ghosh *et al.* (1995) and reported that the total number of phytoplankton species as food for the fish under organic manuring was more than under inorganic fertilization. In low-lying water logged situations (15 – 45 cm water depth) the total productivity could be increased by supplying the appropriate nutrition to both rice and fish in such dual culture system.

Feasibility of monosex culture of male tilapia (*Oreochromis mossambicus*) along with paddy in pokkali field has been studied along the central coastal belt of Kerala and it was reported that under the peculiar conditions of pokkali fields, male tilapia (*Oreochromis mossambicus*) alone was found to be suitable for simultaneous rice-cum-fish culture (Rajendran *et al.*, 1981). The size attained 200 g was acceptable to the consumer and the yield at a medium stocking density of 3000/hectare was 0: 2 tonne in 3 months.

Growing the Chinese grass carp *C. idella* in integrated rice cum fish farming system in eastern India increased the yield of rice by about 20% and 35% and is attributed to the direct and indirect benefits of the control of aquatic weeds and also to the additional manuring of the plots by grass carp faeces. In the studies on the economic viability of poultry-rice and fish in the lowland rice fields in Tamil Nadu, Rangaswamy *et al.* (1992) reported an increase in profit margin by 60 per cent as compared to the conventional farming practice.

Modern aquaculture and agricultural practices are solely dependent on the adequate application of the major nutrients NPK, along with some trace/micronutrients. Generally the chemical fertilisers like urea (N), Murata of potash (K) and phosphate (P) are the common sources of the balanced nutrients. The waste water may be recycled for the production of fish, paddy and vegetable crops. Domestic water contains ammoniacal nitrogen 3.92-11.36, nitrate nitrogen 0.12-0.32, phosphate 1.2-9.18, calcium 40.6-75.0, magnesium 16.0-30.0, potassium 3.0-9.8 mg/l and pH 6.8-7.9. These organic wastes of deft origin should not be destroyed and may be recycled for rearing fish and deft crop plants.

At a time farmers, politicians and planners have often felt that rice cultivation is an unprofitable enterprise. The cost of production, however, has been considerably upward. When compared with other garden crop cultivation, rice cultivation is less lucrative, Kerala has never been self-sufficient in the production of rice the staple food of its population. The net return has always been positive and the benefit-cost ratio has always been more than I. Hence wetland rice cultivation has always been a profitable enterprise in Kuttanad during the past 15 years. However, it must be noted that there has not been any considerable change in the benefit; cost ratio over the past 15 years.

A recent FAO study on the potential capacities of developing countries to support their burgeoning populations indicated that the largest annual increase in world population in history will take place from 1980 to 2020 and the fastest rates will occur in areas where the land resources are least able to meet the demand for increased food production (FAO, 1988). The study pointed out that increased levels of input are essential. A balance is required between the slower but sustainable traditional methods of organic farming, and more rapid 'conventional agriculture' involving use of inorganic fertiliser to increase the flow of nutrients in developing country agroecosystem.

As fish cause a more rapid circulation of nutrients in the pond by mixing the sediments and by accelerating the mineralisation of seston-living and non-living floating matter they may increase the phytoplankton biomass in the pond, which may be increased further by grazing on zooplankton which also filter phytoplankton. This has been called ichthyoeutrophication.

Producing more food to feed the burgeoning population from shrinking land of water, without eroding the ecological foundation will be an uphill task. The surest means to tide over this challenge is through environmentally sustainable farming methods, which are economically rewarding and intellectually stimulating. Among the food grains, rice has a major position. India is the world's second largest producer of rice after China.

The integrated rice-fish rotational farming system for low lying rice fields tested and developed by the Kerala Agricultural University at its Regional Research Station at Kumarakom and introduced in Kuttanad a few years ago as demonstration trial in farmer's fields has become an instant success. As a result there has been even an increase, though marginal, in the area under rice in the low lying fields of Kottayam between 1977-98 and 1998-99 from 13754 hectare to 14393 hectare.

Fish is one of the important items of food all over the world. Due to steady growth of population in India, there is a need to concentrate better to enrich our food basket by including diverse biological items. Fish is a fairly valuable item of human diet and is gaining great recognition. It is also an important source of protein, iron or vitamin A.

Rice fish sequential farming enable raising of aquatic animals alternatively in one rice field to obtain aquatic products in addition to rice production. Yield of rice has been stated to increase 10-15 per cent through the method.

Though the construction of Thottappally Spillway has to some extent mitigated the severity of the monsoon floods, damages are still caused by the breaching of bunds consequent on the floods.

Proper nutritional management is recognised as the key for realising the most efficient production in crop plants. Weeds absorb at least part of the available nutrient and affect crop growth by restricting the absorption by rice. As the weeds removed in manual weeding are throughout and not recycled, the nutrient loss by used removal is a steady and continuous means of nutrient drain.

The study conducted by Padmakumar *et al.* (1990) indicated that integrated farming of giant prawns (*Macrobrachium rosenbergi*) in channels of coconut garden in the wetland area, adjoining southern portion of Vembanad lake is economically viable.

Muraleedharan (1981) in his article on “Resource use efficiency in rice cultivation in low lying lands of Kerala” observed that inputs such as human labour, bullock labour and fertilizers were not efficiently used.

Rajendran *et al.* (1981) conducted experiments in rice-fish simultaneous culture in Pokkali fields of Kerala during 1977-78 and observed that under ideal conditions production up to 183 kg per hectare could be achieved within 109 days period with *Etroplus* sp. Since paddy cultivation was not so economical, additional income gained through fish culture was of great help to the farmers. There was also possibility of increasing production of paddy as *Etroplus* had helped in removing hydrilla.

Joseph (1982) studied resource use efficiency of paddy farms of Kuttanad region in Kerala. The analysis showed that total cultivation expenses per hectare of paddy cultivation were Rs.4240 in lower Kuttanad and Rs.3011 in upper

Kuttanad. Operation-wise break up showed that gap filling and weed control formed the largest expenses followed by fertiliser and its applications. Input-wise study of the cost of cultivation revealed that human labour use per hectare was the most important input cost amounting for about 45 per cent of the total cost. Regression analysis showed that some of the regression coefficients were significant.

Radhakrishnan (1983) conducted a study on economics of paddy cultivation and its impact on production in Palghat, Alleppey and Trichur districts of Kerala. The analysis showed that the relative as well as absolute profitability in paddy cultivation has declined considerably after 1974-75 and this seems to be only one of the reasons for the recent decline in paddy area and production. The low profitability in paddy cultivation appears to have had a depressing effect on paddy land prices and this might have also contributed to the shifting of land away from cultivation.

Purushan (1986) in his study on recent advances in paddy cum fish culture observed that the culture of fish and paddy together could potentially increase and stabilise income on rice farms and also paddy post fish culture increased the total annual yield. The fish could be beneficial in eliminating weeds molluscs and mosquitoes thus reducing labour cost. He also studied the scope of paddy cum fish culture in Kerala and found that the rate of fish production in paddy fields stood much better and suggested the introduction of this practice in kayal lands of Kuttanad and Kole, in addition to 26,000 hectare of Pokkali Fields.

Purushan (1987) studied the economics of traditional prawn farming in brackish water fields of Kerala and found that the integration of paddy cultivation and prawn culture was encouraging if properly operated. On comparing the two, it was seen that almost double the profit was realised from traditional prawn

culture over paddy cultivation. If improved methods of prawn farming were adopted, prawn production from paddy fields could be raised to at least one tone per hectare.

Senthiadhas *et al.* (1989) evaluated the economics of paddy cum prawn culture in Kerala during 1981-84 based on data generated through sample survey covering Ernakulam district. The cost of paddy cultivation worked out to about Rs.2020 to Rs.2780 per hectare. Labour accounted for 81 percent of the total cost, seed 10 percent sluice gate seven per cent and miscellaneous expenditure two per cent. The average yield was 19 quintals per hectare which gave gross return of Rs.3270 to 3900. Analysis of cost and returns of prawn filtration revealed that 80 per cent of the total cost was accounted by lease value, labour cost accounted 10 per cent and sluice gate five per cent. The net returns per hectare of prawn filtration worked out to Rs.1200. The annual net returns worked out to about Rs. 8200 per hectare received by owner farmer from both paddy cultivation and prawn filtration, while those who cultivated paddy and leased for prawn received an annual return of Rs.5130 only. It was also found that on an average 53 man days and 50 women days were employed per hectare for prawn filtration.

Vyas (1989) in his study on fresh water fish culture in Indonesia observed that common carp was grown in this system very often and yielded 1200 kg per hectare per year as an additional product besides rice. It was also found that 15 per cent higher returns could be obtained by growing fish along with rice (international).

While comparing the cost and returns of synchronous and sequential rice-fish farming in Kuttanad, Padmakumar *et al.* (1990) found that the sequential system gave a net profit of Rs. 10450 per hectare per year as against Rs. 6303 per hectare per year in the case of synchronous farming.

Ganesan *et al.* (1991) studied the role of duck cum fish culture as a component in rice farming and also the economics of farming system under small farmer's condition in Cauvery delta region of Tamil Nadu. A net profit of Rs.24117 was obtained in mixed farming with duck cum fish culture and Rs. 13790 was obtained from existing cropping system (rice-rice-pulse) from one hectare farm. The introduction of duck-cum-fish culture as a component in mixed farming yielded attractive returns. Besides, 144 man days of employment was additionally generated by introduction of mixed farming over the conventional cropping system.

Nasser and Noble (1991) compared prawn culture in seasonal and in perennial fields in Vypeen, Kerala and found that prawn production per hectare per month was higher in seasonal fields than in perennial ponds. Absence of predatory fishes and occurrence of soft prawn disease added to its high production and also due to rich organic matter left behind as paddy stubbles after harvest, selective stocking of prawn seed and supplementary feeding will augment production from perennial ponds. He was of the view that converting extensive system to smaller semi-intensive ones, though costly, would add to the economy of the country by increasing the overall prawn production and providing employment opportunities.

Thomas *et al.* (1991) studied the decline in paddy land and factors leading to it in Trichur district of Kerala and found that during a short span of three years (1987-1990) the decline in the area under paddy was to the extent of 31 per cent.

The cost and returns from paddy cultivation showed a benefit-cost ratio of 1.51 over all paid out costs.

Sebastian *et al.* (1992) conducted a preliminary study on intensive farming of fresh water prawn in Kerala and found that taking into account the cost factors a production of 3500 kg per hectare per year of *Macrobrachium rosenbergii* could be achieved under the climatic conditions prevailing in Kerala, if proper management measures was followed.

Singh and Swami (1998) conducted a study on integrated farming with magur fish among small farmers and proposed a model for integrated farming of magur with poultry, ducks, and horticulture as components. Waste products from duck, cattle and poultry were used efficiently by magur fishes and excess water and nutrient rich sediments were utilised for growing vegetables and fruits. The fish culture gave a yield of four to six tonnes per hectare. A net profit of Rs. 41000 per 0.12 hectare was realised from this integrated farming system. He concluded that farming magur fish with other systems of farming was highly profitable and it provides gainful employment to the farming family throughout the year.

Thomas (1993) analysed the cost structures of paddy cultivation in kole lands. The analysis showed that labour input alone was the largest single item of the cost for both local (70.96%) and high yielding varieties (66.41%) followed by fertiliser. The total cost of cultivation per hectare worked out to Rs. 10676 for local and Rs. 11380 for high yielding varieties and returns obtained from local and high yielding varieties were Rs. 15000 and Rs. 17000 respectively.

Gupta (1993) in his study showed that application of lime @ 10 g/m³ or mahua cake at the rate of 200 g/m³ of water is recommended for small culture whereas application of ammonia was recommended for larger fields for the

eradication of predatory organisms. Productivity of the farms could be improved by applying organic or inorganic fertilisers.

Lakshmi (1993) studied the supply utilization and repayment performance of crop loans of commercial banks in Alappuzha district. Paid out cost alone were taken into consideration for estimating the cost of cultivation of paddy. Cost of cultivation estimates showed an inverse relationship to the size of holding. Total paid out cost estimated from paddy cultivation in this area was Rs. 12706. Input-Output ratio was obtained for large farmers (1.87) followed by marginal farmers (1.70) and small farmers (1.64).

Padmakumar *et al.* (1993) again established the economic and ecological superiority of rice-fish rotational farming in Kuttanad paddy fields over rice monoculture and rice-fish synchronous farming.

Santha (1993) studied the cost and returns of paddy cultivation for different seasons in Thrissur, Kerala and found that hired labour was the most important input invariably used for all the seasons. The average net income was lowest in Punja (Rs. 1095.19 per hectare). The return per rupee invested was also lowest for Punja.

Thomas (1993) through his study on prawn farming in Ernakulam district of Kerala state threw some light on the major constraints in prawn production. Most important constraint was the lack of finance for the adoption for the new technology. Non availability of prawn seed was another problem faced by prawn farmers. He suggested that more hatcheries should be set up by the State and Central governments to augment the supply. Institutional financial assistance should be extended to the prawn farmers including the landless.

In an attempt to study the economics of rice production in Kuttanad and kole lands of Kerala, Mohandas (1994) observed that in Kuttanad out of the total cost of production, the cost of fertiliser and its application constituted a major share (24.06%) followed by cost of land preparation (13.52%). The cost of weeding, sowing and plant protection had a share of 12.89 per cent, 6.58 per cent, 5.66 per cent respectively. The benefit cost ratio was worked out to be 1.19.

Dube (1995) studied integrated aquaculture and found that, through fish paddy crop integration the production cost can be reduced to one third. It also reduced land erosion by 57 per cent. Due to synergistic effect of fish on paddy, paddy yield increased by 10 per cent. Weeds and insects were controlled by fish as they feed on it. Fish cum crop integration led to increased efficiency of resource utilisation, reduced investment risk through crop diversification and served as additional resource of food and income. It was also found that with improved management practices a production of 50 kg per hectare of *Penaeus monodon* (Tiger prawn) 250 kg of mullets, 3000 kg per hectare of telopia, besides 2.4 tonnes of rice could be achieved.

Ghosh *et al.* (1995) opined that biological control of aquatic weeds in rice lands could be achieved by culturing certain fish species. Experiments conducted in the farmer's field gave a 20 to 25 per cent increase in the yield of rice by rearing grass carp. Besides increased rice yield an additional production of fish of 113 kg was achieved.

Pandirajan (1995) conducted a case study on rice-duck-fish farming in 0.2 hectare homestead area and found that the fish growing reduced the need for pesticides as they fed on insects such as stem borer. Ducks in rice fields devoured the sprouting seeds which reduced the cost of labour. The average yield of rice was estimated to be 1000 to 1200 kg per 0.2 hectare and that of straw 600 to

800 kg per 0.2 hectare. The cost of cultivation for rice was Rs. 2000 per 0.2 hectare including labour cost. The income from rice alone amounted to Rs. 9000 per year and Rs.3000 per year from the same of ducks and eggs. He concluded that the practice was cheap requiring no major modifications in existing farming system. Integration of fish in the system increased the yield per unit area, improved the family income and was eco-friendly.

Rangaswamy *et al.* (1995) analysed rice based integrated farming systems in Tamil Nadu comprising of cropping, fisheries, poultry and mushroom production. For comparison, conventional cropping systems practiced in the local area were also tested. The study was developed for a holding of 0.40 hectare. The result showed that an average net income of Rs. 7678 per year was obtained from the crop component and per year gave a net profit of Rs. 2083, Rs. 917 per year from poultry and Rs. 1347 per year from mushroom. The total net income under rice-poultry-fish-mushroom was Rs.12025. The net income in conventional cropping system was only Rs. 6334 per year from 0.40 hectare area. Moreover the integrated farming system generated an additional employment of 453 man days per year over conventional cropping system from the specified area and thus helped in the effective utilisation of family labour of the farmer round the year.

