ECOLOGICAL STUDIES ON *LABEO ROHITA* WITH SPECIAL REFERENCE TO GROWTH AND PRODUCTION IN NAGALAND FISH PONDS.

ABSTRACT

NEIVISELIE SIMON DZÜVICHÜ

DEPARTMENT OF ZOOLOGY
SCHOOL OF LIFE SCIENCES

SUBMITTED IN FULFILMENT OF THE REQUIREMENT OF THE DEGREE OF DOCTOR OF PHILOSOPHY

To

THE NORTH-EASTERN HILL UNIVERSITY
SHILLONG-793001
INDIA
AUGUST, 1982

ACKNOLEDGEMENT

At the very outset , I would like to give my heartfelt gratitude to Dr.V.Xaxa,Reader of the department for his valuable guidance and help for the fulfillment of this Dissertation.

And I would like to thank Mrs Puii Muanthanga who rendered her precious time to help me to type-up this Field-Report.

Lastly,but not the least I want to thank all my friends for lending me their helping hands in arranging this volume to the present form.

Dated : Shillong
the 3rd August 1985

F. Lui

(FLORENCE LALMUANPUII)
DEPARTMENT OF SOCIOLOGY
N.E.H.U.

ECOLOGICAL STUDIES ON LABEO ROHITA WITH SPECIAL REFERENCE TO GROWTH AND PRODUCTION IN NAGALAND FISH PONDS.

ABSTRACT

NEIVISELIE SIMON DZÜVICHÜ

DEPARTMENT OF ZOOLOGY
SCHOOL OF LIFE SCIENCES

SUBMITTED IN FULFILMENT OF THE REQUIREMENT OF THE DEGREE OF DOCTOR OF PHILOSOI

To

THE NORTH-EASTERN HILL UNIVERSITY
SHILLONG-793001
INDIA
AUGUST, 1982

7wo (thesis)

ABSTRACT

Aquaculture or culture fisheries has hit the scene in developing countries in the last decade. It was received with great enthusiasm by one and all as it promised to supplement the need to produce additional fish protein for the rapidly increasing population. Although the increase in production of the protein from aquaculture, in the past few years has been significant the overall figures have been much less than anticipated. This is, by and large, to the unwritten and highly site-specific production technology in this field. Moreover the wealth of information needed to such problems do not exist for species of interest to developing countries, and wherever it does, sustained figures have never been obtained. All the more, unlike agriculture there is no strong base of research knowledge for aquaculture.

The present investigation therefore, is a compilation of the results of detailed analysis of most of the important characteristics affecting fish production in a region like Nagaland. The experiments were so designed as to enable the transfer of the technological understanding not only to the State Government in the region but also to the fish farmers. Two sets of aquatic systems were identified for this purpose (i) the natural fish ponds and (ii) the circular plastic pools. In both these systems differential fertilization were administered in addition to supplementary feed in some, to enable the possibility of achieving the highest yield of fish in a particular set of such fertilizer combinations. The fish used in these systems was confined only to one species Labeo rohita, commonly called Rohu, possibly the tastiest of all Indian major carps.

The study was broadly classed into the abiotic and biotic components, like physico-chemical parameters and the phytoplankton and

zooplankton components respectively for the structural understanding and primary production for the functional aspects. These were then correlated to the fish growth and production levels.

The first chapter in the thesis deals therefore primarily with the physico-chemical observation and their interpretation in the various aquatic systems undertaken. It was observed that all the ponds and pools undertaken maintained a steady state equilibrium in relation to the physico-chemical factors in addition to the maintenance of well marked buffering capability. However, in Experimental Fish Pond-2 and Circular Plastic Pool-4, most of the values were on the higher side. The other systems had a magnitude of fluctuation very narrow, though in all of them the values obtained have been shown to be very conducive for fish production. Moreover, the individual physico-chemical parameters analysed revealed a maintenance of a mesoeutrophic condition and not a highly eutrophic one as would normally be expected in such tropical situations.

The second chapter dealing with the biota as the next structural component namely phyto- and zooplankton revealed that algal succession is altered due to fertilization. The phytoplankton analysed both at generic and higher levels indicated that the system controlled the development of blue-green algae while at the same time helping in the development of some of the eutrophic genera among green algae. This seemed to be an excellent inherent quality as the latter group is known to be efficient primary producers. The study of these autotrophs confirmed the physico-chemical parameters in that the systems were never allowed to reach higher levels of eutrophication but having all the qualities of a eutrophic status under control. The abundance in number was however more in the pools than in the ponds. As far as zooplankton was concerned they seemed to be in synchrony with the abundances of phytoplankton. The group rotifera dominated in both the ponds and pools while protozoa though far less possessed larger numbers atleast in the organically manured ponds and pools. There was a clear cut seasonality in their behaviour and the number obtained were at levels essential for fish production.

The third chapter in the thesis was confined to the understanding of the functional aspects of the autotrophs-primary production. The determination of primary production in fish ponds besides giving information on the magnitude of organic production has its practical considerations. Primary production is the basis of the whole biogenic metabolic cycle, and therefore the relative proportion of their values would help in understanding higher trophic levels. In the present investigation it was seen that the highest values obtained were in Experimental Fish Pond-2 among the ponds and Circular Plastic Pool-2 among the pools. The ranges in their values either in the ponds or pools were indicative of high production and is in line with such fertilized systems both in the tropic and the world. The levels though indicative of the eutrophic nature were not equal to higher records of values as in usual eutrophic systems in the tropics. In addition, whenever respiration exceeds production which was observed more than once over the different seasons in the different ponds and pools was another indication of eutrophication. The inorganic fertilizers alone, when administered were seen not to have any significant results but certainly organic fertilizer along with supplementary feedings were seen to enhance the production levels in both the ponds and pools wherever administered. Once again it was seen that primary production levels behaved as well, as that of established equilibrium systems.