Sasidharan and Sekhara (1996) studied the cultivation practices of paddy in Pokkali lands, sprouted seedlings were planted on mounds during the monsoon season. Fertilizers and pesticides were not generally used in these fields as they became toxic to fishes and prawns in the following season. Since the brackish water inundated to the field, the weeds were controlled naturally. While harvesting only the panicles were cut and the stubbles left behind in the field will become the habitat for the fishes and prawn juveniles.

The Fish Farmer's Development Agency, Kottayam (1997) reported that the total net income per hectare from rice fish rotational farming in Kuttanad was Rs. 32,400/- as against a net return per hectare of Rs.7350 from monoculture. The internal rate of return in the case of sequential farming worked out to be 48 per cent.

Rao and Raju (1997) estimated the economics of fresh water fish culture in Andhra Pradesh. The per hectare net profit from fish farm was Rs. 4423. The technological coefficients showed over-optimal resource use with respect to stocking rate, labour, fertiliser use and electricity charges.

A study undertaken in pond based farming system research and extension programme in Bhubaneswar district of Orissa (Beliera and Mahapatra, 1998) identified that a small farmer who could divert his pond for fish production could get an attractive profit and boost his income. Analysis revealed that a gross and net return of Rs. 20325 and Rs.16603 per hectare respectively could be generated with a minimal expenditure of Rs.3722.

Comparative study on different prawn culture in Pokkali lands of Ernakulam district (Maryvijaya, 1998) found that prawn yield in traditional methods were comparatively lower than that in improved method. Farm income, family business income, family labour income and benefit cost ratio were substantially higher in improved method as compared to traditional method.

Singh and Swami (1998) in their study in Punjab revealed that by the integration of aquaculture with agriculture and use of supplementary feed, a sustainable fish production of over 10 tonnes per hectare can be easily obtained.

About 55,000 hectares of wet lands are available for paddy cultivation in Kuttanad, India, Kerala. In recent years, the extent of polders lying fallow either perennially or seasonally is alarmingly increasing mainly due to the diminishing

and poor returns from the paddy cultivation. As per the date completed in 1987, around 699 hectares of polders were lying fallow in upper, lower and northern Kuttanad regions while 2791 and 34597 hectares were only utilised for Virippu and punja respectively (Harikrishnan and Kurup, 1995). The role that microorganisms playing organic nutrient cycles in fish ponds is examined in detail with respect to improving the pond heterotrophic production for maximum yields of fish in integrated farming systems by Radheyshyam (1986).

II.3 Secondary data

List of integrated farms in Kottayam district from 1993 to 2001

Year	Name of Farmers	Panchayath	Area (hectare)
1993-94	Joy Ittoop	Kumarakom	20
1994-95	Raj Mohan*	Kumarakom	09
	P. K. Chacko	Nattakom	10
	V. J. Varkey	Kallara	12
Cumulative Total			51
1995-96	John Mathew	Kallara	10
	T. A. Babu	Kumarakom	10
	T. K. Kurian	Kuarakom	12
	Varkey George	Aymanam	25
	P. J. James	Udayanapuram	15
Cumulative Total			112
1996-97	Thoopram Padasekharom*	Vazhappally	266
	Kurian	Aymanam	07
	Pattithanam Padasekharom	Vazhappally	76
	Kuruvilla V. V.	Kumarakom	10
	Thuruthikattukantom*	Aymanam	10
	Lukose Thodukayil	Neendoor	19
	Anthonikayal Padom	Kumarakom	54
Cumulative Total			554
1997-98	Thundiylkadavu Padom	Vazhappally	22
	Chirakkadavu	Vazhappally	40
	Kalathodu*	Kallara	89

	Pallom Thollayiram	Nattakom	320
	Kavalackal Block	Aymanam	100
	Vaniyamkary	Kurichi	48
	Kurichi-Karivattom	Kurichi	315
	Ayyanandan Puthenkary	Vechoor	232
	Shaji Joseph	Kallara	30
	Thattamprampu S. Block	kallara	105
	Kalapurackal	Thalayazhom	50
	P. J. Sebastian	Thalayazhom	28
	Vanam Vadakke Block	Thalayazhom	287
	CKN Block	Thalayazhom	135
	Sebastian John	Kumarakom	28
	Cumulative Total		2081
1998-99	Kolam-kary	Vechoor	163
	Kattamada	Vechoor	71

Please see landscape table 1

Water quality tolerance guidelines for fish farming

<p>1. Dissolved Oxygen</p> <p>Effect of dissolved oxygen concentration on pond fish Desirable range 5, mg. litre Fish survive but growth slow1-4, mg. litre Lethal if exposure is prolonged 1-0.3, mg, litre</p> <p>Lethal concentration of Dissolved Oxygen for Selected Fish</p> <table border="1"> <thead> <tr> <th>Species</th> <th>Lethal level (mg/litre)</th> </tr> </thead> <tbody> <tr> <td>Catla</td> <td>0.7</td> </tr> <tr> <td>Rohu</td> <td>0.7</td> </tr> <tr> <td>Mrigal</td> <td>0.7</td> </tr> <tr> <td>Grass Carp</td> <td>0.5- -0.6</td> </tr> <tr> <td>Silver carp</td> <td>0.3- -1.1</td> </tr> <tr> <td>Common carp</td> <td>0.2- -0.8</td> </tr> </tbody> </table>		Species	Lethal level (mg/litre)	Catla	0.7	Rohu	0.7	Mrigal	0.7	Grass Carp	0.5- -0.6	Silver carp	0.3- -1.1	Common carp	0.2- -0.8
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<p>2. Salinity</p> <p>Highest concentration of salinity which permit normal survival of some cultured Fish Salinity (mg/litre)</p> <table border="1"> <thead> <tr> <th>Species</th> <th>Salinity (mg/litre)</th> </tr> </thead> <tbody> <tr> <td>Catla</td> <td>Slight brackish</td> </tr> <tr> <td>Rohu</td> <td>Slight brackish</td> </tr> <tr> <td>Grass Carp</td> <td>12,000</td> </tr> <tr> <td>Common carp</td> <td>9000</td> </tr> <tr> <td>Silver carp</td> <td>800</td> </tr> </tbody> </table>		Species	Salinity (mg/litre)	Catla	Slight brackish	Rohu	Slight brackish	Grass Carp	12,000	Common carp	9000	Silver carp	800		
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(Source FFDA, Kottayam)

Please see Landscape table 2

Environmental variables in the Rice-Fish Integrated system, Pazhaya Kayal

pH	7.00
Free carbon Dioxide (CO ₂)	3.8 ppm
Dissolved Oxygen (DO)	9.6 ppm
Turbidity	72 cm
Nitrite (No ₂ -N)	40 micrograms at/litre
Nitrate (No ₃ -N)	20 ”
Phosphate (Ph 4-p)	10 ”
Phytoplankton	8.16 x 10 . . . 5 cells/litre
Zooplankton	9 x 10 5 cells/litre

(Source: Environmental parameters observed on 16-6-1998 during the fish-farming season, one month before fish harvest from KRPLLD, project report by K. G. Padmanabhan 1995).

Chapter III

MATERIALS AND EXPERIMENTAL

III.1 Ecological Parameters

A. Physicochemical parameters of farming medium

- (a) (i) Water: Temperature, Light, Transparency, pH, DO, CO₂, Alkalinity, Salinity, Hardness
- (a) (ii) Primary productivity
- (a) (iii) Nutritional status: Phosphate, Nitrate, Nitrite (Micronutrients of water)
- (b) Sediments: NPK, Organic carbon particle size/gram size
- (c) Benthic biomass of micro-organisms

1. The standard procedure for analysis of physicochemical parameters can be followed as described in Gotterman and Chymo, IBP Handbook No. 8, *Methods for Physical and Chemical Analysis of Freshwaters/Chemical Analysis of Fish and Soil and Water* (IBP Manual No. 16). APHA standard methods for the analysis of water and waste waters, Chemical and biological methods for water pollution studies, Trivedy and Goel, Environmental publications.

2. Hardness

EDTA Titrimetric Method

Principles

Ethylenediaminetetra acetic acid and its sodium salts (EDTA) form a chelated soluble complex when added to a solution of certain metal cations. If a small amount of a dye such as erichrome black T is added to an aqueous solution

containing calcium and magnesium ions at a pH of 10 ± 0.1 , solution becomes wine red. EDTA is added as a titrant, the calcium and magnesium will be complexed, and when all of the Mg and Ca has been complexed, the solution turns from wine red to blue, making the end point of the titration.

Reagents

- (a) Buffer solution – dissolve 16.9 g ammonium chloride (NH_4Cl) in 143 ml conc. ammonium hydroxide (NH_4OH). Add 1.25 g magnesium salt of EDTA and dilute to 250 ml with distilled water.
- (b) Indicator: Erichrome black T.
- (c) EDTA.

Procedure

Take 100 ml of the water sample. Add 2 ml of the buffer and a few drops of the indicator erichrome black T. Titrated against EDTA till blue colour appears. End point is the change of colour from red to blue.

Classification of hardness

Mg/l

0-75	Soft
75-150	Moderately hard
150-300	Hard
Above 300	Very hard

CO_2 estimation

Principle

Free CO_2 can be determined by titrating the sample using a strong alkali to pH 8.3. At this pH all the free CO_2 is converted into bicarbonate.

Reagents

(a) NaOH 0.05 N.

Prepare 1.0 N NaOH by dissolving 40 g of NaOH in CO₂ free distilled water to make 1 litre of solution – Dilute 50 ml of 1.0 N NaOH to 1 litre.

(b) Phenolphthalein indicator

Procedure

Take 100 ml of sample in a conical flask and add a few drops of phenolphthalein indicator. If the colour turns pink, free CO₂ is absent. If the sample remains colourless titrate against 0.05 N NaOH. At the end point a pink colour appears.

$$\text{Free CO}_2 \text{ mg/L} = \frac{(\text{ml} \times \text{N}) \text{ of NaOH} \times 1000 \times 44}{\text{ml of sample}}$$

Dissolved oxygen

Winkler's Iodometric Method

Principle

The manganous sulphate reacts with the alkali to form a white precipitate of manganous hydroxide which in the presence of oxygen, gets oxidised to a brown coloured compound. In the strong acid medium, manganic ions are reduced by iodide ions which get converted into iodine equivalent to the original concentration of oxygen in the sample. The iodine can be titrated against thiosulphate using starch as an indicator.

Reagents

Sodium thiosulphate 0.01 N. Dissolve 24.82 g of $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ in boiled distilled water and make up the volume to 1 litre. This is 0.1 N stock solution. From this 0.01 N solution is prepared by 10 times dilution.

Alkaline potassium iodide solution

Dissolve 100 g of KOH and 50 g of KI in 200 ml of boiled distilled water.

Manganese sulphate solution

Dissolve 100 g of $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$ in 200 ml of boiled distilled water and filter.

Starch solution

Dissolve 1 g of starch in 100 ml of warm (80-90°C) distilled water.

Sulphuric acid

Conc. H_2SO_4 conc. - spgr. 1.84.

Procedure

Fill the sample in a glass stoppered bottle (BOD bottle) of known volume (100-300 ml) carefully, avoiding any kind of bubbling and trapping of the air bubbles in the bottle after placing the stopper. Pour 1 ml of each MnSO_4 and alkaline KI solution well below the surface from the wells. The reagent can also be poured at the bottom of the bottle. Use always separate pipettes for these two reagents. A precipitate will appear.

Place the stopper and shake the contents well by inverting the bottle repeatedly. Keep the bottle for sometime to settle down in precipitate.

Add 1-2 ml conc. H_2SO_4 and shake well to dissolve the precipitate.

Pipette out 40 ml in a conical flask for titration. Titrate the contents, within one hour of dissolution of the precipitate against sodium thiosulphate solution using starch as an indicator. As the end point, dark blue colour changes to colourless.

Calculation

$$\text{Dissolved oxygen mg/L} = \frac{\text{ml} \times \text{N of titrant} \times 8 \times 1000}{V_2 \left(\frac{V_2 - v}{V_1} \right)}$$

where V_1 = volume of sample bottle after placing the stopper.

V_2 = volume of part of the contents titrated

v = volume of MnSO_4 and KI added.

Salinity

Reagents

Silver nitrate solution 1.698 g AgNO_3 was dissolved in 1000 ml (0.01 N).
 Potassium chromate indicator solution: Dissolve 0.5 g K_2CrO_4 in 100 ml H_2O .
 Take 50 ml of water sample in a conical flask, add 2 to 3 drops of I_2CrO_4 and titrate against AgNO_3 until a red precipitate just forms.

Calculation

Calculate the chlorosity equivalent to 1 ml AgNO_3 solution.

$$\text{CIEe} = \text{N} \times 0.0355$$

where CIEq = chlorosity equivalent and N = normality of AgNO_3 .

Calculate the chlorosity

$$Cl = d \times ClEq \times \frac{1000}{25}$$

where d = ml titrant used and ClEq = chlorosity equivalent $AgNO_3$.

Convert chlorosity to salinity by using the Table – Chart – Record salinity, S as % or Convert chlorosity to chlorinity by substrating the appropriate factor given in chart.

$$\text{Salinity (ppt)} = \text{Chlorinity (ppt)} \times 1.805 + 0.03$$

Alkalinity

Principle

Total alkalinity is the measure of the capacity of the water to neutralise a strong acid. The alkalinity in the water is generally imparted by the salts of the carbonates, bicarbonates, phosphates, nitrates, borates, silicates, etc. together with the hydroxyl ions in free state.

Total alkalinity, carbonates and bicarbonates can be estimated by titrating the sample with a strong acid, HCl or H_2SO_4 first to pH 8.3 using phenolphthalein as an indicator and then further to pH between 4.2 and 5.4 with methyl orange.

Reagents

Hydrochloric acid, 0.1 N

Dilute 12 N concentrated HCl to 12 times to prepare 1.0 N HCl, dilute it further to make 0.1 N HCl, standardise it against sodium carbonate solution.

Methyl orange indicator, 0.05%

Dissolve 0.5 g of methyl orange in 100 ml of distilled water.

Phenolphthalein indicator

Dissolve 0.5 g of phenolphthalein in 50 ml of 95% ethanol and add 50 ml of distilled water. Add 0.05 N CO₂ free NaOH solution dropwise, until the solution turns faintly pink.

Sodium carbonate 0.1 N

Dissolve 5.3 g of Na₂CO₃, previously dried at 250°C for about 4 h in distilled water to prepare 1 litre of solution.

Procedure

Take 100 ml of sample in a conical flask and add 2 drops of phenolphthalein indicator. If the colour changes to pink, titrate it with 0.1 N HCl until the colour disappears at end point. Now add 2-3 drops of methyl orange to the same sample and continue the titration further, until the yellow colour changes to pink at end point.

Calculation

$$\text{PA as CaCO}_3 \text{ mg/L} = \frac{(\text{A} \times \text{Normality}) \text{ of HCl} \times 1000 \times 50}{\text{ml of sample}}$$

$$\text{TA as CaCO}_3, \text{ mg/l} = \frac{(\text{B} \times \text{Normality}) \text{ of HCl} \times 1000 \times 50}{\text{ml of sample}}$$

where A = ml of HCl used with phenolphthalein

B = ml of total HCl used with phenolphthalein and methyl orange

PA = phenolphthalein alkalinity

TA = total alkalinity.

Nitrite

Principle

Nitrite (NO_2^-) is determined by the formation of a reddish purple dye produced at pH 2.5 by coupling diazotised sulphanilic acid with NED dehydrochloride OD at 543 nm.