The last chapter of the thesis was related to fish growth and production. It was seen that the fertilized fish ponds revealed much higher growth rates than the control. Moreover, in these fertilized ponds, the sixth month and the twelfth month was observed to be phases of sudden exponential increases in weight. Experimental Fish Pond-2 again revealed the maximum growth rate as far as mean weight was concerned. Such was not observed in the mean length of fish among the different ponds, though Experimental Fish Pond-2 had the maximum length. The Circular Plastic Pools though showed after the twelfth month a similar phenomena of increase was not significantly different from each other. The rate of survival among the fishes in the different systems was again seen to be maximum in Experimental Fish Pond-2 and the lowest in Experimental Fish Pond-3, the former being nearly 70% and the latter with only 50%. Here again as in the primary production values, the inorganic fertilizer seemed to inhibit the growth rate of the fishes. However, the organic fertilized system revealed higher mortality. A similar observation was also seen among the Circular Plastic Pools. The production or the fish yield was also calculated during the study period and again the highest value obtained was seen in Experimental Fish Pond-2. Among the Plastic Pools it was Circular Plastic Pool-4, and since the stocking densities were very high the figures though incorporated have not been used for comparision. The ponds revealed nearly six times the production figures of India though not near to the maximum record available. Both increased growth rates and higher yields from the present study reveal that maximum out-put can be obtained by a judicious combination of organic and inorganic fertilizers along with supplementary feed. However this study has helped in the understanding that quite high fish yield can be obtained by simple scientific management even with monoculture of an economically important fish like <u>Labeo rohita</u> in places like Dimapur, Nagaland.

With the knowledge of these four sections it was seen finally to correlate and integrate all of these for a total comprehension of the ecosystems, helping in understanding higher fish yields. Though these individual components revealed an existence of a cyclic development of the pulses of the various factors undertaken, the initiation or termination got displaced over annual periods. Therefore, statistical correlation between these pulses were found out to enable the integration and also anyone factor responsible for a number of variables. As would be expected phytoplankton and primary productivity had significant correlations and very little effect of other abiotic factors was seen on the functioning of the systems or in relation to fish growth and yield. Moreover, nutrients did not play a significant role and it was observed that there was hardly any major differences amongst such correlations between the different systems. The various correlations that have obtained, however, has been discussed and implications drawn upon.

Finally, it was calculated to see, how much of the primary production or the autotrophic biomass as it were, got converted into fish flesh expressed as yield. In the present investigation it was observed that such conversions even in the control pond was quite high and significantly so in the fertilized ponds. Though higher production/ha was seen in Experimental Fish Pond-2 the conversion helped us to show that Experimental Fish Ponds-2 and 3 both had the same conversion figures. This indicated that fish production alone is not a correct measure but in addition such conversion values helped in understanding the basic ecological theories that operate in such ecosystems. Moreover annual production is theoretically and empirically a better predictor of fish yield from aquatic bodies than other suggested relationships between fish yield and environmental variables.

Knowing that both fish yield and conversion are encouraging from the present study an economics was worked out for the application of such a study in atleast the region under consideration. Experimental Fish Pond-2 and Circular Plastic Pool-4 were found to be the most profitable ventures undertaken and even though these had the maximum inputs of expenditures they out-ranked the others in terms of their out-put of fish. All these helped us in arriving at a certain generalised recommendation for implementation in fish ponds in Nagaland.

ECOLOGICAL STUDIES ON LABEO ROHITA WITH SPECIAL REFERENCE TO GROWTH AND PRODUCTION IN NAGALAND FISH PONDS.

NEIVISELIE SIMON DZUVICHU

DEPARTMENT OF ZOOLOGY
SCHOOL OF LIFE SCIENCES

SUBMITTED IN FULFILMENT OF THE REQUIREMENT OF THE DEGREE OF DOCTOR OF PHILOSOPHY

To

THE NORTH-EASTERN HILL UNIVERSITY
SHILLONG-793001
INDIA
AUGUST, 1982

Grams : NEHU Phone : 23390

NORTH-EASTERN HILL UNIVERSITY

Dr. J.R.B. ALFRED,
Reader in Zoology.

Department of Zoology,
School of Life Sciences,
Shillong-793014.

I certify that the thesis entitled "ECOLOGICAL STUDIES ON *Labeo rohita* WITH SPECIAL REFERENCE TO GROWTH AND PRODUCTION IN NAGALAND FISH PONDS", submitted by Neiviselie Simon Dzüvichü for the Degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong embodies the record of original investigation carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of Ph.D.Degree. This work has not been submitted for any Degree of any other University.

DATE : 25/8/82
PLACE : Shillong

Signature of the Supervisor

.....

ACKNOWLEDGEMENTS

I wish to acknowledge my profound gratitude to Dr. J.R.B. Alfred for the expedient guidance and supervision during the period of investigation and also for the help and emendation in the final analysis.

I owe my indebtedness to Professor R. George Michael for initiating me into this field of Science.

I am grateful to Professor M.K. Khare, Head, Department of Zoology, for providing the necessary requirements. The facility and assistance extended to me by the Nagaland Fishery Department's officials are gratefully acknowledged.

Thanks are also due to the North-Eastern Council for the financial support given under the Scheme "Hydrobiological conditions for fishery development in the North-Eastern Region".

Finally, I wish to record my profound gratitude to my parents for their endeavours and encouragements for my educational persuits, and to my wife for her loving solicitude, appreciations and encouragements.

Neiviselie Simon Dzüvichü

••••••

CONTENTS

++++++

FIGURES

++++++

TABLES

++++++

PLATES

.....

GENERAL INTRODUCTION.

GENERAL INTRODUCTION

Aquatic ecosystems differ in many ways by their abiotic and biotic characteristics due to their distinct structure and functional components. It is usually, therefore, of interest to the academics primarily to understand the ecological theory and methodology concerning the dynamics of spatio-temporal system and in particular of aquatic ecosystems interacting over space and time. Studies in such systems become relevant to inland waters and fisheries for optimizing social benefits and maintaining a balance between land-water and man-resource interactions. Aquatic ecosystems at any given time are at different adaptive states due to natural processes or man-induced process. Human interaction may occur at different intensities (primitive, rural, urban-industrial) or scales depending on the level of scientific and technological acculturation. These interactions may be directly with the interest in the large scale development of aquaculture as a manageable food production system.

The escalation of development efforts in culture fisheries stems by and large, from (i) the need to produce additional fish protein to meet the demand of rapidly increasing population, (ii) the fact that production from aquaculture is related to manageable inputs, for example, in the control of the production process; aquaculture is less susceptible than capture fisheries to unpredictable natural influences, and (iii) the levelling off of world catch from conventional capture fisheries.