Apparatus

Spectrophotometer for use at 543 nm providing a light path of 1 cm or larger.

Reagents

- (a) Sulphanilamide reagent: Dissolve 5 g sulphanilamide in a mixture of 50 ml conc. HCl and about 300 ml nitrite free water. Dilute to 500 ml with nitrite free water.
- (b) N-(1-naphthyl)-ethylenediamene-di-hydrochloride solution: Dissolve 500 mg N-(1-naphthyl)-ethylene diamine dihydrochloride in 500 ml nitro free distilled water. Store in a dark bottle.
- (c) HCl: 1 + 3. Use nitrogen free distilled water for dilution.

Procedure

To 25 ml of the sample solution add 0.5 ml sulphanilamide. Keep it for 2 min. Then add 0.5 ml Naphthyl ethylene diamene-dihydrochloride within 8 min. The colour developed was measured using spectrophotometer OD at 543 nm.

Phosphate

Ascorbic acid method

Principle

Ammonium molybdate and potassium antimonyl tartrate react in acid medium with orthophosphate to form a heteropoly acid-phosphomolybdic acid - that is reduced to intensely coloured molybdenum blue by ascorbic acid.

Minimum detectable concentration

Approximately 10 µg P/L

<u>Approximate P Range (mg/L)</u>	<u>Light Path (cm)</u>
0.30-2.0	0.5
0.15-1.30	1.0
0.01-0.25	5.0

Apparatus

Spectrophotometer with infrared phototube for use at 880 nm, providing a light path of 2.5 cm or larger.

Reagents

- (a) Surface acid H_2SO_4 5N. Dilute 10 ml conc. H_2SO_4 to 500 ml with distilled water.
- (b) Potassium antimonyl tartrate: Dissolve 1.3715 g potassium antimonyl tartrate in 400 ml distilled water.
- (c) Ammonium molybdate solution: Dissolve 20 g $(\text{NH}_4)_6\text{MO}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}$ in 500 ml distilled water.
- (d) Ascorbic acid, 0.01 M: Dissolve 1.5 g ascorbic acid in 100 ml distilled water.
- (e) Combined reagent: Mix the above reagents in the following proportions for 100 ml of the combined reagent, 50 ml 5N H_2SO_4 , 5 ml potassium antimonyl tartrate solution, 15 ml ammonium molybdate solution and 30 ml ascorbic acid solution. Mix after addition of each reagent. Shake and keep for sometime until turbidity disappears.
- (f) Standard phosphate solution: Dilute 50 ml stock phosphate solution to 1000 ml with distilled water: 1.00 ml = 2.50 µg P.

Procedure

Pipette 50.0 ml sample into a clean, dry test tube. Add 0.05 ml (1 drop) phenolphthalein indicator, of a red colour develops add 5 N H₂SO₄ solution dropwise to just discharge the colour. Add 10 ml combined reagent and mix thoroughly. After at least 10 min, but not more than 30 min, measure absorbance of each sample at 880 nm using reagent blank as the reference solution.

Prepare individual calibration curves from a series of six within the phosphate ranges indicated. Use a distilled water blank with the combined reagent to make photometric readings for the calibration curve.

Calculation

$$\text{mg P/L} = \frac{\text{mg P (in approximately 58ml final volume)} \times 1000}{\text{ml sample}}$$

III.1 B Soil Analysis

(a) Soil texture

The objective of determining textural composition of soils is to know the percentage of soil materials contained in different grain size fractions viz., sand, silt and clay and to classify the soils to any particular textural group so that dominant grain sizes present in the soil can be identified easily.

Principle

Textural composition of soils can be estimated by means of mechanical analysis. This consists essentially of two distinct operations viz. dispersion of the soil to ultimate grain sizes and grading the dispersed grains according to their groups.

Requisites

- (a) Apparatus : Mechanical shaker, stirrer.
- (b) Glasswares : 1 litre cylinder, 20 ml pipette, 500 ml and 50 ml beaker, 250 ml conical flask etc.
- (c) Reagents:
- (i) 6 per cent hydrogen peroxide (H_2O_2): H_2O_2 is generally sold at 30 per cent concentrations. For the purpose of preparing 6 per cent H_2O_2 , this 30 per cent solution is to be diluted at 1:5 H_2O_2 :water ratio.
 - (ii) 2 N HCl: Dilute 100 ml concentrated HCl to 500 ml for getting approximately 2 N HCl.
 - (iii) 2 N NaOH: Dissolve 40 g NaOH pellets in about 300 ml DW. Allow it to cool and dilute up to 500 ml with water.
 - (iv) 5 per cent silver nitrate (AgNO_3): Dissolve 5 g AgNO_3 in 100 ml DW.

Procedure

Take 20 g of soil in a 50 ml beaker and add about 250 ml DW. Boil it for about 10-15 min and decant the supernatant water. Now add 30 ml of 6 per cent H_2O_2 to this soil samples and digest on a water bath. Add more H_2O_2 if necessary and continue digestion till the frothing stops. Add about 30 ml N HCl and 100 ml DW, boil for a few minutes and allow the soil suspension to stand for one hour with frequent stirring to make the soil free from carbonates. Filter the soil and wash it repeatedly with hot water till the filtrate becomes chloride (Cl) free. This can be tested by receiving a few drops of filtrate in a test tube containing small amount of AgNO_3 . Presence of Cl will develop white colours in the solution. Transfer the suspension to a 250 ml conical flask, add 5 ml of 2 N NaOH and shake for half an hour with a mechanical shaker. Transfer the contents immediately to a 1000 ml tall cylinder, make up the volume with DW and stirr the entire volume thoroughly with the help of a stirrer. Allow the suspension to stand for exactly 4 min, immediately lower a 20 ml pipette to 10 cm depth of the suspension and collect 20 ml of the content. Transfer it in a 50 ml previously

weighed beaker marked as beaker A. Make up the volume of the 1000 ml cylinder with DW, stir the suspension as before and allow it to stand for 6 h. Repeat the same procedure to collect 20 ml of suspension to a previously weighed beaker marked as B. Dry the suspension in two beakers in an oven to constant weights. Get the actual weights of dry materials in the beakers after subtracting the weights of the empty beakers from the values of beakers + dried materials.

Calculation

If the weight of dry material in beaker A be x g and that in beaker B be y g. then

$$\begin{aligned}\text{Percentage of clay} &= y \times 250 \\ \text{Percentage of salt} &= (x-y) \times 250 \\ \text{Percentage of sand} &= 100 - (x \times 250)\end{aligned}$$

(b) Organic system

The role of organic carbon (OC) in maintaining the productivity of fish pond is well recognised. Apart from influencing various physico-chemical properties of bottom soils and releasing different nutrient elements to more available forms in the pond environment, it controls an important property of the pond ecosystem viz. oxidation reduction reaction (Mandal and Chattopadhyay, 1992).

Principle

The rapid titrimetric method of Walkley and Black (1934) using heat of dilution is widely used for determination of OC in soils. This method has an advantage that it excludes less active elementary carbon of soil (e.g., graphite) and includes only that part of OC which is involved in maintenance of pond productivity. Under this method organic matter in soil is oxidised with excess

standard potassium dichromate ($K_2Cr_2O_7$) using the heat of dilution of added concentrated H_2SO_4 . The unutilised $K_2Cr_2O_7$ is then titrated with standard ferrous ammonium sulphate ($Fe(NH_4)_2(SO_4)_2$) and the amount of OC is determined from the amount of standard $K_2Cr_2O_7$ used for oxidation.

Requisites

- (a) Glasswares: 500 ml conical flasks, pipette, burette, measuring cylinder, 1 litre volumetric flasks.
- (b) Reagents:
 - (i) 1 N $K_2Cr_2O_7$: Dissolve 49.0 g of solid $K_2Cr_2O_7$ in DW and make up the volume to 1 litre.
 - (ii) 1N $Fe(NH_4)_2(SO_4)_2$: Dissolve 392.2 g of $Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$ in 800 ml of DW, add 20 ml conc. H_2SO_4 and dilute to 1 litre.
 - (iii) Diphenyl amine indicator: Dissolve 0.5 g diphenyl amine in 20 ml DW and add 100 ml conc. H_2SO_4 .
 - (iv) Conc. H_2SO_4 .
 - (v) 85 per cent orthophosphoric acid (H_3PO_4).

Procedure

Take 1 g of soil sample in a 500 ml conical flask and moisten it with a few drops of DW, keep for about 10 min. Add exactly to 1 ml of 1 N $K_2Cr_2O_7$ and then 20 ml of conc. H_2SO_4 . Mix the contents thoroughly and keep in a dark place for 30 min. Then add 200 ml DW and 10 ml of H_3PO_4 . Put about 1 ml of diphenyl amine indicator to develop a deep blue colour. Titrate the solution with standard $Fe(NH_4)_2(SO_4)_2$. At the end point the blue colour suddenly flushes to bright green. Carry out a blank with all the reagents but without the soil.

Calculation

$$\text{Organic carbon (per cent)} = (B - A) \times 0.3$$

where B = titration value (ml) of $\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2$.

A = titration value (ml) of $\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2$ with sod.

III.1.C Water Analysis

III.1.C(a) Primary productivity

Primary Productivity – Light and Dark Bottle Method (Trivedy and Goel, 1989) Primary productivity (PP) of an ecological system, community or any part thereof, is defined as the rate at which radiant energy is stored by photosynthetic or chemosynthetic activity of producer organisms (chiefly green plants) in the form of organic substances which can be used as food materials (Odum, 1971). Of this gross primary productivity (GPP) is the total rate of photosynthesis including the organic matter used up in respiration during the measurement period while net primary productivity (NPP) indicates the amount of organic matter that is stored in the plant tissues after meeting the demand of respiration. Close correlation between primary productivity and fish yield has been emphasised by many workers (Wolny and Grygierek, 1972; Sreenivasan, 1968 and others).

Principle

Primary productivity of a water body is usually determined from the differences in DO values of water samples incubated in bottles under light and dark conditions thus allowing photosynthetic activity to take place in one bottle and the same to be restricted under the other. The decrease in DO content in the dark bottle, as compared to initial value represents the amount of DO consumed by respiration by all the biomass in the bottle. The increase in DO in the light bottle indicates that amount of DO in water which exceeded oxygen consumption by respiration. Both GPP and NPP can be calculated from the differences in these DO values.

Requisites

(a) Glasswares

Light and dark bottles: Use two 125 ml stoppered transparent glass bottles as initial and light bottles. For using as dark bottle, paint a similar bottle with black colour and then wrap with black cloth or polythene sheet in such a way that light penetration in the bottle can be prevented.

(b) Reagents

All the chemicals for DO estimation (Winkler's method)

Procedure

Taken in water sample cautiously as well as uniformly in three bottles (initial, light and dark) from the desired depth of water. Add 1 ml of manganous sulphate and alkaline iodide each in the initial bottle. Invert the stoppered bottle a few times. Take the other two bottles and dip them in the water under the depth from which water samples were collected. Incubate the water samples under water for some period which should not normally be less than 3 h. After expiry of the time, take up both of the bottles and fix oxygen as before. Determine DO values of water in all the bottles as stated (Winkler's method).

Calculation

$$\text{GPP} = \frac{\text{LB} - \text{DB}}{\text{T}} \times \frac{0.375}{1.2} \times 1000 \text{ mg cm}^{-3}\text{h}^{-1}$$

$$\text{NPP} = \frac{\text{LB} - \text{IB}}{\text{T}} \times \frac{0.375}{1.2} \times 1000 \text{ mg cm}^{-3}\text{h}^{-1}$$

where LB = DO (ppm) in light bottle

DB = DO (ppm) in dark bottle

IB = DO (ppm) in initial bottle

T = Time (h) of incubation

0.375 = ratio of the weight of C and O

1.2 = photosynthetic coefficient

Measurement of productivity

Direct measurement based on the determination of photosynthesis. Oxygen method (Gaarder & Gram, 1921). Calculated the photosynthesis from amount of oxygen produced by phytoplankton during a given time.

Sampling

Water samples should be collected from regular depths or at percentage of surface illumination (100%, 75%, 50%, 25%, 1%) with vandorn bottle of 2L capacity, are filled in the four bottles i.e. initial (one) light (two) and dark. Dark bottles are prepared by polishing or painting the clear corning ground stoppered bottles with black enamel paint. To ensure the absence of light a black cloth or resin bag may be used as a cover of the bottles. The depths can be calculated by sechi-disc readings.

Procedure

Add Winkler A and Winkler B (0.5 ml in 125 ml sample) in the initial bottle. Sets of light and dark bottles are suspended in situ at the original depth from which the water sample is taken. They can be suspended from sunrise to noon or from noon to sunset on a float or from a simple bamboo stand which is triangular in shape. After a given period 6 or 12 or 24 h the oxygen content of each bottle is determined by the Winkler's method. From the difference between the initial and final concentrations of oxygen production is obtained in the transparent bottle (L-I) and respiration in the dark bottle (I-D). However, it should be noted that the decrease of oxygen in the dark bottle resulted from the consumption of oxygen not only through respiration of phytoplanktons and other organisms, but also through the decomposition of organic debris in the water. It should also be noted that the condition inside the dark bottle favours the bacterial growth. Then bacteria also liberate dissolved oxygen and the total oxygen in the

bottle has increased. If this increase is accounted for M calculation, it leads to the over estimation of gross production.

Calculations

Oxygen estimated by Winkler's method is used for the calculation of primary productivity.

$$\text{Primary production (mg/L)} = \frac{\text{O}_2(\text{ml}) \times 0.375}{\text{PQ}}$$

PQ = photosynthetic quotient = 1.25 (Strickland, 1960)

0.375 = factor (Qasim et al. 1968)

O₂ (ml) I-D respiration (in respiration instead of PQ, RQ is used which is generally equivalent to 1.

L-D = Gross production

L-I = Net production

These data are converted into gm of oxygen per cubic meter by multiplying the numerator by denominator by 1000.

$$\text{Mgl/m}^3 = \text{mg/l} \times 1000$$

$$\text{Primary productivity (mg/m}^3\text{/hr)} = \frac{\text{O (ml)} \times 0.375 \times 1000}{\text{PQ} \times \text{No. of incubation hours}}$$

$$\text{Plankton community respiration (mg. oxygen consumed per hour)} = \frac{\text{I} - \text{D}}{24}$$

To calculate the photosynthetic activity per square meter of the lake surface either (1) multiply cubic meter value by depth (in meters), (2) plot actual m³ values on linear graph against depth (m) and integrate area beneath the curve by planimeter or counting of squares.

Since we know the relationship of O₂ evolution to carbon assimilation, photosynthetic rate can be calculated in various terms equivalent to the other parameters. Table A indicates phytoplankton equivalents and permits the conversion of oxygen evolution data to other forms. For example, the evolution 1 ml of O₂ (column 3) is equivalent to the synthesis of 0.53 mgc, 1 mg and 1.05 mg dry plankton (Lind 1974).

Table A

	Carbon 1 mg	Dry organic matter 1 mg	Oxygen 1 ml	1 mg	Plankton biomass 1 mg	Dry plankton 1 mg
Carbon (mg)	1.0	0.54	0.53	0.375	0.11	0.55
Dry organic matter (mg)	1.85	1.0	1.0	0.69	0.20	0.92
Oxygen (mg)	1.87	1.0	1.0	0.70	0.21	0.93
Oxygen (mg)	2.67	1.44	1.44	1.0	0.29	1.34
Plankton biomass (mg)	8.9	4.8	4.7	3.3	1.0	4.45
Dry plankton (mg)	1.98	1.07	1.05	0.74	0.22	1.0

III.1.D Estimation of total nitrogen in soil by Micro Kjeldahl's method

Principle

The nitrogen present in combined organic form is converted to ammoniacal form by digestion with conc. H₂SO₄ in the presence of catalyst mixture. The digestion is made alkaline and NH₃ liberated is distilled off into an acid solution. Quantity of NH₃ liberated is determined by titration against standard acid.