Although the increase in production from aquaculture, in the past few years has been significant in some countries, the overall growth rate has been less than anticipated. The factors which account for the slow growth are characteristics of emerging industries, an amalgamation of technical, economic, institutional and cultural barrier. To date, technical problems have received the most attention and biologists have by and large, dominated the aquacultural field. Inadequate attention has been devoted to other equally important problem areas and to the interplay among them. In some respect, development related activities are ahead of science and technology in international aquacultural efforts as a result of strong interest in, need for and potential of controlled fish production.

The technical problems are perhaps the easiest to identify. Traditionally, aquaculture has been restricted largely to Asia where practices have been developed through trial and error and passed on through generations. Existing production methodology is empirical, with a narrow scientific base. Production technology is unwritten and highly site specific and is passed from producer to producer in an informal base with few exceptions, the wealth of information needed to tackle such problem areas does not exist for species of interest to developing countries and even if it does for certain species is very sketchy. The growing realization of the urgent need of such a data base has precipitated, repeated recommendations for national and international support of relevant research in developing countries.

To be responsive to these needs, research programmes must not only focus on immediate requirements but also anticipate future problems that may be created by internal and external influences on the industry. On the bases of problems that are beginning to surface, it can be anticipated that expansion of aquaculture will be limited by scarcity of resources used in agriculture and husbandry of terrestrial animals like land, water, feed and fertilizer. Continuing increase in production will then have to be achieved by increasing production per unit of the scarce resource.

Such research and management gaps in India were sought to be bridged by the creation of Central Inland Fisheries Research Institute and other state level research organizations. The objectives were well defined inter alia, included studies of trophic structure and function of freshwater ecosystems, material recycling, physico-chemical features, ecological production functions, fish behaviour, recruitment and other population parameters and development of management principles with a view to achieving optimum fish productivity and fish yield. However, though individual experiments have revealed the possibility of large scale production to meet the needs of the country through such institutions yet, because of the existence of poorly co-ordinated short term and inadequate effort does not allow the producer to get the needed information. Further, a constraint on multidisciplinary approaches to development is one of the several reasons aquaculture has not developed at anticipated rates throughout the country as India. This is primarily due to the failure of funding agencies to support such approaches proposed. Moreover unlike agriculture, a strong base research knowledge does not exist for aquaculture.

The goal of national development plan or the context on which aquaculture is to be practised and the role it is intended to play, will determine the type of aquacultural systems to be used. Added to this will be the nature of the research required to support and improve the chosen system and the overall infrastructure and policies required to successfully underpin development. Because complementary and competitive relationship exist between aquaculture and other sectors of economy, a realistic appraisal of aquaculture's development prospects requires an examination of more than historical trends from which extrapolation are made. The dynamics of change in any economy suggests that there are some areas from which forces that influence aquacultural development emanates. These could be the relative economics of rearing and marketing of various species, the relative economics of agriculture and other sectors that either require the same input used by aquaculture or compete with it in the same market place and finally the expansion of non-agricultural sectors that produce positive or negative impact on aquaculture.

The extent to which aquaculture will successfully compete for limited resources depends in part on the relative efficiency with which aquacultural producer convert inputs into products and upon the extent to which integrated agro-fish farming system lead to complimentariness in place of conflicts. All these considerations imply that a broad economic view of aquaculture's 'fit' in each country is likely to yield a more realistic appraisal of the sectors potential than would a view that is anything else.

It was with this idea that the present investigation was initiated. The areas in the general plan of work for achieving the objectives were (i) to identify and clarify ecosystems such as fish ponds and Circular Plastic Pools and their dynamic inherent patterns of behaviour utilizing the knowledge of both their structural and functional components; (ii) to be able to use the application of this science in the management of inland fisheries particularly in a regional context; and (iii) finally to attempt to characterize some types of aquatic systems perturbed and manipulated to consider how the potential fish yield can be changed for the better.

BACKGROUND OF THE REGION AND STUDY SITE

BACKGROUND OF THE REGION

LOCATION

The State of Nagaland lies between 93°20' to 95°15'E latitude and 25°6' to 27°4'N longitude and encloses a total geographical area of 16,626 sq. km. With the exception of some flat areas in the foot hills, the State is mostly hilly. These rolling hills, with terraces cut across the lower slopes, the narrow glens at their base, the mountain summits clothed with profuse vegetation comprising of diverse flora blooming in their verdant colours are panoramic views of the State. 'Saramati' is the highest peak situated 3840.5 m above the sea level, while Kohima is the capital of the State which is at an altitude of 1444.12 m (Fig. 1).

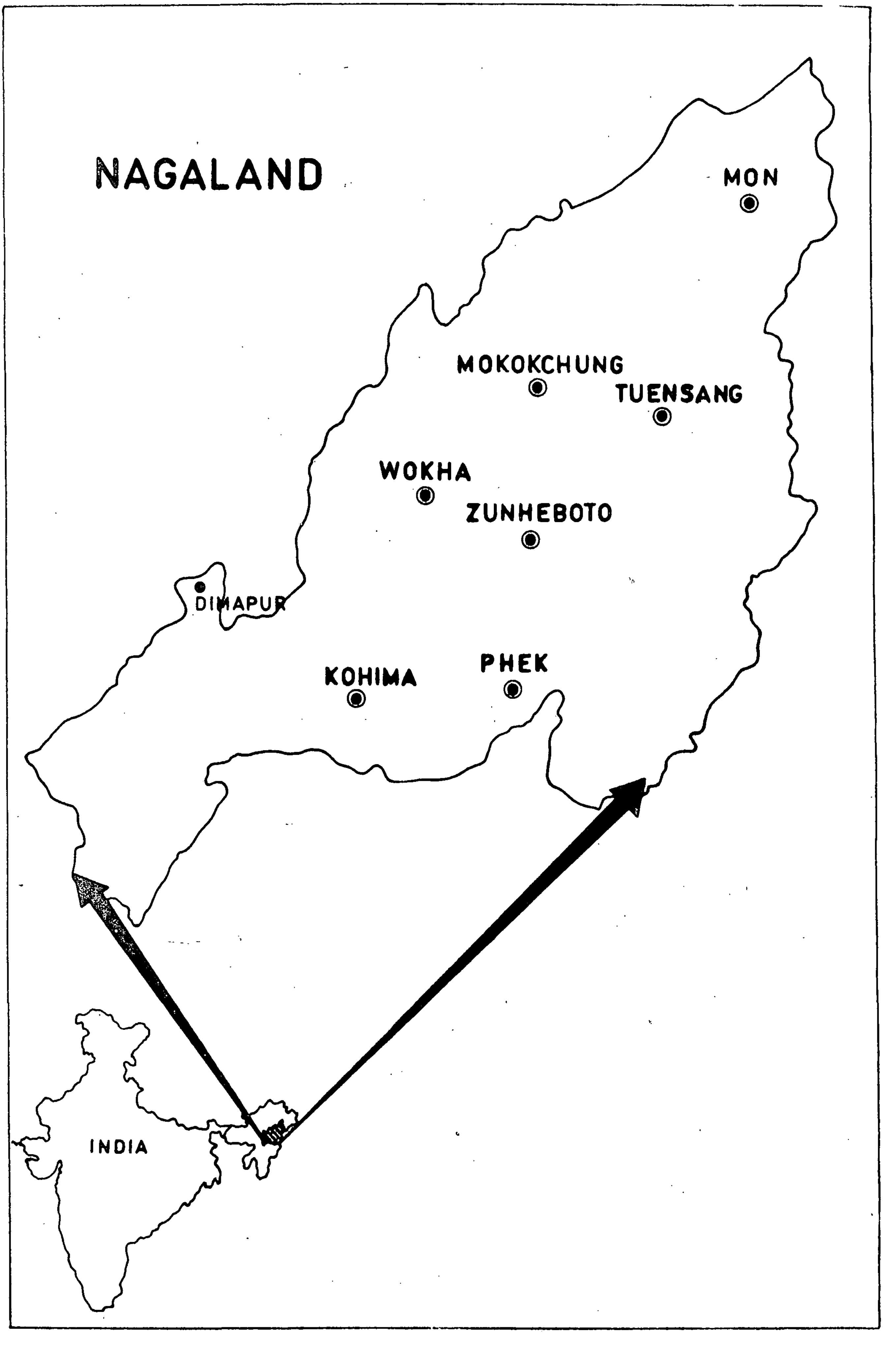
PHYSIOGRAPHY

The entire geological structure of Southern, Central and Northern Nagaland is essentially the same. Southern Nagaland is governed by the Disang and the Barail series of rocks. The Disangs conforming to the oldest rocks are dominant towards the east between Japfu and Saramati at an altitude of 3,000 to 4,000 ft, but the Barail series are abundant towards the west. Disang series exhibits their splintery grey shales interbedded with hard bands of fine grained flaggy sand stones. Disang beds generally dip at steep angles. The structure is soft. Their splintery character has resulted in frequent landslides. The Barail series comprise of fine-grained sand-stones, hard bluish grey, thin bedded and flaggy in nature. Towards the South-West, the Barail exhibits the formation of massive sand-stone but the shale is absent.

SOIL

Soil vary according to altitudes. On mountain tops, soil

Fig. 1 - Map of Nagaland.


NAGALAND
MON
MOKOKCHUNG
TUENSANG
WOKHA
ZUNHEBOTO
DIMAPUR
KOHIMA
PHEK
INDIA

generally exhibits organic matter with heavy texture varying from high tc medium. Lower slopes and the base have scanty undergrowth and a shallow texture, while on the foot hills, soils are generally poor and light and contain low organic matter varying from loamy to sandy. Generally, soils are acidic and made up of P.20.5 to K.20.0. Alluvial soils are comparatively more fertile although such formations are diminutive being confined to the banks of Barak and Dhansiri rivers.

CLIMATE

The climate is warm and sub-tropical in the foot hills, moderate and submontane in the mid-slopes and cool and temperate at higher hills. The average temperature in winter and summer seasons vary from 5°C to 25°C on the hills and 12°C to 34°C at the foot hills. The average rainfall is around 2000 mm spread over six months between May and October. The foot hills afford a corridor to Assam being contiguous to the plains, share a tropical weather. Dimapur and the areas along the road to Kohima, upto Medziphema where the veritable ascent starts into the hills is hot and malarious a contrast of the hills.

VEGETATION

The State is rich in forest resources. The reserved and protected areas constitute 17.7% of the total geographical area. Vegetation varies from alpine to sub-himalayan and from tropical to subtropical and also temperate. It is mainly classified as wet evergreen, sub-tropical wet hills, wet temperate and conifers.

The plain belt on the North-West abounds in wet evergreen vegetation, the main species being Nahor, Sam, Poma, Khokan, Ajhar, Makai, Amari and Hallong. This zone constitutes a tropical broad leaf vegetation The sub-tropical vegetation thrives at an altitude ranging from 1000 to 4000 ft, characterized by species such as Chestnut (Castanopsis spp.), Michelia champaca, Schima wallichii, Albizzia spp. and members of Meliaceae. Pine forests are found over an altitude varying from 3000 ft to 4000 ft but confined only to the South-Eastern 'Chakhesang' region, oak and rhododendron are also associated with it. The wet temperate is widespread on a 5000 ft elevation where Betula, Rhododendron, Magnolia and Jugleans regia are the main species. The vegetation is found mostly in moist and swampy places. Generally, Nagaland resembles closely that of the sub-himalayan type of vegetation.

FAUNA

As Nagaland constitutes a meeting ground of the sub-himalayan elements, Indian, Chinese and Burmese type of fauna overlap and therefore it is as much varied. Rhinoceros along with the monkey and jackal tribes are not only dwindled but those present are sparsely distributed. The others comprise of wild buffaloes, pigs, bears and antlers etc. but the present games vary to squirrels, bats, otters and musk-rat. Snakes are common and made up of viper, kraites, rat-snakes, grass snakes and cobra.

The lower hills have a reduced variety of birds and fowls but the best species still abound at higher altitudes which include the patridge, warbler, robin, woodpecker, hornbill, pheasant, swift, hawk and snipe. More domesticated in the lower hills are the sparrows, sun-birds, parrots etc.