Reagents

1. Conc. H_2SO_4
2. Digestion activator – $\text{K}_2\text{SO}_4 + \text{CuSO}_4 + \text{Selenium powder}$
3. Standard acid.
4. Mixed indicator solution
5. 4% boric acid
6. 40% NaOH solution

Preparation of Reagents

1. 4% boric acid – Dissolved 4 g boric acid in 100 ml water.
2. 40% NaOH – Dissolved 40 g NaOH in 100 ml water.
3. Mixed indicator – Mixed 2 parts of 0.2% alcoholic methyl red indicator solution with 1 part of 0.2% methylene blue indicator solution in alcohol (20 ml for 500 ml in water)
4. 0.02 N HCl – 17.8 ml of conc. HCl is diluted to 10 litre (8.9 a ml made up to 580 ml)

Standardisation of acid

Reagents required

- (1) Methyl orange indicator 0.1% in water.
- (2) Reference solution: 80 ml of CO_2 from water with 3 drops of methyl orange indicator.
- (3) Na_2CO_3 solution 0.02 N: For this dry A.R. Na_2CO_3 at 120°C kept for 2 h. Cool in a desiccator and weigh 1.068 g into 100 ml volumetric flask and make up to the mark with distilled water. This gives 0.2 N solution. 20 ml of the solution is diluted to 200 ml to get 0.02 N solution.

Procedure for standardisation

40 ml of 0.02 N. NaCO_3 solution is taken in a 250 ml conical flask. Three drops of methyl orange indicator is added and this is titrated against the HCl to be

standardised until the colour begins to deviate from water tint (reference solution). Boiled the solution gently for 2 min to expel CO₂. Cooled and titrated against the acid until the colour is water tint of indicator.

Procedure

1 g soil (passed through 0.2 mm sieve) is placed in a digestion flask. About 1 g digestion mixture and 10 ml conc. H₂SO₄ are added to the sample and digestion is affected in a Kjeldahl digestion rack with low flame for the first 10-30 min until the frothing stops. Then the flame is gradually increased until the sample is completely charred. The flask is rotated at intervals and heating is continued until organic matter is destroyed and this end point is judged by timing the digestion for 15 min after the solution had charred. At the end of the digestion the flask taken out and kept for cooling. After cooling the digest up to 100 ml.

Distillation

10 ml of the digest (made up to 100 ml) is transferred into the vacuum mantle of the steam distillation assembly. 10 ml of 40% NaOH is added and washed in with distilled water. The ammonia is distilled out for about 5 min and is collected in a 100 ml conical flask containing 10 ml of 4% boric acid 30 ml of the distillate is then collected and back titrated against standard acid.

Result

Percentage of N ₂ in the soil sample 1	= 0.308%
Percentage of N ₂ in the soil sample 2	= 0.224%

Calculation

Weight of soil sample taken	= 1 g
Volume of acid used for titration in sample 1	= 1.2 ml
Volume of acid used for titration in sample 2	= 0.9 ml

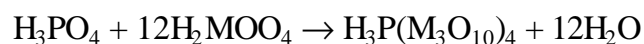
$$\begin{aligned}
\text{Blank value} &= 0.1 \text{ ml} \\
\text{Normality of acid} &= 0.02 \\
\text{1 ml of 1 N acid} &= 0.014 \text{ g of N}_2 \\
&= \frac{(\text{T.V.} - \text{B.V.}) \times \text{Normality} \times 0.014 \times 100 \times 100}{10 \times 1} \\
&= \frac{(1.2 - 0.1) \times 0.02 \times 0.014 \times 100 \times 100}{10 \times 1} \\
&= 0.308\%
\end{aligned}$$

$$\begin{aligned}
\text{\% of nitrogen in the soil sample no. 2} &= \frac{(0.9 - 0.1) \times 0.02 \times 0.014 \times 100 \times 100}{10 \times 1} \\
&= \frac{0.8 \times 0.02 \times 0.014 \times 100 \times 100}{10 \times 1 \times 10000} \\
&= 0.224\%
\end{aligned}$$

DETERMINATION OF AVAILABLE PHOSPHORUS IN SOIL CALORIMETRIC METHOD

Principle

The extracted phosphorus in solution is estimated by the blue colour of the chlorostannous reduced molybdo phosphoric acid in hydrochloric acid system. A heteropolycomplex is thought to be formed by co-ordination of molybdate ions, with phosphorus as central co-ordinating ions, the oxygen of the molybdate radical being substituted for that of PO_4^-



A characteristic blue colour is produced by selective induction of the complex by stannous chloride. The colour intensity is measured by Klett. Summerson photoelectric colorimeter at 660 nm using red filter. The intensity of the colour is proportional to the P concentration of the medium.

Apparatus

Klett Summerson photoelectric colorimeter, conical flask, funnel, whatman no. 40 filter paper, pipette, volumetric flask, etc.

Reagents

(1) Bray Extract No. 1

(0.03 N, NH_4F in 0.025 N hydrochloric acid extraction medium).

Dissolved 22.5 g of NH_4F in 200 ml distilled water, filtered and added that filtrate to 18 litres of water containing 40 ml of conc. HCl. Made up the volume to 20 litre with distilled water.

(2) Molybdate Reagent

Dissolved 15 g of ammonium molybdate $(\text{NH}_4)_6\text{MO}_7\text{O}_{24}\cdot 4\text{H}_2\text{O}$ in 300 ml distilled water. Added this solution into 350 ml. 10 N HCl gradually with stirring and diluted to 1 litre with distilled water.

(3) Stannous chloride (Stock solution)

Dissolved 10 g of stannous chloride ($\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$) in 25 ml conc. HCl. Added a piece of metallic tin and stored the solution in glass stoppered bottle.

(4) Stannous chloride (working solution)

Diluted 1 ml of the stock solution to 66 ml with distilled water just before use. Always prepare fresh solution.

Procedure

(a) Preparation of standard curve

Dissolved 0.2195 g of pure dry KH_2PO_4 in 1 litre of distilled water to get a 50 ppm, P solution. For the preparation of a secondary working standard of 10 ppm P solution, pipetted out 20 ml of the above solution and make to 100 cc. Pipetted out 0, 0.5, 1.5, 2 and 2.5 ml to a 50 ml volumetric flask serially numbered from 0 to 5. Added 5 cc Bray solution followed by 5 ml molybdate reagent to each of these flasks and mixed well. Then added 1 cc of SnCl_2 solution, shaken and diluted to 50 ml with distilled water. Thus these will contain 0 (blank), 0.1, 0.2, 0.3, 0.4 and 0.5 ppm of P respectively. After 10 min the blue colour of the solution is read in the photoelectric colorimeter, using red filter with the blank adjusted to zero. A graph is constructed with meter reading against concentration of P.

(b) Assay of P in soil extract

Weighed out 5 g soil into a 500 ml shaking bottle. Added 50 cc of Bray solution and the mixture is shaken for 5 min in a mechanical shaker. Filtered the contents through a Whatman No. 42 filter paper, collecting the filtrate in a beaker. Transferred 5 ml of the soil extract into a 50 ml volumetric flask. Added 5 ml of molybdate reagent followed by 1 cc of SnCl_2 . Made up the solution to 50 ml. Mixed well and kept for colour development. Then it is fed to a photoelectric colorimeter and the light transmission is read. The ppm concentration of P is found out from the standard curve.

Result

Amount of P in the soil in kg/ha,

Sample 1 = 2.6 kg/ha

Sample 2 = 7.0 kg/ha

P₂O₅ content of soil in kg/ha,

Sample = 5.954 kg/ha

(It is rated as low)

P₂O₅ content of sample 2 soil in kg/ha,

= 16.03 kg/ha

(It is rated as low)

Rating scale for P₂O₅

Low = 20 kg/ha

Medium = 20-50 kg/ha

High = 50 kg/ha

Observation

ppm	Meter reading
0	-
0.1	26
0.2	52
0.3	80
0.4	-
0.5	-
s ₁ ()	11
s ₂ ()	27

Calculation

$$\text{Amount of P in the soil} = \frac{X \times 50 \times 50\%}{5 \times 5 \times 10000}$$

where X is the ppm of P from graph

$$\begin{aligned}
\text{Amount of P in the soil sample 1} &= \frac{0.04 \times 50 \times 50\%}{5 \times 5 \times 10000} \\
&= 0.0013\% \\
&= 0.0013 \times 10000 \times 2.24 \\
&= 2.6 \text{ kg/ha} \\
\text{Amount of P in soil sample 2} &= \frac{0.105 \times 50 \times 50\%}{5 \times 5 \times 10000} \\
&= 0.00035\% \\
&= 0.00035 \times 10000 \times 2 \\
&= 7.0 \text{ kg/ha}
\end{aligned}$$

Determination of available potassium in soils

Principle

The principle underlying this is that a large number of elements when excited in a flame emit radiation at characteristic wave lengths. The excitation causes one of the outer electrons of neutral atoms to jump to an outer orbit of higher energy level or the atoms maybe excited sufficiently to loss an electron completely (ionisation). When excited atoms return to lower energy levels, light of characteristic wavelength is emitted. Excited atoms or ions give light radiation at a very definite wavelength and thus K gives at 404.4 and 767 nm. The flame photometer employs a relatively low temperature for excitation and measures with a photocell the emission intensity which is proportional to concentration in solution.

Apparatus and reagent

1. Flame photometer with K filter
2. Pipette
3. 100 ml conical flask

4. 1 N ammonium acetate pH 7.0. Dissolve 1540 g of solid ammonium acetate in 20 litre of water. Adjusted to pH 7.0 by adding either NH_4OH or acetic acid.
5. Standard potassium solution. Dissolved 1.5851 g pure KCl in 1 litre of distilled water. This solution contains 1 mg K_2O per millilitre (1000 ppm).
6. Working standard, 60 ppm K_2O solution. 60 ml of the stock solution is diluted to 1 litre with the N ammonium acetate solution. This solution contains 60 mg/litre of K_2O (60 ppm).

Procedure

1. Added 50 ml of 1 N ammonium acetate pH 7.0 to 100 ml conical flask containing 10 g of soil. Set the tightly stoppered flask in a wooden rack. The flask is shaken for 30 min on the mechanical shaker or vigorously by hand intermittently every 5 min.
2. Filtered the flask solution.
3. Made up one of the extract to 50 ml.
4. The K filter is put in the flame photometer and taken the reading of the test solution.
5. Also prepared the standard curve of K by taking graded amounts of standard K solutions. Set up the flame photometer by atomising 0 and 60 mg K_2O per litre alternatively to 0 and 100 scale readings, respectively. Atomise intermediate working standard solution and record the meter reading. Plot these reading against the respective K content and connect them with a straight line.

Result

Content of K in kg/ha in

Soil sample S_1 = 50 kg/ha

$$\text{Soil sample } S_2 = 138 \text{ kg/ha}$$

Content of K_2O in kg/ha in

$$\text{Soil sample } S_1 = 95 \text{ kg/ha}$$

(It is rated as low)

$$\text{Soil sample } S_2 = 262.2 \text{ kg/ha}$$

Rating scale of K_2O

$$\text{Low} = 125 \text{ kg/ha}$$

$$\text{Medium} = 125-300 \text{ kg/ha}$$

$$\text{High} = 300 \text{ kg/ha}$$

	Instrument	ppm
Sample 1	25	2.5
Sample 2	69	6.9

$$\text{Weight of soil taken} = 10 \text{ g}$$

Extract volume made up to 100 ml

$$\text{Amount of K in kg/ha in soil} = \frac{X \times 50 \times 2.24}{10}$$

Content of K in kg/ha in

$$\text{Soil Sample } S_1 = \frac{2.5 \times 100 \times 2.24}{10}$$

$$= 50 \text{ kg/ha}$$

Content of K in kg/ha in

$$\text{Soil Sample } S_2 = \frac{6.9 \times 100 \times 2.24}{10}$$

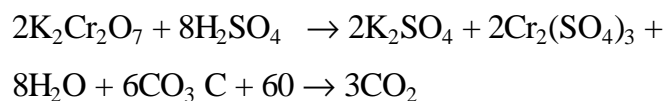
$$= 138 \text{ kg/ha}$$

ESTIMATION OF ORGANIC CARBON CONTENT OF SOIL BY WALKLEY AND BLACK RAPID TITRATION METHOD

Principle

Organic carbon present in organic matter is oxidised to CO₂ in the presence of K₂Cr₂O₇ and H₂SO₄. K₂Cr₂O₇ produces nascent oxygen which combines with organic carbon producing CO₂. The excess potassium dichromate not reduced by the organic matter of soil is determined by titration with standard ferrous ammonium sulphate. Nitrates may interfere when present more than 1/20th of the carbon content.

The reaction:



Reagents required

1. 1 N K₂Cr₂O₇ – 49.04 g of K₂Cr₂O₇ dissolved in distilled water and volume made up to a litre.
2. 0.5 N Ferrous Ammonium Sulphate – 362 g of ferrous ammonium sulphate dissolved in distilled water. Added 15 ml conc. H₂SO₄ and made up to 2 litre.
3. Orthophosphoric acid (85%).
4. Conc. H₂SO₄ (36%).
5. Diphenyl amine indicator. Dissolved 0.32 g of diphenyl amine in a mixture of 100 ml H₂SO₄ and 20 ml distilled water.

Procedure

2 g of soil is weighed in a 250 ml conical flask. 10 ml of 1 N K₂Cr₂O₇ and 20 ml conc. H₂SO₄ are added in the sample. The flask is kept sometime for cooling. Then 10 ml of orthophosphoric acid and 100 ml of distilled water is

added in the flask. 10 drops of phenyl amine indicator is added and titrated against 0.5 N. Ferrous ammonium sulphate. End point is the appearance of brilliant green colour. A blank is to be estimated.

Result

Organic carbon content of sample 20	= 1.065%
rated as high	
Organic matter content of sample 20	= 1.8318%
Organic carbon in sample 8	= 1.1175%
Rated as high	
Organic matter content of sample 8	= 1.9221%
Approx. Nitrogen content of sample 20	= $\frac{1.065}{10}$
	= 0.1065%
Approx. Nitrogen content of sample 8	= $\frac{1.1175}{10}$
	= 0.11175%
% of organic C in sample 20	= 0.66% medium
∴ % of organic matter	= 1.1352%
% of N	= 0.066
% of organic C in sample 8	= 0.51% medium
% of organic matter	= 0.9804
∴ % of N	= 0.057%
Rating scale for organic carbon	
Low	< 10.4%
Medium	0.4-0.75%
High	> 0.75%

Calculations

$$\% \text{ of organic carbon} = \frac{(S - T) \times 0.003 \times 100}{2 \times \text{wt. of soil}}$$

S = volume of N/2 ferrous ammonium sulphate used for blank.

T = volume of N/2 ferrous ammonium sulphate used for sample test.