FISH CULTURE

The State has enormous fish culturable water areas, though the presently utilised water is estimated to be 9.0 hectares and 645 hectares under the State and private farms respectively. The present surge of interest in fish cultures has brought additional cultivable areas resulting in an increase in the demand for fish seed. But there exists a significant gap in the supply positions of fish seeds. Efforts are being made by the State Fishery Department to produce sufficient quality fish seeds to cater to the fish farmers, and in addition to the constructions of more demonstration farms to impart the knowledge and basic techniques of management of fish culture practices. Recently in addition to the culture of fish in ponds, the paddy-cum-fish culture has created a popular stride among the farmers particularly in Kohima Districts.

STUDY SITE

Location: The present study was conducted at Dimapur in Kohima District. It lies between latitude 93°48'E and longitude 25°51'N and is at an elevation of 198 m. The climate is warm and sub-tropical with the average temperature ranging between 12°C and 34°C during the winter and summer seasons. Dimapur is at the foot hills and is 2 hours drive down the hills from Kohima.

Four fish ponds were selected from the State farms at Fish Brooder's cum experimental farm and at Jorpukhri fish seed production farm. The water surface areas of these four experimental fish ponds varied from 0.009 to 0.028 hectares and the mean depth of the water ranged between 1.5 m during monsoon and 1.0 m in winter seasons. In addition to the four experimental fish ponds, five circular plastic pools were also simultaneously taken for a detailed study of fish growth under differential fertilization in these systems. The control circular plastic pool, pool-1 and pool-3 each had a diameter of 135 cm and a height of 105 cm. The water depth was maintained at a constant level of 85 cm. Each pool had a total water volume of 1217 litres. Pool-2 had the same diameter as the others, but had a height of 130 cms. The depth of water in this pool was maintained at 120 cm.

The total volume of water was 1718 litres. Pool-4 had 165 cms and 105 cm as its diameter and depth respectively with a water depth of 75 cm. The total water volume of this pool was 1604 litres (Plate-1 and 2 and Table-I).

MANAGEMENT

All the ponds were rainfed and completely independent without inlets or outlet and were well exposed to sunlight. The initial pond management was limited to clearance of all existing predatory fishes by draining the pond and drying it. Thereafter water from the adjoining ponds was pumped into the respective ponds through a sieve preventing fish to enter. The circular plastic pools were filled with water from these ponds similarly.

Fertilization: Fertilization of the ponds and pools were then executed. The organic fertilizer added was cowdung and the inorganic fertilizer was a mixture of three agricultural fertilizers N.P.K. (18:8:4). The organic manure was distributed equally at the four corners of the ponds while N.P.K. was first dissolved in a bucket of water and then spread over the water surface. Both fertilizers were then given as per programme at regular intervals (Table-I).

One pond was maintained as control where no fertilizer nor supplementary feed was administered. Three ponds (1,2 and 3) received cowdung (organic manure) @ 26,666 kg/ha/yr and ponds 1 and 2 in addition received N.P.K. @ 888 kg/ha/yr. Ponds 1 and 2 received cowdung in monthly instalments @ 19.0 and 31.0 kg respectively, while N.P.K. was applied at quarterly intervals @ 1.3 and 3.0 kg respectively. Pond-3 was treated only with cowdung given @ 62.0 kg per month. Similarly, one circular plastic pool was maintained as control. Pool-1 received no fertilizers but the fishes were fed daily with rice bran as supplementary feed. Pools 2 and 4 received both organic

PLATE 1 : The Experimental Fish Ponds.

1. Control pond.

2. Experimental Fish Pond-1.

PLATE - 1

1

2

PLATE 1-Contd: 3. Experimental Fish Pond-2.

4. Experimental Fish Pond-3.

PLATE - 1 contd.

3

4

PLATE 2 : The five Circular Plastic pools.

CP = Circular Plastic pools.

PLATE - 2

TABLE-I

	Area	Average depth (cm)	Coudung kg/ha/yr	N.P.K. kg/ha/yr	Coudung/ month (kg)	N.P.K./ Quarterly (kg)	No.of instalments		Total Amount of fertilizers/18 months	
							Coudung	N.P.K.	Coudung (kg)	N.P.K. (kg)
CONTROL POND	0.014 ha	120.0	-	-	-	-	-	-	-	-
EP-1	0.009 ha	120.0	26,666	888	19.0	1.3	18	6	342.0	7.8
EP-2	0.014 ha	120.0	26,666	888	31.0	3.0	15	6	560.0	18.0
EP-3	0.028 ha	130.0	26,666	-	62.0	-	18	-	1116.0	-
CONTROL POOL	1.43 m^2	85.0	-	-	-	-	-	-	-	-
CP-1	1.43 m^2	85.0	-	-	-	-	-	-	-	-
CP-2	2.14 m^2	120.0	26,666	-	0.3	-	18	-	5.4	-
CP-3	1.43 m^2	85.0	-	888	-	0.089	-	18	-	1.6
CP-4	2.14 m^2	75.0	26,666	888	0.45	0.19	18	18	8.2	3.42

TABLE-II

	Stocking Rate/ha.	No.of fingerlings stocked/ Pond and Pool	Rice bran at 1% body weight Av. daily rate/(kg)	Total quantity of feed/ 18 months (kg)	Cost of artificial feed @ Rs. 0.80/18 months
CONTROL POND	10,000	150	-	-	-
EP-1	10,000	106	-	-	-
EP-2	10,000	140	0.4	219.2	Rs. 175.36
EP-3	10,000	204	-	-	-
CONTROL POOL	1,39,664	20	-	-	-
CP-1	1,39,664	20	0.014	7.43	Rs. 5.94
CP-2	1,40,186	30	0.021	11.67	Rs. 9.34
CP-3	1,39,664	20	0.011	5.97	Rs. 4.78
CP-4	1,40,186	30	0.021	12.5	Rs. 10.00

TABLE-I

Physical characteristics of the four Experimental Fish Ponds and the five Circular Plastic Pools and their fertilization schedules.

Table-II

Details of supplementary feeding with rice bran.

EP = Experimental fish Ponds.
CP = Circular Plastic Pools.

manure (cow-dung) @ 26,666.0 kg/ha/yr and N.P.K. @ 888.0 kg/ha/yr, while Pool-3 was treated only with N.P.K. @ 888.0 kg/ha/yr. Pools 2 and 4 were treated with cow-dung @ 0.3 and 0.45 kg respectively per month, while Pool-3 received only N.P.K. @ 0.089 kg per month and Pool-4, in addition to organic manure was treated with N.P.K. @ 0.19 kg per month (Table-I).

Supplementary feed: Supplementary feeding in the form of rice bran was supplied daily to the fish ponds and pools wherever so chosen at 1% of the body weight. In the experimental ponds only Pond-2 was supplied with rice bran, whereas all the four circular plastic pools received supplementary feeds. The rate of feeding was executed after each monthly fish growth rate sampling and the amount of feed required was worked out progressively. This amount was then given daily for the following month. The total quantity of feed given was calculated and also in terms of kg/ha/yr (Table-II).

Fertilizers, both organic and inorganic and supplementary feed were calculated at kg/ha/yr. For the ponds the area was calculated simply by multiplying the length and breadth and for the pools, the area was calculated by the use of the formula πr^2. Both were subsequently converted to hectares.

PHYSICO-CHEMICAL FACTORS

INTRODUCTION

Since the time of Forel (1892-1895) when original limnological observations were made, there is nothing worth the mention, till Caspari (1910) and Muttkowski (1918) who formulated a set of criteria or categorization, either for the bottom deposits or for the thermal stratification of water respectively. Kemmerer et. al., (1923) probably, were the first to identify a thermal stratification with depth and followed by Atkins (1925), and though retaining the term "thermocline", introduced epithalassa for the upper stratum, and hypothalassa for the lower stratum of oceans. Lundquist (1927) brought about the classification based on bottom deposits while Stromsten (1927) was of the view, that only heavy winds could disturb waters below 20 m depth.

The interplay of factors, was probably first reported by Wiebe (1930) who revealed pH and carbonates directly proportional to each other. Ruttner (1931), has been one of the earliest workers in the tropics, where he did identify a thermal stratification in places like Java and Sumatra. The concept of metalimnetic oxygen deficit, goes to Strom (1931) and Kusnetzove and Karsinkin (1931) respectively. The earliest tropical studies in Africa, dates back to 1933, when Worthington and Beadle, proved the non-existence of the thermoclines. In India, the work of Pruthy (1933) could be the earliest, though, other than the monthly observations, no intricate relationships were discussed. It was Hutchinson (1938) who attributed a hypolimnetic oxygen deficit, as an indicator of the trophic status of a lake. The absorption of light energy by the particulate matter in aquatic bodies was revealed in detail by James and Birge (1938).

Phosphorus as an important limiting factor, was revealed as early as 1940 by Deevey, and simultaneously in India on other hydrological factors by Ganapati (1940, 1941 and 1943). It was only from 1942, when the causative factors for the nutrient complexes and release from the sediments, their interplay with oxygen concentration levels, identification of spring turnover and summer stratification, accompanied by an increased level of CO_2 and related substances, with a decrease in pH was identified (Aberg and Rodhe, 1942; Mortimer, 1942). Since then, relationship between two factors or more, started pouring in limnology, either directly or indirectly, proving to be indices of lake productivity (Moyle, 1946; Gonzalves and Joshi, 1947; Edmondson, 1948; Ohle, 1952; Komarovsky, 1953; Lauff, 1953; Wallen, 1955; Ganapati, 1955 and 1959).

It was in the late fifties, that the importance of one or more nutrients being responsible for the biotic elements, their rise and fall, indicative of the levels of presence and utilization was observed (Hutchinson, 1957 and Vallentyne, 1957). The erratic fluctuations of these nutrients being affected by rainfall, was revealed by Tucker (1958). Goldman (1960), attributed the importance of minor nutrients responsible for the different rates of carbon fixation, while Shapiro (1960) attributed rapid eutrophication due only to metalimnetic depletion of dissolved oxygen. This was confirmed by Lund <u>et. al.</u>, (1963) who revealed that the upper zones of hypolimnion has consumption of oxygen, two or three times faster than the lowerzones. Wetzel (1966) attributed differential patterns of thermal stratification while Hussainy (1967) revealed turbid waters, being warmer than clear ones. The chemical characteristics of the surface waters being closely related to the soil characteristics of their drainage basins, was detailed by Keup (1968) and Vollenweider (1968). This sediment-water interface, affecting the whole column of water, has been well documented by Golterman (1969). Vijayaraghavan <u>et. al.</u>, (1969), Kalff (1970) and King (1970) attributed carbon as the ultimate limiting nutrient in relation to that in the form of dissolved carbohydrates released and utilized. This was supported by Kerr et. al., (1970) and Lange (1970) who identified carbon, rather than nitrogen and phosphorus to limit production. The different forms of phosphate and that of chelation was identified by Stumn and Morgan (1970). However, Sreenivasan (1970), Timms (1970) and Vijayaraghavan (1971) considered oxygen deficit as a factor to be reckoned with in production. The concepts of nitrification and denitrification in lake sediments affecting the total biota was shown by Chen et. al., (1972), Keeney (1973), Tan and Overbeck (1973). Lasenby (1975) and Wetzel (1975) attributed turbulence patterns of waters to be related to oxygen, and correlated with average secchi disc depth. The lake water as the largest pool of nitrogen and the sediments as the reservoir of phosphorus was revealed by Serruya et. al., (1975), while Sreenivasan (1975) attributed trace elements to be of greater importance than major nutrients.

The late seventies have been a period of utilising the factors identified, their permutations and combinations in the manipulation experiments, either at microcosm or macrocosm levels and were more so in fish ponds (Garith, 1976; Blinn, 1976; Cheng and Tyler, 1976; Alfred and Chellapa, 1977; Allen and Ocevski, 1977; Schindler, 1977; Alfred et. al., 1978 and Dhillon, 1978).

A review on the present status on limnology in India based primarily on publications in Hydrobiologia is excellently given by Gulati and Wurtz (1980). They have identified 325 papers of Indian work upto 1979, and have revealed that two-thirds appeared in the last one decade alone. Simultaneously, Michael (1980) had reviewed till that date, as far as possible all Indian freshwater investigations.