Blank value = 17.5

Sample 20 = 3.3

Sample 8 = 2.6

$$\begin{aligned}\text{Organic carbon in sample 20} &= \frac{(S - T) \times 0.003 \times 100}{2 \times 2} \\ &= \frac{(17.5 - 3.3) \times 0.003 \times 100}{2 \times 2} \\ &= 1.065\%\end{aligned}$$

Organic matter content = $1.065 \times 1.724 = 1.8318\%$

$$\begin{aligned}\text{Organic carbon in sample 8} &= \frac{(17.5 - 2.6) \times 0.003 \times 100}{4} \\ &= 1.1175\%\end{aligned}$$

Organic matter content = $1.1175 \times 1.72 = 1.9221\%$

III.2 Microbiological parameters

- (i) Studies on the heterotrophic, aerobic and anaerobic microbial communities – microbial diversity and microbial count (Cfu/ml)
- (ii) Studies on microbial activity of sediments, water and soil role of microbes, both aerobic and anaerobic bacterial community in the bioconversion and recycling (cellulolytic and protolytic bacteria)
- (iii) Studies on relationship of management practices (by adding rice polish, manure, oil cake, cowdung etc. as feed) and microbial growth manipulation and enhancement of microbial activities in rice-fish rotation farming by management practices. The isolation, enumeration and identification was

done by standard methods mentioned in Cheesbrough (1989) and Bergese Manual for systematic bacteriology (Vol. 1 – 7).

Media

The following media were employed:

Nutrient Agar

It is a simple medium. It consists of the materials which are the basic requirements for the growth of the micro organism. It is also called the basic media.

Composition

Peptone	–	1 g
Beef extract	–	1 g
Agar	–	2 g
Sodium chloride	–	0.5 g
Distilled water	–	100 ml

All the ingredients were mixed and dissolved by heating. The pH was adjusted to 7.5 and the mixture was autoclaved at 121°C for 15 minutes.

Mac Conkey's Agar

Peptone	–	2 g
Lactose	–	1 g
Agar	–	2 g
Neutral red, 2% in 50% ethanol	–	0.35 ml
Sodium taurocholate	–	0.5 g

Dissolved peptone and taurocholate in water by heating and added agar, dissolved by steaming. If necessary clear by filtration. Adjust pH to 7.5. Add lactose and neutral red, mix.

Medium for Indole Test

Peptone	–	20 g
NaCl	–	5 g
Distilled water	–	1 litre

pH was adjusted to 7.5. It was then dispensed in test tubes and sterilised by autoclaving at 121°C for 15 minutes.

Kovac's Reagent

Amyl or isoamyl alcohol	–	150 ml
Paradimethyl amino benzaldehyde	–	10 g
Concentrated HCl	–	50 ml

Aldehyde was dissolved in alcohol and acid was added slowly.

Simmon Citrate Medium

Composition

Koser's medium	–	1 litre
Agar	–	20 g
Bromothymol blue	–	40 ml

Autoclaved at 121°C for 15 minutes and allowed to set as slopes.

Christensen Urea Agar

Composition

Peptone	–	1 g
Sodium chloride	–	5 g
Dipotassium hydrogen phosphate	–	2 g
Phenol red	–	6 ml
Agar	–	20 g
Glucose	–	10 g
Urea	–	20%

Stains and Reagents for Gram's Staining

a) *Methyl violet stain*

Methyl violet 6B – 10 g

Distilled water – 1000 ml

The dye was dissolved in distilled water and filtered for use.

b) *Gram's Iodine*

Iodine crystals – 10g

Potassium iodide – 20g

Distilled water – 1000 ml

Potassium iodide was dissolved in 250 ml water and then iodine was added when dissolved made up to one litre.

c) *Acetone*

d) *Safranine* – counter stain

Safranine – 0.20 g

Distilled water – 1000 ml

Safranine was dissolved in distilled water and filtered.

Methods

Collection of Water Samples

Water from different sources were collected in sterile screw capped bottles.

Enumeration of Water Micro-organisms

A pre-requisite in the study of any ecosystem is the enumeration of its component species per unit volume.

Pour Plate Method

The number of living bacteria or groups of bacteria in a liquid or water sample can be counted by a cultural method such as the pour plate method. A measured amount (i.e. 0.1 ml) of water was pipetted out and mixed with molten nutrient agar medium in a sterile petridish. After setting and incubation, number of colonies were counted from which the number of cfu/ml of water was calculated.

Identification of Bacteria

By microscopy, staining, motility and by different biochemical tests.

Methods

Water samples for bacteriological analysis were aseptically collected into sterile bottles about 50 cm below the water surface. Bottles were prewrapped with filter paper to minimise contamination through handling. Samples after collection were immediately taken to laboratory for examination. The samples were preserved at 4°C up to 6 h, if immediate analysis were not possible.

- (a) Standard plate count (SPC): Appropriate dilution were selected according to the expected SPC. Generally undiluted (1.0) and diluted 100 times (1:100) are prepared, 1 ml and 0.1 ml if plated from each of them will give a dilution of 1:10, 1:100 and 1:1000 respectively. For this the sample was shaken vigorously for 10 seconds and prepared an initial dilution 1:10 by pipetting 1 ml of the original sample into 99 ml of sterile distilled water or 0.1 ml + 9.9 ml of sterile distilled water. Additional dilutions were prepared in sterile dilution bottles using a separate pipette every time.

- (b) The nutrient agar medium and Mac Conkey's agar medium were prepared. The medium after melting was placed in a water bath maintained at 44-46°C for 1 hr and the temperature was monitored.
- (c) 1 ml and 0.1 ml from the diluted samples was transferred in aseptic conditions to already marked plates (2 sets each) (sterilised). After delivering the samples, the tip of the pipette was touched to a dry spot in the plates.
- (d) About 20 ml of liquefied media (44°C) was poured to these petriplates by gently opening the plates. The medium was mixed thoroughly with samples in petriplates when the media was solidified, the plates were inverted and kept for incubation at $37^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$ for 48 ± 3 h.

The colony counts were taken after incubation. The results were recorded and SPC/ml of water or cfu/ml of water was calculated.

Total bacterial count was obtained from nutrient agar plates and the total coliform count and the count of *E. coli* and *Klebsiella* colonies were obtained from Mac Conkey's agar plates. Standard media from Hi Media Pvt. Ltd., Bombay was used for investigation.

3) Growth rate of fishes

The final weight and size of the cultured fishes may be recorded and comparative study with the previous years crop has to be conducted. The data of input and output of fish farming in rotational system has to be collected and compared with a few previous years farming activity. The common culture fishes include Catla, Rohu, Grasscarp and Cyprinus.

Chapter IV

RESULTS

IV.1 Physico-chemical parameters

Various ecological or physico-chemical parameters of the farming medium during the fish growing period, and the straw decomposition period in the rice-fish rotational farming model has been subjected to investigation. The various ecological parameters analysed were pH, Free CO₂, Dissolved oxygen, Alkalinity, salinity and the temperature of the water surface and bottom. The data was subjected to statistical analysis, 't' test was applied. Table 1a to 1f represents the results of the physico chemical parameters during the fish growing period and tables 2a to 2e represents the results of the physico chemical parameters during the straw decomposition period.

Significant variation has been noticed between the surface and bottom waters with respect to the ecological parameters namely Free CO₂, DO and temperature but no significant variation has been noticed in pH, alkalinity and salinity, in fish growing period in the rice-fish rotational farming model. Significant variation has been noticed between the surface and bottom water with respect to the ecological parameters namely pH, Free CO₂, dissolved oxygen and salinity, significantly high in the water bottom, but no significant variation has been noticed in alkalinity during the straw decomposition period in rice-fish rotational farming model.

Ecological parameters during the Fish growing period in rice fish rotational farming model

Table 1a

pH		
	Water Sur.	Water Bot.
Mean	6.96	6.9
SD	0.43	0.37
t	0.56	NS

NS - Not significant

** - Significant

Table 1b

Free CO ₂		
	Water Sur.	Water Bot.
Mean	9.57	11.8
SD	3.62	3.22
t	-2.67	**

NS - Not significant

** - Significant

Table 1 c

Dissolved Oxygen		
	Water Sur.	Water Bot.
Mean	4.07	3.22
SD	1.15	136
t	2.53**	**

NS - Not significant

** – Significant

Table 1d

Alkalinity		
	Water Sur.	Water Bot.
Mean	3.48	3.39
SD	0.44	0.77
t	0.55	NS

NS – Not significant

** – Significant

Table 1 e

Salinity		
	Water Sur.	Water Bot.
Mean	0.18	0.18
SD	0.07	0.066
t	0	NS

NS – Not significant

** – Significant

Table 1 f

Temperature		
	Water Sur.	Water Bot.
Mean	30.71	29.63

SD	1.18	1.16
t	3.45	**

NS - Not significant

** - Significant

Ecological (Physico chemical) parameters during the straw decomposition period in rice fish rotational farming model

Table 2a

pH		
	Water Sur.	Water Bot.
Mean	6.84	6.41
SD	0.75	0.18
t	6.84**	**

NS - Not significant

** - Significant

Table 2b

Free CO ₂		
	Water Sur.	Water Bot.
Mean	12.62	15.69
SD	2.95	2.08
t	-4.17**	**

NS - Not significant

** - Significant

Table 2c

Dissolved oxygen

	Water Sur.	Water Bot.
Mean	4.05	2.05
SD	2.22	1.61
t	3.57**	**

NS – Not significant

** – Significant

Table 2d

Alkalinity		
	Water Sur.	Water Bot.
Mean	2.04	2.02
SD	0.25	0.18
t	0.32	NS

NS – Not significant

** – Significant

Table 2e

Salinity		
	Water Sur.	Water Bot.
Mean	29.6	29.22
SD	0.25	0.32
t	4.95**	**

NS – Not significant

** – Significant

IV. 2(a) Correlation matrix of various physico chemical parameters of the farming medium and Phyto and Zooplankton

In order to explore the relationship between the various environmental parameters, physico-chemical parameters and the phyto and zooplankton count correlation matrix have been computed (Table 3-8). In rice fish rotational farming model – fish growing period – water surface (Table 3) during the fish growing period (Nov-June), the significant relationship between temperature and pH, salinity, nitrate and plankton count (phytoplankton), zooplankton and depth and transparency exists, significant relationship between pH and alkalinity, salinity, nutrient nitrate, plankton count (phytoplankton), Depth/transparency and zooplankton exists. No significant relationship exists between Free CO₂ and other parameters; significant relationship exists between dissolved oxygen and salinity and nutrients nitrate. Significant relationship exists between dissolved oxygen and salinity, and nutrients nitrate. Significant relationship exists between salinity and nutrient phosphate, nutrient nitrate, nutrient nitrite, phytoplankton count, zoo plankton count, and depth/transparency. Significant relationship exists between the nutrient-phosphate (X7) and phytoplankton count and zooplankton count. No significant relationship exists between nutrient nitrate (X8) and other parameters namely, phytoplankton, depth/transparency, significant relationship exists between nutrient nitrate (X9) and phyto and zooplankton count and depth/transparency. Significant relationship exists between phytoplankton count (X10) and zooplankton count. Significant correlation exists between depth/transparency and zooplankton count.

b. Rice-fish rotational farming model-fish growing period (water bottom)

Significant correlation exists between temperature and pH, alkalinity, nutrient phosphate, nitrite, zooplankton and salinity. Significant correlation exists

between free CO₂ and DO (inverse) and nutrient nitrite. Significant correlation exists between DO and zooplankton. Significant correlation exists between alkalinity and nutrient phosphate, nitrate nitrate, zooplankton count and salinity. Significant correlation exists between nutrient phosphate and nutrient nitrite, zooplankton count and salinity. Significant correlation exists between nutrient nitrate and zooplankton count and salinity. Significant correlation exists between salinity and the count of zoo plankton (inverse) (Table 4).

c. Rice-fish rotational farming model – straw decomposition period-surface water

Significant correlation exists between temperature and free CO₂, dissolved oxygen, salinity and nutrient nitrate. Significant correlation exists between pH and salinity, nutrient nitrite, and phytoplankton count. Significant correlation exist between free CO₂ and DO (inverse), salinity, nutrient phosphate, nutrient nitrite and count of phytoplankton. Significant correlation exists between DO and alkalinity, salinity, and count of phytoplankton. Significant correlation exists between alkalinity, count of phytoplankton and depth. Significant correlation exists between nutrient phosphate and count of phytoplankton, the other parameter being not significant (Table 5).

d. Rice-fish rotational farming model-straw decomposition period-sediments

Significant correlation exists between temperature and Free CO₂; pH and DO, nutrient phosphate, and salinity. Significant correlation exists between free CO₂ and nutrient nitrite; DO and nutrient phosphate; alkalinity and nutrient nitrate, nutrient phosphate and salinity, nutrient nitrite and nutrient nitrate (Table 6).

e. Fish pond – water surface-physical chemical parameters

Significant correlation exists between Free CO₂ and nutrient nitrite, temperature; between DO and nutrient phosphate, between alkalinity and nutrient

phosphate, nitrate and nitrite, between hardness and salinity, phosphate nitrate, pH and depth/transparency, between nutrient phosphate and nitrite, temperature, pH, between temperature and pH, Depth/transparency (Table 7).

f. Fish pond-water bottom-physico chemical parameters

Significant correlation exists between free CO₂ and nitrate, between DO and hardness, salinity, nitrite temperature, pH and depth/transparency; between alkalinity depth/transparency; between hardness and salinity, phosphate, nitrate, nitrite, pH, depth/transparency; between salinity and phosphate, nitrate, nitrite, pH and depth/transparency; between phosphate and nitrate, nitrite, temperature and pH between nitrate, nitrite, temperature and pH between nitrite and temperature and pH.

Correlation matrix of various physico-chemical parameters during fish growing period (Rice-fish rotational)

Table 3 Fish growing (water surface)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
		**				**			**	**	**	**
X1	1	0.908	0.026	0.013	0.29	0.695	-0.345	0.244	-0.929	-0.701	0.748	-0.766
					**	**			**	**	**	
X2		1	0.071	0.247	0.379	0.525	-0.377	-0.015	-0.946	-0.732	0.604	-0.705
X3			1	-0.013	0.235	-0.139	0.319	-0.005	-0.095	0.235	0.235	0.25
						**		**				
X4				1	-0.173	-0.503	0.237	-0.514	-0.3	-0.013	-0.178	-0.188
					**	**					**	
X5					1	0.657	0.03	-0.338	-0.326	-0.154	0.412	0.065

X6						1	-0.763*	0.634**	-0.438*	-0.725**	0.38**	-0.657**
X7							1	-0.248	0.181	0.822**	0.126**	0.603**
X8								1	-0.022	-0.054	0.225**	-0.191**
X9									1	0.633**	-0.752**	0.703**
X10										1	-0.313**	0.884**
X11											1	0.391*
X12												1

X1 = Temperature X7 = Nutrient a. phosphate
 X2 = pH X8 = Nutrient b. nitrate
 X3 = Free CO₂ X9 = Nutrient c. nitrite
 X4 = Dissolved oxygen X10 = Plankton count (Phyto plankton)
 X5 = Alkalinity X11 = Depth transparency
 X6 = Salinity X12 = Zoo plankton

** : significant for p < 0.01
 * : significant for p < 0.05
 NS : not significant
 – : inversely related
 + : direct relationship

Table 4 Correlation matrix of various physico chemicals parameters during fish growing period – water bottom (Rice fish rotational)

Fish growing (water bottom)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X11
X1	1	0.884**	-0.11	0.305	0.731**	0.786**	-0.382**	0.433**	-0.87**	0.576**
X2		1	-0.312	0.49**	0.649**	0.504**	-0.203**	0.582**	-0.989**	0.765**
X3			1	-0.857**	0.162	0.316	-0.669**	0.306	0.327	-0.118

X4				1	-0.177	-0.158	0.319	-0.12	-0.525	0.181
X5						**		**	**	**
X6					1	0.637	-0.306	0.599	-0.635	0.629
X7						*		**	**	**
X8						1	-0.474	0.239	-0.475	0.385
X9							1	-0.324	0.187	0.044
X11								**	**	**
								1	-0.608	0.735
									1	-0.787
										1

X1 = Temperature X6 = Nutrient a. phosphate
 X2 = pH X7 = Nutrient b. nitrite
 X3 = Free CO₂ X8 = Nutrient c. nitrate
 X4 = Dissolved oxygen X9 = Zoo plankton
 X5 = Alkalinity X11 = Salinity

** : significant for p < 0.01
 * : significant for p < 0.05
 NS : not significant
 – : inversely related
 + : direct relationship

Table 5 Correlation matrix of various physico-chemical parameters in the straw decomposition period, surface (Rice fish rotational farming model)

Straw decomposition (Surface)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	1	0.185	-0.677	0.754	0.274	-0.696	-0.135	-0.184	0.526	0.245	-0.064
X2		1	-0.342	0.231	0.317	-0.78	0.333	0.578	-0.045	0.961	0.036

X3			1	** -0.802	* -0.418	** 0.684	** -0.574	* 0.407	-0.227	** -0.511	-0.297
X4			1	* 0.389	** -0.743	** 0.305	-0.366	0.067	0.39	*	0.011
X5			1	-0.381	0.33	-0.075	0.322	0.382	0.464	*	
X6			1	-0.24	-0.234	0.001	-0.829	0.025			
X7			1	-0.351	0.15	0.537	0.382			**	
X8			1	-0.178	0.379	-0.179					
X9			1	-0.0133	0.822					**	
X10			1	0.095							
X11			1								

X1 = Temperature

X7 = Nutrient a. phosphate

X2 = pH

X8 = Nutrient b. nitrite

X3 = Free CO₂

X9 = Nutrient c. nitrate

X4 = Dissolved oxygen

X10 = Phyto plankton

X5 = Alkalinity

X11 = Depth transparency

X6 = Salinity

X12 = Zoo plankton

** : significant for $p < 0.01$

* : significant for $p < 0.05$

NS : not significant

- : inversely related

+ : direct relationship

Table 6 Correlation matrix of various physico-chemical parameters during straw decomposition period-sediments

X1	X2	X3	X4	X5	X6	X7	X8	X10
----	----	----	----	----	----	----	----	-----

X1	1	0.017	0.584 ^{**}	0.166 ^{**}	-0.008	0.162 ^{**}	-0.29	-0.089	-0.351 ^{**}
X2		1	-0.068	0.569 ^{**}	0.123	-0.841 ^{**}	0.149 ^{**}	0.266	0.481
X3			1	-0.312	-0.069	0.362 ^{**}	0.496 ^{**}	0.212	-0.164
X4				1	0.072	-0.781	-0.294	-0.354 [*]	-0.248
X5					1	-0.18	-0.048	-0.387	0.158 [*]
X6						1	-0.018	0.155 [*]	-0.378 [*]
X7							1	0.387	0.2
X8								1	0.28
X10									1

X1 = Temperature

X6 = Nutrient a-phosphate

X2 = pH

X7 = Nutrient b. nitrite

X3 = Free CO₂

X8 = Nutrient c. nitrate

X4 = Dissolved oxygen

X9 = Zoo plankton

X5 = Alkalinity

X10 = Salinity

** : significant for $p < 0.01$

* : significant for $p < 0.05$

NS : not significant

- inversely related

+ direct relationship

Table 7 Correlation matrix of various physico chemical parameters Fish pond-water surface

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	1	-0.232	-0.341	-0.127	-0.089	-0.219	-0.056	0.557	-0.4	-0.071	0.521
						*		**	*		**
X2		1	0.118	-0.322	-0.362	0.825	0.349	-0.023	0.905	0.936	-0.505
						**	**	**		**	**
X3			1	0.052	0.087	0.497	-0.545	-0.693	0.104	0.208	0.088
					**	**	**			**	*
X4				1	0.996	-0.551	-0.756	0.265	-0.174	-0.508	-0.421
						**	**			**	
X5					1	-0.56	-0.791	0.248	-0.217	-0.534	-0.371
								**	**	**	
X6						1	0.22	-0.473	0.631	0.9	-0.053
X7							1	0.104	0.356	0.347	-0.053
X8								1	0.081	-0.069	-0.295
X9									1	0.788	-0.755
										**	**
X10										1	-0.249
X11											1

X1 = Free CO₂ X7 = Nitrate
 X2 = Dissolved oxygen X8 = Nitrite
 X3 = Total alkalinity X9 = Temperature
 X4 = Hardness X10 = pH
 X5 = Salinity X11 = Depth/Transparency
 X6 = Phosphate

** : significant for p < 0.01
 * : significant for p < 0.05
 NS : not significant
 - : inversely related
 + : direct relationship

**Table 8 Correlation matrix of various physico chemical parameters water bottom
– Fish pond**

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	1	-0.269	-0.679**	-0.297*	-0.356*	-0.008	0.423**	-0.027*	0.05**	-0.103*	0.199**
X2		1	-0.217	0.463	0.421*	0.209	-0.111	0.463*	0.645**	0.408*	-0.68**
X3			1	-0.282	-0.177**	0.297**	-0.119**	0.164*	-0.305**	0.253*	0.437*
X4				1	0.991**	-0.714**	-0.853**	-0.465**	-0.061**	-0.446**	-0.45**
X5					1	-0.723**	-0.901**	-0.483**	-0.125**	-0.46**	-0.38**
X6						1	0.791**	0.927**	0.594**	0.895**	-0.06**
X7							1	0.653**	0.505**	0.557**	-0.022**
X8								1	0.776**	0.855**	-0.258**
X9									1	0.562**	-0.762**
X10										1	-0.179**
X11											1

X1 = Free CO₂ X7 = Nitrate
X2 = Dissolved oxygen X8 = Nitrite
X3 = Total alkalinity X9 = Temperature
X4 = Hardness X10 = pH
X5 = Salinity X11 = Depth/Transparency
X6 = Phosphate

** : significant for p < 0.01
* : significant for p < 0.05
NS : not significant
– : inverse relationship
+ : direct relationship

IV. 3 Quantitative Analysis of weeds and Zoobenthos

Quantitative analysis of weeds in fish only cultivating pond was made and the weeds identified were Elodia, Utricularia, Panicum, Nymphia, Ceratoteris and Lymnocaris. Gradual decrease and significant variation in quantity has been noticed as the fish growth has increased (Table 9). Analysis of variance for variation in Zoobenthos has been studied in fish pond. No significant variation has been observed (Table 10).

Table 9 Analysis of variance for quantitative analysis of weeds in fish pond
Mean Table

Treatment	Mean
T1	6.697000
T2	11.404000
T3	10.021000
T4	19.993000
T5	5.602000
G Mean	10.743400

VR : 4.65**

CD : 7.49

** : Significant

NS : Not significant

Table 10 Analysis of variance for variation in Zoobenthos
Mean Table

Treatment	Mean
T1	0.290000
T2	0.165000
T3	0.232000
T4	0.089000
T5	0.120000
T6	0.008000

T7	0.002000
G Mean	0.129429

VR : 2.61

CD : 0.19

IV. 4 Microbial activity

a. Variation in microbial count

The TBC, Cfu/ml in the various samples collected were subjected to analysis of variance in order to find out the seasonal and monthly variation in bacterial count in the rice-fish rotational farming model and the results are represented in table 11-20. The bacterial genera identified were *Bacillus* (predominant) *E.coli*, *Klebsiella* sp., *Pseudomonas* sp. (moderate) and *Enterobacter*, *citrobacter* etc. (scanty) Gram positive, gram negative, aerobic and Facultative anaerobic bacteria were observed.

Analysis of variance for the bacterial count in water and sediment of rice fish rotational farming area has been studying between the months. The variance ratio was found to be highly significant. This shows that there is significant difference in the bacterial count between the months in the farming water and sediments of rice fish rotational model (Table 11 & 13).

Analysis of variance for the bacterial count in water and sediment of rice fish rotational model between the seasons namely paddy cultivating, fish growing and straw decomposition period has been analysed. The variance ratio was found to be highly significant. This shows that there is significant difference in the bacterial count in between the three seasons in both water and sediments in the rice fish rotational model.

Analysis of variance for monthly variation in microbial count in fish culture pond water and sediments has been analysed, between months. The variance ratio was found to be highly significant. This shows that there is

significant variation in bacterial count between the months in both water and sediments of fish alone cultivating pond (Table 15 and 16).

Analysis of variance for monthly variation in bacterial count of water and sediments of rice alone cultivating field has been analysed. Significant variation exists between the months, in rice alone cultivating area (Table 17 and 18).

Analysis of variance for seasonal variation in bacterial count between the rice cultivating season in rice fish rotational farming and rice alone cultivating fields both water and sediments has been analysed (Table 19 and 20). Significant variation in microbial activity has been observed, the bacterial count being significantly high in rice fish rotational plot, in water and sediments during the rice growing season.

Analysis of variance for seasonal variation in bacterial count between the fish growing seasons in rice-fish rotational farming model and fish alone cultivating pond, water and sediments has been done. Variance ratio was significantly high (Tables 21 and 22). This shows that there is significant variation in microbial activity exists between the two systems in the fish growing period, both in water and sediments.

Table 11 **Analysis of variance for monthly variation Total bacterial count (water) rice fish rotational**

Mean Table

Treatment	Mean	SE
T1	2425.000000	145.834799
T2	1800.000000	145.834799
T3	2400.000000	145.834799
T4	5525.000000	145.834799
T5	4675.000000	145.834799
T6	660.000000	145.834799
T7	475.000000	145.834799

T8	250.000000	145.834799
T9	887.500000	145.834799
T10	3675.000000	145.834799
T11	2925.000000	145.834799
T12	2950.000000	145.834799
T13	4625.000000	145.834799
G Mean	2559.423077	

VR = 140.15 **

** significant

CD = 416.81

NS =not significant

CV = 11.395912%

Table 12 **Analysis of variance for monthly variation - Total bacterial count – Sediments Rice fish rotational**

Mean Table

Treatment	Mean
T1	7575.000000
T2	2450.000000
T3	1550.000000
T4	1300.000000
T5	7700.000000
T6	720.000000
T7	1075.000000
T8	495.000000
T9	5500.000000
T10	2950.000000
T11	4275.000000
T12	4275.000000
T13	5400.000000
G. Mean	3481.923077

VR = 64.90 **

** significant

CD = 891.29

NS =not significant

Table 13 Analysis of variance for seasonal variation in Bacterial count (water)
Rice-fish rotational

Mean Table

Treatment	Mean
T1	2565.750000
T2	568.750000
T3	3543.750000

VR = 562.61 **

** Significant

CD = 204.50

NS = not significant

Table 14 Analysis of variance for seasonal variation in Bacterial count –
(Sediments) Rice fish rotational

Mean Table

Treatment	Mean	SE
T1	3195.750000	411.370161
T2	1760.000000	411.370161
T3	4225.000000	411.370161
G Mean	3060.250000	

VR = 9.05 **

** Significant

CD = 1315.9

NS = not significant

Table 15 Analysis of variance for monthly variation in microbial count in fish
culture pond (water)

Mean Table

Treatment	Mean
T1	2900.000000
T2	4000.000000
T3	7500.000000
T4	7500.000000
T5	6750.000000
T6	482.500000
T7	807.500000
T8	792.500000
T9	547.500000
G Mean	3475.555556

VR : 453.47 **
CD : 418.83

** : significant
NS : not significant

Table 16 Analysis of variance for monthly variation in microbial count in fish culture ponds – Sediments

Mean Table

Treatment	Mean
T1	3900.000000
T2	9300.000000
T3	9600.000000
T4	9325.000000
T5	9000.000000
T6	5200.000000
T7	5650.000000
T8	5650.000000
T9	3825.000000
G Mean	6827.777778

VR : 163.86 **
CD : 553.93

** : significant
NS : not significant

Table 17 Analysis of variance for microbial count in Rice alone cultivating field (water)

Mean Table

Treatment	Mean
T1	3125.000000
T2	8725.000000
T3	8575.000000
T4	7375.000000
T5	202.500000
T6	282.500000
T7	187.500000
T8	775.000000
G Mean	3655.937500

VR : 229.76 **
 CD : 755.13

** : significant
 NS : not significant

Table 18 Analysis of variance for monthly variation in microbial count in Rice alone cultivating field (Sediments)

Mean Table

Treatment	Mean
T1	3125.000000
T2	8725.000000
T3	8575.000000
T4	7375.000000
T5	202.500000
T6	282.500000
T7	187.500000
T8	775.000000

G Mean	3655.937500
--------	-------------

VR : 229.76 **
 CD : 755.13

** : significant
 NS : not significant

Table 19 Analysis of variance for seasonal variation in bacterial count between the rice cultivating season in rice-fish rotational and water rice alone cultivating field (sediments)

Mean Table

Treatment	Mean	SE
T1	4714.000000	99.920541
T2	481.250000	99.920541
G Mean	2597.625000	

VR : 879.2**

CR : 345.78

** : Significant

NS : not significant

T₁ : June – Aug season of rice cultivation in (rotational farming)

T₂ : June – Aug season of rice cultivation (rice alone cultivating area)

Table 20 Analysis of variance for seasonal variation in bacterial count between rice cultivating season in rice fish rotational (Rice alone cultivating field - Sediments)

Mean Table

Treatment	Mean
T1	2809.750000
T2	1286.250000
G Mean	2048.000000

VR : 754 **

CD : 135.69

** : Significant

T₁ : June –July- Aug season of rice cultivation in (rotational farming)

T₂ : June –July- Aug season of rice cultivation (rice alone cultivating area)

Table 21 Analysis of variance for variation in bacterial count in fish cultivating season of rotational farming and fish culture pond (water)

Mean Table

Treatment	Mean
T1	4276.500000
T2	670.000000

VR : 4002 **

CD : 139.50

** : Significant

T₁ : Fish growing season Dec. 2000 to June 2001 (rotational farming)

T₂ : Fish growing season Dec. 2000 to June 2001 (Fish pond)

Table 21a Analysis of variance for variation in bacterial count in fish cultivating season of rotational farming and fish culture pond (sediments)

Mean Table

Treatment	Mean
T1	7424.250000
T2	5442.500000

VR : 6.08**

CD : 1966

** : Significant

T₁ : Fish growing season, Dec. 2000 - June 20001 (Rotational model)

T₂ : Fish growing season, Dec. 2000 - June 20001 (Fish pond)

IV.4b Microbial diversity

The microbial diversity of the farming medium in the rice-fish rotational farming model (water and sediments) during the straw decomposition period (Table 22) and fish growing period (Table 23) has been studied. *Bacillus* sp. was found to be predominant in incidence, *E.coli*, *Klebsiella*, *Enterobacter* and *Citrobacter* moderate, *Staphylococcus* and *Pseudomonas*, Scanty in straw decomposition period; whereas *Bacillus* sp., *E.coli* and *Klebsiella* sp.

predominant, *Pseudomonas*, *Alcaligenus* and *Citrobacter*, *Enterobacter* sp. moderate in incidence and *Chromobacterium violaceum*, *Staphylococcus aureus*, *S. citreus* and *Flavobacterium*, scanty in incidence in fish growing period. Though the bacterial count is high in both, the diversity is more in the fish growing season.