These foregoing review of literature, though inclusive of both large and small water bodies, yet it was felt to identify those works which have a direct relationship to fish ponds. The effect of fertilisation and supplementary feedings, on the basic physico-chemical factors in fish ponds and other such works of direct importance are those of Villadolid et. al., 1954; Depasse, 1956; Swingle, 1957 and Michael, 1969, who have identified either pH, carbon-dioxide and other physico-chemical factors as limiting factors in the role of fish culture. Burdach et. al., 1972; Russo et. al., 1977; Colt et. al., 1978 and Tamasso et. al., 1979, similarly had identified the buffering capacity in a fish pond and the role of ammonia and nitrate in farming and husbandry of freshwater fishes. An overall review of the effect of the physico-chemical factors in both fertilised and non-fertilised ponds in India have been well compiled and documented by Jhingran (1980).

MATERIALS AND METHODS

Ten physico-chemical parameters were undertaken for a detailed investigation in the four experimental ponds and five plastic pools. The period of study was from October, 1979 to March, 1981. Water samples were collected weekly, at the different experimental ponds and circular plastic pools for analysing these ten parameters. The time of collection was always confined to the morning hours just after sunrise (0600 hrs. to 0900 hrs.). All weekly samplings were brought together as monthly averages for the sake of convenience and brevity and the figures represent the seasonal variations monthwise.

Two set of water samples were collected in 125 ml ground glass stoppered bottles and fixed for oxygen and carbon-dioxide analysis. For the other set, water was taken into polythene bottles of 500 ml and closed tightly for nutrients analysis and also for pH, Total alkalinity and Conductivity analysis.

Air temperature was measured with the help of an ordinary mercury thermometer at about 1 m above the surface of water at the different stations. The water temperature was taken with a similar thermometer at the water surface and readings were immediately recorded.

All other factors were analysed in the laboratory within one hour of collection. pH and Conductivity were read off from a TOSHNIWAL pH METER (Model No. CAT. CL-43) and ELICO CONDUCTIVITY BRIDGE (Model No. Type CM-82) respectively. For oxygen, the samples which were fixed in the field was further reacted as per Azide (Asterberg) method and with the help of the unmodified Wrinkler's technique was estimated (American Public Health Association, 1965). Carbon-dioxide and alkalinity were determined in the usual way after Welch (1948).

Nitrate was estimated by phenol-disulphonic acid method, while phosphate was by the Stannous Chloride and Molybdate method both after the American Public Health Association (1965). Silicate was estimated after Mackereth (1963), though the standards were prepared after Golterman and Clymo (1968).

RESULTS

Experimental Fish Ponds

In the four experimental fish ponds, ten physico-chemical factors were undertaken for a detailed investigation for eighteen months (October, 1979 - March, 1981).

Temperature

The air temperature for both the cycles were more or less the same with the minimum being recorded in December or January, nearly 18.5°C and the maximum in September with the temperature around 34°C. As with air temperature, the water temperature recorded, though with a variation of ±1 and usually on the positive side was minimum in the months of December and January and the maximum in September, recording 19.3°C and 35.5°C respectively. This phenomenon of water temperature was seen to be more or less consistent in all the experimental ponds undertaken (Fig. 2).

pH

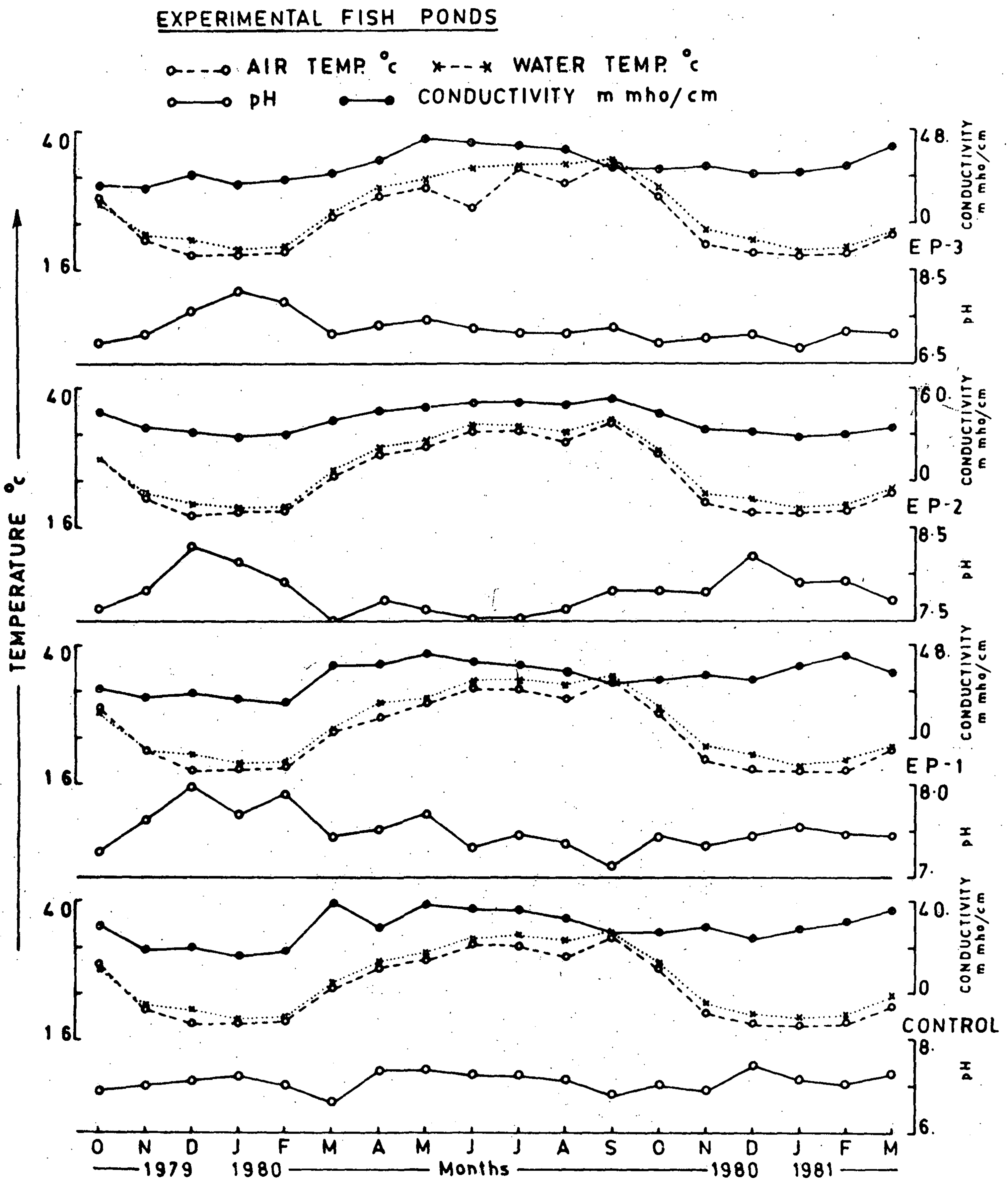
The next abiotic factor pH, was seen to be mostly on the alkaline side in all the four experimental ponds undertaken, with the minimum values touching neutral and if lower, only very slightly.