Table 22 Bacterial diversity (Rice-fish rotational farming model)

Straw decomposition period	
Water	Sediments
<i>E.coli</i> ++	<i>E.coli</i> ++
<i>Klebsiella</i> ++	<i>Klebsiella</i> ++
<i>Enterobacter</i> ++	<i>Bacillus</i> +++
<i>Citrobacter</i> ++	<i>Pseudomonas</i> +
<i>Bacillus</i> +++	<i>Enterobacter</i> +
<i>Staphylococcus</i> +	
<i>Pseudomonas</i> +	

+++ : Predominant

++ : Moderate

+ : Scanty

Table 23 Bacterial diversity (Rice fish rotational model) fish growing period)

Fish growing period	
Water	Sediments

<i>Klebsiella</i> sp +++	<i>Bacillus</i> sp +++
<i>Chromobacterium- violaceum</i> +	<i>Klebsiella</i> +++
<i>E.coli</i> +++	<i>E.coli</i> +++
<i>Citrobacter</i> ++	<i>Chromobacterium violaceum</i> +
<i>Enterobacter</i> ++	<i>Pseudomonas</i> ++
<i>Bacillus</i> sp +++	<i>Staphylococcus citreus</i> +
<i>Staphylococcus aureus</i> +	<i>Flavobacterium</i> +
<i>Staphylococcus citreus</i> +	<i>Alcaligenus</i> sp ++
<i>Alcaligenus</i> sp ++	

+++ : Predominant

++ : Moderate

+ : Scanty

IV.5 Primary productivity in rice-fish rotational farming model

The productivity measures have been taken during the fish growing period (Table 24) the gross productivity of the system and the net productivity was found to be considerably high, which proves that the system to be efficient in trapping sunlight and bioconversion.

Table 24 Primary productivity in rice-fish rotational farming model (Fish growing season)

Month	Gross productivity Cal/m ³ /hr	Net productivity Cal/m ³ /hr
Nov. 2000	1.35	1.05
December 2000	260.87	52.17
January 2001	120	45
Feb. 2001	75	32
March 2001	60	20
April 2001	192	132
May 2001	45	15

VI. 6 Growth rate of fishes

Regression analysis of weight versus length

The length and weight of different species of culture fishes, Rohu, Silver carp, Mrigal, Grass carp, Common carp and Catla were taken at the time of harvest (June 2001, 2002 and 2000). The data has been subjected to regression analysis. It was found that the effect of length on weight is highly significant. Around 84% variation in weight is explained by the length (Table 25) Rohu 2000. The effect of length on weight is highly significant around 56% (Table 26) Rohu 2001, 45% (Table 27) Silver carp 2000, 28% (Table 28) Silver carp 2001, 89% (Table 29) Mrigal 2001, 13% (Table 30) Grass carp 2000, 9% (Table 31) Grass carp 2001, 59% (Table 32) Common carp 2000, 12% (Table 33) Common carp 2001, 53% (Table 34) Catla 2000, 27% (Table 35) Catla 2001, 57% Catla 2002 (Table 36) 97% Rohu 2002 (Table 37), 93% Common carp, 2002 (Table 38) 86% Silver carp 2002 (Table 39), 94% grass carp (Table 40) 2002.

Table 25 Growth rate of Fishes (Rohu 2000)

It is found that effect of length on weight is highly significant. Around 84% variation in weight is explained by the length.

Dependent variable = log of weight

L_1 = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	-2.5800897	0.3331319	-7.7449498
L_1	3.4982897	0.2207466	15.847536
R-squared	0.839542		

Table 26 Growth rate of Fishes (Rohu 2001)

It is found that effect of length on weight is highly significant. Around 56% variation in weight is explained by the length.

Dependent variable = log of weight

L_1 = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	-1.8868450	0.5795945	-3.2554573
L_1	2.9480654	0.3757634	7.8455362
R-squared	0.561854		

Table 27 Growth rate of Fishes (Silver carp 2001)

It is found that effect of length on weight is highly significant. Around 45% variation in weight is explained by the length.

Dependent variable = log of weight

L_1 = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	0.5360826	0.3226429	1.6615356

L ₁	1.3473287	0.2126847	6.3348655
R-squared	0.455353		

Table 28 Growth rate of Fishes (Silver carp 2001)

It is found that effect of length on weight is highly significant. Around 28% variation in weight is explained by the length.

Dependent variable = log of weight

L₁ = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	1.6554472	0.0174906	94.646478
L ₁	-0.0327574	0.0075477	-4.3400211
R-squared	0.281822		

Table 29 Growth rate of Fishes (Mrigal 2001)

It is found that effect of length on weight is highly significant. Around 89% variation in weight is explained by the length.

Dependent variable = log of weight

L₁ = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	-1.8309823	0.2254212	-8.1224945
L ₁	2.8874684	0.1452550	19.878612
R-squared	0.891687		

Table 30 Growth rate of Fishes (Grass carp 2000)

It is found that effect of length on weight is highly significant. Around 13% variation in weight is explained by the length.

Dependent variable = log of weight

L₁ = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	19.331226	7.0027605	2.7605151
L1	-11.254501	4.3520069	-2.5860485
R-squared	0.129386		

Table 31 Growth rate of Fishes (Grass carp 2001)

It is found that effect of length on weight is highly significant. Around 9% variation in weight is explained by the length.

Dependent variable = log of weight

L₁ = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	12.243983	4.5532629	2.6890568
L ₁	-6.2420614	2.8329635	-2.2033681
R-squared	0.091852		

Table 32 Growth rate of Fishes (Common carp 2000)

It is found that effect of length on weight is highly significant. Around 59% variation in weight is explained by the length.

Dependent variable = log of weight

L₁ = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	-2.0701528	0.5215752	-3.9690400
L ₁	1.4033491	0.3226732	4.3491342
R-squared	0.592668		

Table 33 Growth rate of Fishes (Common carp 2001)

It is found that effect of length on weight is highly significant. Around 12% variation in weight is explained by the length.

Dependent variable = log of weight

L_1 = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	9.6092860	3.0281528	3.1733161
L_1	-5.0029739	1.9655787	-2.5452931
R-squared	0.118919		

Table 34 Growth rate of Fishes (Catla 2000)

It is found that effect of length on weight is highly significant. Around 53% variation in weight is explained by the length.

Dependent variable = log of weight

L_1 = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	-0.3050545	0.4204249	-0.7255861
L_1	1.9262817	0.2865668	6.7219288
R-squared	0.524275		

Table 35 Growth rate of Fishes (Catla 2001)

It is found that effect of length on weight is highly significant. Around 27% variation in weight is explained by the length.

Dependent variable = log of weight

L_1 = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	13.422397	2.8027971	4.7889292
L_1	-7.5148724	1.7844856	-4.2112261
R-squared	0.269789		

Table 36 Growth rate of Fishes (Catla 2002)

It is found that effect of length on weight is highly significant. Around 57% variation in weight is explained by the length.

Dependent variable = log of weight

L_1 = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	-0.6072668	0.6238463	-0.9734237
L_1	2.3065208	0.3643675	6.3302051
R-squared	0.571866		

Table 37 Growth rate of Fishes (Rohu 2002)

It is found that effect of length on weight is highly significant. Around 97% variation in weight is explained by the length.

Dependent variable = log of weight

L_1 = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	-2.2423885	0.1037708	-21.609054
L_1	3.1745831	0.660766	48.044009
R-squared	0.976727		

Table 38 Growth rate of Fishes (Common carp 2002)

It is found that effect of length on weight is highly significant. Around 93% variation in weight is explained by the length.

Dependent variable = log of weight

L_1 = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	-2.7987774	0.2877280	-9.7271632
L_1	3.7573974	0.1823468	20.605775
R-squared	0.938135		

Table 39 Growth rate of Fishes (Silver carp 2002)

It is found that effect of length on weight is highly significant. Around 86% variation in weight is explained by the length.

Dependent variable = log of weight

L_1 = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	-2.5470032	0.3343595	-7.6175597
L_1	3.3396052	0.1909188	17.492278
R-squared	0.864399		

Table 40 Growth rate of Fishes (Grass carp 2002)

It is found that effect of length on weight is highly significant. Around 94% variation in weight is explained by the length.

Dependent variable = log of weight

L_1 = Log of length

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT
C	-2.0243724	0.1761478	-11.492468
L_1	3.0084855	0.1132459	26.565947
R-squared	0.940060		

Table 41 Growth rate of fishes (Percentage of variation)

Percentage of variation			
Name of fish	Year		
	2000	2001	2002
Catla	53%	27%	57%

Rohu	84%	56%	97%
Grass carp	13%	9%	94%
Silver carp	45%	28%	86%
Common carp	59%	12%	93%

IV. 7 Biological energy conversion efficiency

The principal aim of rice-fish rotational farming is to enhance the utilization of biological energy by means of shortening the food chain. The input of solar energy was estimated from the determination of primary productivity (Dark and light bottle method).

The gross yield was determined as the total weight of fishes harvested. The number of the fish harvested was determined and the total weights recorded. The net yield was estimated by subtracting the weight stocked (fingerlings) from the gross yield. A comparison of the inputs, survival rates, net production, yield and efficiency of biological energy conversion in terms of input output ratio and percentage of energy obtained from the system in 1998, 1999, 2000, 2001 and 2002 is presented in Table 42.

Table 42 Input output structure of fish culture

Terms	Year				
	1998	1999	2000	2001	2002
Input (tonne)					
a. Manure-cowdung, salt, Bengal gram cake, tapioca powder, Raw rice powder, Rice polish, Groundnut cake, coconut cake	9745 (kg.)	20885 (kg)	20885 (kg)	19080 (kg)	12460 (kg)
b. Species - Fingerlings	91860	234321	85630	188651	141350

(0.5 g average weight)	(45.930 kg)	(117 kg)	(42.815 kg.)	(94.33 kg)	(70.68 kg)
c. Fish yield	14524.60 (kg)	35500.15 (kg)	27215.600 (kg)	17629 (kg)	22798 (kg)
d. Net yield	14478.67 (kg)	35383 (kg)	27172.79 (kg)	17534.67 (kg)	22727.32 (kg.)
e. Average net yield (kg/ha)	670.30 (kg/ha)	1638 (kg/ha)	1257 (kg/ha)	811.79 (kg/ha)	1052.19 (kg/ha)
f. Total no. of fishes	21402	74440	63642	36228	39321
g. Average weight	678.67 (g)	477 (g)	427 (g)	484 g	578 g
h. Survival rate - Silver carp>Rohu>Common carp	23.3%	31.7%	74%	19.20	27.82
i. Average intake/fish	455 g	281 g	328g	477 g	317 g
j. Input output ratio	455:678	281:477	328:427	477:484	317:578
k. Biological energy conversion efficiency percentage	33%	31%	23%	1.5%	45%

Chapter V

DISCUSSION

In the present investigation the various ecological aspects and the microbial activity of rice-fish rotational farming model has been subjected to study. The study has been carried out considering the peculiar status of the ecosystem, a natural ecosystem has been modified for agricultural and aquaculture purposes with the approach of enhancement of the productivity. This peculiar type of farming model is unique to lower Kuttanad padasekharam, though integrated farming models are now practised in Kaipad, Kannur and Kole padasekharams in Trichur.

The results revealed that integrated rice fish rotational farming can result in nutrient enhancement, pest control, feed supplementation, biological control and with high biological energy conversion efficiency. The results are comparable to the findings of Cagauan *et al.*, 2000 in Phillipines. The interesting observation in the present investigation is that the rice-fish culture in Kuttanad is in the process of development from extensive culture to semi intensive culture, from self sufficient natural economy to commercial economy as described by Lie *et al.* (1994) from the studies in China.

The growth rate of fishes has not been decreased in subsequent years, but there is certain amount of fluctuation among the different species. In the previous years silver carp was smaller in size but in the recent harvest silver carps were the larger variety. The Rohu and Grass carp were found to be reduced in size. This may be due to the variation in the ecological conditions and also the abundance of the species and the increased food supply. A similar observation was found in

Malaysia by Ali (1990) where the decline of weight of herbivorous fishes were noticed.

V. 1 Economic viability of rice-fish rotational farming model

Rice-fish rotational farming system has a centuries old tradition in developing countries, the practice which emphasises environmental quality and the resource base on which agriculture depends has emerged only recently as one of the most prominent issues across the world.

The rice-fish rotational farming model has proved to be an economically viable farming model, and hence more farmers of Kuttanad switch on to this type of farming practices. The data showing the economics of rice-fish rotational farming system of Anthonikkayal per acre for the last six years (1995-2001) is given below. (Source P.V. Jose, Puthenpura, Cheepunkal). The data shows that the profit from the two periods, puncha and virippu, paddy cultivation was only Rs. 686 i.e. less than Rs. 700 per annum (1995-96), but in the rice-fish rotational farming model, the profit was above Rs. 10,000 per annum. This shows that the paddy cultivation alone in the two seasons is not economical but rice-fish rotational type of farming is highly economical. Hence more farmers of Kuttanad adopt this method of farming practice, the rice-fish rotational farming model spreads very fast in the wetlands of Kuttanad.

Virippu (June-Octo) Puncha (Nov-June)	Farming expenses (in Rs.)	Product Rice/Fish	Price of commodity (in Rs.)	Profit (in Rs.)
1995-96 puncha	4968.10	928.50 kg Rice	5256.75	288.65
1995-96 virippu	4641.00	940.83 kg Rice	5039.37	398.37
1996-97 puncha	1340.00	139.80 kg Fish	3921.31	2581.31
1996-97 virippu	4370.05	1425.60 kg Rice	7856.28	3486.25
1997-98 puncha	4561.37	268.94 kg Fish	7945.5	3384.13

1997-98	virippu	4711.66	1642.00 kg	Rice	10052.00	5340.34
1998-99	puncha	8672.90	657.41 kg	Fish	16116.66	7443.76
1998-99	virippu	3425.00	1670.56 kg	Rice	10591.00	7166.00
1999-2000	puncha	8798.05	506.13 kg	Fish	14105.58	5307.53
1999-2000	virippu	4185.25	1595.34 kg	Rice	10220.94	6035.69
2000-2001	puncha	5928.74	326.37 kg	Fish	9087.93	3159.19
2000-2001	virippu	3855.46	1623.47 kg	Rice	10832.55	6977.10

(Data from Anthonikkayal 21.6 ha padasekharam)

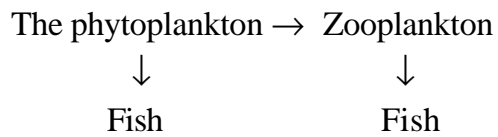
V.2 Sustainable agricultural system

V.2a Polyculture of fishes

The polyculture of selected varieties of fishes namely Grass carp (*Ctenopharyngodon idella* (exotic sp), Common carp, *Cyprinus carpio* (exotic sp.), the silver carp, *Hypophthalmichthys molitrix* (exotic sp.) catla, *catla catla* (Indian major carp), Rohu, *Labeo rohita* (Indian major carp) and Mrigal, *Cirrhinus mrigala* (Indian major carp) has great significance in the effective bioconversion process. The performance of exotic food fishes in our aquaculture system has been quite encouraging (Ansal *et al.*, 2000). The grass carp, an omnivorous fish was found to be very effective for controlling submerged vegetation, and has proved itself very effective in the biological control of the submerged weeds like Hydrilla, Vallisneria, Lemna, Wolfia etc. This is in agreement with the studies by Shetty *et al.*, 1988. Since grass carp feeds on submerged vegetation, there is no adverse impact on the Indian major carps, when cultured together.

The silver carp, a surface feeder and an herbivore is stenophagic with feeding range limited to planktonic algae. It was assessed that the fish play a complementary role to native species *Catla catla* (surface feeder) in our mixed carp farming system. However, the increased growth rate of silver carp in the

polyculture was noticed, and may be due to the feeding vigour and competition exhibited by silver carp, when compared to the native species *Catla catla*. Rohu is omnivorous and column feeder while common carp and mrigal are bottom feeders-Detritus feeders. This peculiar combination of feeding habits help in the efficient utilization of naturally occurring energy flow for food production.



The detritus feeders consume the organic carbon from the wastes of food. The fish requires the feed 2% of its body weight, of which 1% was supplied from the external source and the remaining 1% was received from the system. The survival rate was found to be varying, 65% survival rate was shown by silver carp, whereas only 20% survival was shown by the common carp, the other species ranges in between. The escape of cultivated exotic carps from ponds and padasekharams due to flooding during rainy season to the river systems and freshwater bodies may have adverse effects on indigenous fish fauna and may be a threat to their very existence. Such a situation has been reported by Ansal *et al.*, (2002) and Sehgal 1989, and, Johal *et al.*, 1989 and Jhingran, 1989 from North India. The ecological impact of exotic fishes on native fish fauna has to be studied with special reference to central and southern Kerala, since the rice fish rotational farming using polyculture of exotic carps spreads widely in wetlands of Kuttanad. Any manmade change in the delicately balanced species structure may upset the whole process of community succession (Jhingran, 1989). The introduced species may fulfil the primary objective of increasing the fish production, to fulfil a vacant niche, biological control of weeds, insects etc. but it might do so at the cost of ruining the biotype. The exotic carp species will not breed in the natural conditions of Kuttanad makes the issue less serious, otherwise the situation would have been changed.

The small (around 0.5 g) sized carps were grown into marketable size of 2-3 kg and above in a short culture period of 6 to 8 months under this system. In shallow rice field environment bottom feeding species generally exhibit a higher rate of growth and common carp has been reported to be the most promising species for rice fields (Vinke, 1980). In the present study also the exotic carp, *C. carpio* exhibited higher rate of growth and biomass production in contrast to the Indian bottom feeding carp *C. mrigala*.

Quantitative analysis of weeds on zoobenthos showed a gradual decrease and significant variation in quantity of weeds during the fish growing period. It is due to the grass carp which help to destroy the weeds, but only bottom feeders the Common carps help to destroy the zoobenthos.

The small intramuscular bones in some culture fishes make them less edible but if larger fishes of about 2 or 3 kg. with larger intramuscular bones are more palatable, since these bones are easily removable.

V.2b Physico-chemical parameters (Rice cultivating season) in sequential farming of rice and fish)

The study revealed that at the early stages of paddy cultivation, the organic carbon and nutrients contents was very high and the amount became considerably low, as the plants grow. This shows that the plants nutrient absorbing ability has been greatly increased. The silt deposition of the soil being very high, the root system becomes well developed and the plant is capable of absorbing the maximum amount of nutrients from the soil. The dry weight (biomass) of the plant was comparatively high, when compared to the plants of the same age, grown in fields where rice is cultivated in both seasons.

The total absence of weeds and pests was noticed during paddy cultivation and this avoids totally the use of agricultural pesticides.

V.2c Physico chemical parameters-Fish growing and straw decomposition period

By growing fish during the period Nov–June, the maintenance of the watershed is effected. The water holding capacity of the soil is maintained. The humus content also remains very high. The water quality parameters were studied. The fluctuations in environmental variables were noted. The analysis showed that there is significant variations in CO₂, DO and temperature in the fish growing period and in pH, CO₂ and DO in the straw decomposition period. The surface waters showed higher value of DO whereas bottom water showed more CO₂ values. The ecological parameters showed direct correlation with the phyto and zooplankton count. Natural fertilizers like cowdung added to the field during the early stages of fish growth added the production of phytoplankton and zooplankton, which in turn provided more food to the phyto and zooplankton feeders.

Various ecological and physico-chemical parameters of the farming medium during the straw decomposition and fish growing seasons has shown that significant variation in ecological parameters has been noticed during the fish growing period and straw decomposition period, but no significant variation in physico chemical parameters. The significant variation in O₂, CO₂ temperature etc. may be due to the activity of phytoplankton, Zooplankton, microbes and the culture fishes of the farming medium.

V.3 Microbial activity, Microbial count and Microbial diversity

The microbial activity was very significant in water and sediments of the rice-fish rotational farming model during the straw decomposition period and the fish growing period. A variety of genera such as *Bacillus* sp., *E.coli*, *Klebsiella* sp., *Pseudomonas* sp., *Enterobacter*, *Citrobacter* were observed. Their significant variation between the seasons indicate the activity becoming high at the time of decomposition and recycling of materials. Aerobic bacteria and facultative anaerobes were predominant showing their increased role in bioconversion process. Facultative anaerobes such as *E.coli* sp, *Klebsiella* sp. and *Citrobacter* sp and the aerobic *Bacillus* sp. were also predominant in sediments. The bacterial flora released from the fish excreta and body parts may be the reason for the increased microbial count in the fish growing period, both in water and sediments. This is in agreement with the work done by Fang Xiuzhen *et al.*, (1994) in their studies of pond water and sediments of polyculture fish ponds. Bacteria of genus *pseudomonas* were the predominant one in both pond water and sediments, but in the present investigation, the aerobic *Bacillus* sp. were predominant in water and anaerobes and facultative anaerobes were predominant in sediments.

There are luxuriant growth of bacteria in fish growing water and sediments. They play a very important role in organic matter decomposition and water quality maintenance. Pond fish yields are usually affected directly or indirectly by microbial process Schroeder (1978) pointed out that 50-70% of fish yield of a manured fish pond results from the heterohophic production starting from bacteria. It has been proved by the earlier investigations by Shuju (1984) and Kimura *et al.* (1986) that heterotrophic bacteria in sediments can stimulate algal growth. The significant variation in bacterial count between the seasons in fish growing period and straw decomposition period was noticed. The increased bacterial count and their fluctuation show the microbial activity. The nitrogen

fixers like *Klebsiella* sp, help in the biological nitrogen fixation which help greatly in the natural food generation for fish. The phosphorus solubilizing role was done by *pseudomonas* sp. The various bacteria in the bacterial community can break down organic matters and contribute to the detritus food chain. The fluctuations in bacterial growth in water column is subject to, a great extent, to the fish pond management, especially water management, and feeding activities of fish and the manure and other external materials introduced into the water.

The fluctuations of TBC in sediments had not so wide as the range in water column. It has significant relations with temperature and other environmental factors. The relatively high count of TBC in sediments was observed. This may be due to the richer organic matter in sediments and less chance for fish to ingest bacteria in sediments than in water column. Sometimes suspended detritus particles with attached bacteria will sink down to the pond bottom. The only manure applied in cowdung and the predominance of *Bacillus* sp. is noticed. This is a feature already noticed in earlier investigation (Guo Xianzhen *et al.*, 1994) In cow manured water system, the lowest fertilizer conversion was noticed when compared to pig and chicken manured ponds.

The rice-fish rotational farming water is a semi closed artificial ecosystem. From manure application and feed supplement to fish yield, it undergoes a complicated dynamic process of bio-feeds growth, energy flow, and cycling of matters, making itself dynamically balanced. Aquatic bacteria is not only a decomposer, but energy passer and an important fish feed.

V.4 Growth Rate of Fishes

Growth rate of fishes for the three years, 2000, 2001 & 2002 harvest, showed that the effect of length on weight is highly significant and 9% to 97%

variation in weight is explained by the length. The study revealed that these culture fishes do not exhibit isometric growth. Deviations from the isometric value of 3 has been reported in carps (Jhingran, 1952). When the length-weight relationship is meant for the prediction purposes, the units of measurement employed at the time of finding the L-W model are important. The main purpose of L-W relationship is computation of weight from an easily measurable parameter, the length (Mohan and Sankaran, 1999).

Among the different biological aspects of fish, length-weight relationship and correlation factor are very important for scientific culture and management of the fish and great biological interest of it (Islam *et al* 1999). The value of correlation coefficient indicated that the relationship between total length and body weight was very strong. In the rice-fish rotational farming model, the growth rate is not isometric, the variation in length and weight has been noted the variation in weight is explained by the lengths but the total weight shows that the fishes show very good growth rate, i.e within a period of 6-8 months, 2-3 kg. and above weight has been achieved; this shows that the growth rate is very high. The Catla has attained good size in 2000 & 2002 Rohu is 2000 and 2002, Grass carp in 2002, Silver carp in 2002, and Common carp in 2002. In other words, Common carp, Rohu and Catla were larger and Grass carp and silver carp of smaller in size in 2000 harvest, Rohu, Catla, and Silver carp larger and Common Carp and Grass

carp smaller in 2001 harvest, where as Silver carp, Common carp, Grass carp, Rohu and Catla were larger in size in 2002 harvest. This shows that, the doubt whether the same field used for rotational farming years after years may have any ill effects on the fish growth rate, is baseless. But, instead, the growth rate and the yield in terms of weight of fish is higher year by year, and the high yield of fishes obtained in the recent harvest supports the fact. This shows, how effectively the bioconversion process has taken place.

V.5 Productivity and Bioconversion efficiency

The net productivity rate during the fish growing period (7 months) in rice-fish rotational farming model was found to be 42:46 Cal/m²/hr. The input output ratio shows that in the year 1998 the average intake of food was 455g/fish and the net yield was 678g/fish. About 33% of energy required for the net yield was obtained from the system, refers the solar energy. In the year 1999 about 41% of energy was obtained from the system. In the year 2000 about 23% was obtained and only 1.5% during 2001 and 45% from the system during the year 2002. The data shows that the system is efficient in utilising the energy and the bioconversion rate is very high. The paddy plant cultivated after fish growth shows very elaborate root system which enabled it to absorb more nutrients. The earhead showed much biomass and the total yield of paddy was found to be very high. In short, the manure like cowdung enhanced the growth of phytoplankton, bacteria also flourished. The feed and the phyto and zooplankton with bacteria and benthic organism formed the food of fishes. These fishes through their excreta also added the fertility. The ploughing action was done by common carps. The paddy field after fish harvest was the most fertile field, free of weeds and pests. The bacterial activity was very predominant with diversity and count. The bioconversion efficiency is directly correlated with bacterial count and diversity.

The principal aim of rice-fish rotational farming is to enhance the utilization of biological energy by means of shortening the food chain. It treats the water and land ecosystem as a whole with the goal of producing valuable protein from wastes, changing ecological damage into benefit and sustaining local circulation of resources. This strategy of ecofriendly aquaculture can, not only increase fish production and further improve ecological efficiency, but also improve social and economic efficiency. The manure and feed ingredients provide a broad availability of these byproducts.

Chapter VI

SUMMARY AND CONCLUSION

The project work entitled 'Studies on the ecological aspects and the microbial activity of rice-fish rotational farming system in wetlands of Kuttanad, Kerala,' is unique in the fact that it is for the first time such a study has been conducted in the farmers field. The previous investigations were conducted in the farm of RARS Kumarakom. The present investigation was mainly concentrated in the farmers field, Anthonikkayal padasekharam, which occupied an area of 53 acres and group fish farming was in practice for the last 5 years; and practising the rice-fish rotational farming very efficiently.

The economic viability of the model has already been worked out by many and proved to be highly profitable in terms of rice yield, fish yield and of low cost in production. Those farmers mainly involved in paddy cultivation in both seasons found paddy cultivation highly unprofitable; integration of aquaculture as sequential farming proved to be highly attractive in terms of money. So more farmers switched on to this method. The objective of the study was the scientific analysis of this farming model, to find out whether it is a sustainable agricultural system. The ecology, microbial activity, bioconversion efficiency, energy transfer etc. are studied to find out the impact of this farming model in the ecology of the ecosystem of Kuttanad.

The rice-fish rotational farming model has been introduced to Kuttanad by the efforts of Dr. K.G. Padmakumar, Associate professor, RARS Kumarakom and a series of studies has been undertaken by the various people, mainly on its economics. The present investigation on the ecology and microbial activity has arrived on the following conclusions. It is a sustainable mode of agricultural

practice suitable for the agroecosystem of Kuttanad, because it reduce the main problem of pollution due to the use of pesticides and chemical fertilizers, as they are not required in this farming model. The weed control and the pest control are effected by the activity of fishes; the fertilizers are not required for paddy cultivation, the soil after fish culturing has become highly fertile and free from weeds and larvae of pests, resulted in a high yield of rice crop. The only thing the has to do was to adjust the pH by adding lime, since the soil appeared to be more acidic.

Secondly, the conversion of paddy fields for other cultivations by the farmers will not take place as they find rice cultivation sequentially with aquaculture brings high yield. In that way also the Kuttanad ecosystem can be protected from human interference.

As a sustainable agricultural system, this method has been found to use the existing soil nutrients, water cycles and naturally occurring energy flows for food production. The energy conversion efficiency of the system was found to be very high. The myriads of bacteria present in the sediments and water column formed an effective link in the food chain as food for zooplankton and fishes, in addition to other function of fixation of nitrogen and phosphate solubilization. Both aerobic and anerobic decomposition process was done by the bacterial community and the count of anaerobes of facultative anaerobes was found to be very high in the aquaculture period, both in sediments and water. The fishes require feed 2% of its body weight, of which 1% is supplied from the external source and the remaining 1% was received from the system. The excrete of the fishes served as manure to fertilize the water and sediments.

The study also showed that the rice plants cultivated in sequential farming has the elaborately developed root system, and the reason is the soil with high silt

deposition. These plants absorb the nutrients very efficiently. The reason for the high yield of paddy 1425-1670 kg/ha/year (years 1997-2001, virippu) when compared to 940.0 kg/ 21.6 ha/year (prior to rotational farming) is due to the above mentioned factors. The dry weight (biomass) of the plant is comparatively high when compared to the plants of the same age grown in fields where rice is cultivated in both seasons. In the aquaculture season, Nov-June, the maintenance of the watershed is effected, and the ecosystem has been protected. The biological energy conversion efficiency was found to be very high which makes this agricultural-aquaculture practice unique and suitable for wetlands of Kuttanad.

Before concluding, a few drawbacks in rice fish rotational farming system have to be brought into attention. Firstly, the chances of escape of exotic carps into the natural system of rivers and ponds cannot be ignored. They may compete with the native fauna which may lead to the deterioration and extinction of native fish fauna. However, the fact that the exotic carps will not breed in the natural conditions of Kuttanad makes the issue a little dilute. For culture purposes induced breeding is in practice to produce the fingerlings. Secondly, efficient management of group farming is very important because it is the joint venture of a group of farmers. In short except these few minor drawbacks the rice-fish rotational farming model seems to be very ideal and sustainable mode of agricultural-aquaculture practice most suitable for the wetlands of Kuttanad; because it helps in maintaining the ecological balance, in alleviating the pesticide and fertilizer pollution problems in achieving the high yield and profit that leads to the development of an economically sound society.

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About 55,000 hectares of wet lands are available for paddy cultivation in Kuttanad, India, Kerala. In recent years, the extent of polders lying fallow either perennially or seasonally is alarmingly increasing mainly due to the diminishing and poor returns from the paddy cultivation. As per the data completed in 1987, around 699 hectares of polders were lying fallow in upper, lower and northern Kuttanad regions while 2791 and 34597 hectares were only utilised for Virippu and punja respectively (Harikrishnan and Kurup, 1995). The role that microorganisms playing organic nutrient cycles in fish ponds is examined in detail with respect to improving the pond heterotrophic production for maximum yields of fish in integrated farming systems by Radheyshyam (1986).

Family farms, approximately 80% of farm households in Vietnam have their own small pond garden and canal for aquaculture. Integration of vegetable garden, pig and livestock is a traditional approach to family food production since 1960s (Aldan, 1997).

The potentials of the integrated farming technology for transforming existing traditional farming systems to become more sustainable in Ghana has been reported by Light foot et al. (1996). The integrated farming technology has become an appropriate method for replenishment of decimated fish populations in the rice fields with improvement of incomes, nutrition and environment for sustainable operations and resource management to support healthy human life in Bangladesh (Mazid and Hussain, 1996).