CONTROL POND : In the control pond, pH ranged between 6.7 and 7.2 units. During the first annual cycle in this pond the minimum was in March (6.6 units) and the maximum in April (7.3 units), while during the second cycle the minimum was in November (6.9 units) and the maximum in December (7.4 units), though the variation in the latter was very insignificant. However, throughout the period of investigation, the pH in this pond oscillated around 7.0 units. An overall picture of the fluctuation showed an increase in the winter and rainy months with a drop in the summer months (Fig. 2).

EXPERIMENTAL FISH POND-1 : The pH recorded, in experimental fish pond-1 was definitely alkaline, with the lowest being recorded in

Fig. 2 - Showing the seasonal rhythmicity of the physico-chemical parameters in the Control and Experimental Fish Ponds.

EP = Experimental Fish Ponds.



EXPERIMENTAL FISH PONDS
AIR TEMP. °c
WATER TEMP. °c
pH
CONDUCTIVITY m mho/cm
TEMPERATURE °c
40
16
48.
0
CONDUCTIVITY m mho/cm
EP-3
8.5
6.5
pH
60.
EP-2
7.5
EP-1
8.0
7.
40.
CONTROL
8.
6.
O N D J F M A M J J A S O N D J F M
1979 1980 Months 1980 1981

the months of September (7.1 units), while the maximum was 8.0 units in the month of December, during the first annual cycle. In the next six months there was very little change, with the pH oscillating around 7.3±0.2 units, with a maximum of 7.5 units recorded in January. The trend of fluctuation seasonwise was like the control pond (Fig. 2).

EXPERIMENTAL FISH POND-2 : pH revealed maximum in contrast to all the other ponds throughout the period of investigation and normally oscillated around 8.0±0.1 units, and hence only alkaline. The maximum pH was recorded in December with 8.3 units, while the minimum in March with 7.5 units, during the first annual cycle. The next cycle recorded minimum in March with 7.7 units and maximum in December with 8.3 units. Here also as in the previous ponds, the trend of fluctuation was similar with a winter maxima and summer minima (Fig. 2).

EXPERIMENTAL FISH POND-3 : It revealed a gradual trend of increase in pH with the minimum in October as 6.9 units till it touched a peak in January with 8.0 units. Thereafter it oscillated around 7.2±0.2 during the first annual cycle. Similarly, the second cycle, also revealed the same trend of fluctuation but with the maximum and minimum in February and January with 7.2 units and 6.8 units respectively (Fig. 2).

Conductivity

CONTROL POND : Conductivity was the next abiotic factor. In the control pond it never exceeded above 40.0 mmho/cm and not below 17 mmho/cm. The lowest record in the control pond was observed in January and the highest conductivity in March with 39.3 mmho/cm during the first annual cycle. December and March recorded minimum and maximum with 24.7 and 36.2 mmho/cm respectively in the second cycle. The seasonal trend of fluctuation revealed a summer maxima and winter minima (Fig.2).

EXPERIMENTAL FISH POND-1 : The Conductivity in this pond-1 showed more or less a similar trend of fluctuation seasonally, to that of the control pond. This pond however, recorded higher ranges of conductivity, the minimum and maximum being 19.1 mmho/cm in February and 43.2 mmho/cm in May during the first annual cycle. The months of December and February recorded minimum and maximum of 30.0 and 42.3 mmho/cm respectively, in the second cycle. Though the trend showed a clear cut winter minima, the summer did not reveal significant increase as in the other ponds except that, the onset of spring did show a rise in the conductivity values in this pond (Fig. 2).

EXPERIMENTAL FISH POND-2 : It recorded the maximum conductivity in relation to all the other ponds. The lowest value observed was in January with 29.5 mmho/cm and the maximum with 52.5 mmho/cm in September during the first annual cycle. In the next cycle January and October recorded the minimum and maximum with 29.0 and 43.0 mmho/cm respectively. The seasonal trend of fluctuation was however similar to the other ponds (Fig. 2).

EXPERIMENTAL FISH POND-3 : It revealed a range of fluctuation in conductivity from 19.0 to 43.7 mmho/cm throughout the period of investigation. It was however seen, that the minimum and the maximum ranges were recorded during the first annual cycle, in November and May respectively. In the second cycle the lowest range was observed in December with 25.5 mmho/cm which thereafter recorded a steady trend of increase to touch a peak of 39.5 mmho/cm in March. Once again the seasonal trend of fluctuation was similar to the other ponds (Fig. 2).

Total alkalinity

CONTROL POND : Total alkalinity as the next abiotic factor ranged between 80.0 mg/l and 190.0 mg/l in the control pond. The minimum was seen in December and the maximum in March during the first annual cycle. The second cycle revealed a minimum in November and a maximum in January with 78.0 and 130.0 mg/l respectively. The fluctuation of total alkalinity, in addition recorded smaller peaks of increased values in the months of May, August, October and February and a fall in November, April, June, September and March of the study period. Generally, the trend could be seen to be as winter minima and spring maxima with a smaller peak of increase in the rainy season (Fig. 3).

<u>EXPERIMENTAL FISH POND-1</u> : The total alkalinity ranged between 90.0 and 200.0 mg/l. The minimum recorded during the first annual cycle was in October, which thereafter, increased gradually to touch a peak in March. In the next cycle, November and January recorded minimum and maximum with 97.5 and 140.0 mg/l respectively. Besides, the maximum and minimum peaks recorded smaller peaks of increase were also seen in May and August, whereas their fall were observed in April, July and October during both the cycles. The seasonal trend revealed a spring maxima and winter minima (Fig. 3).

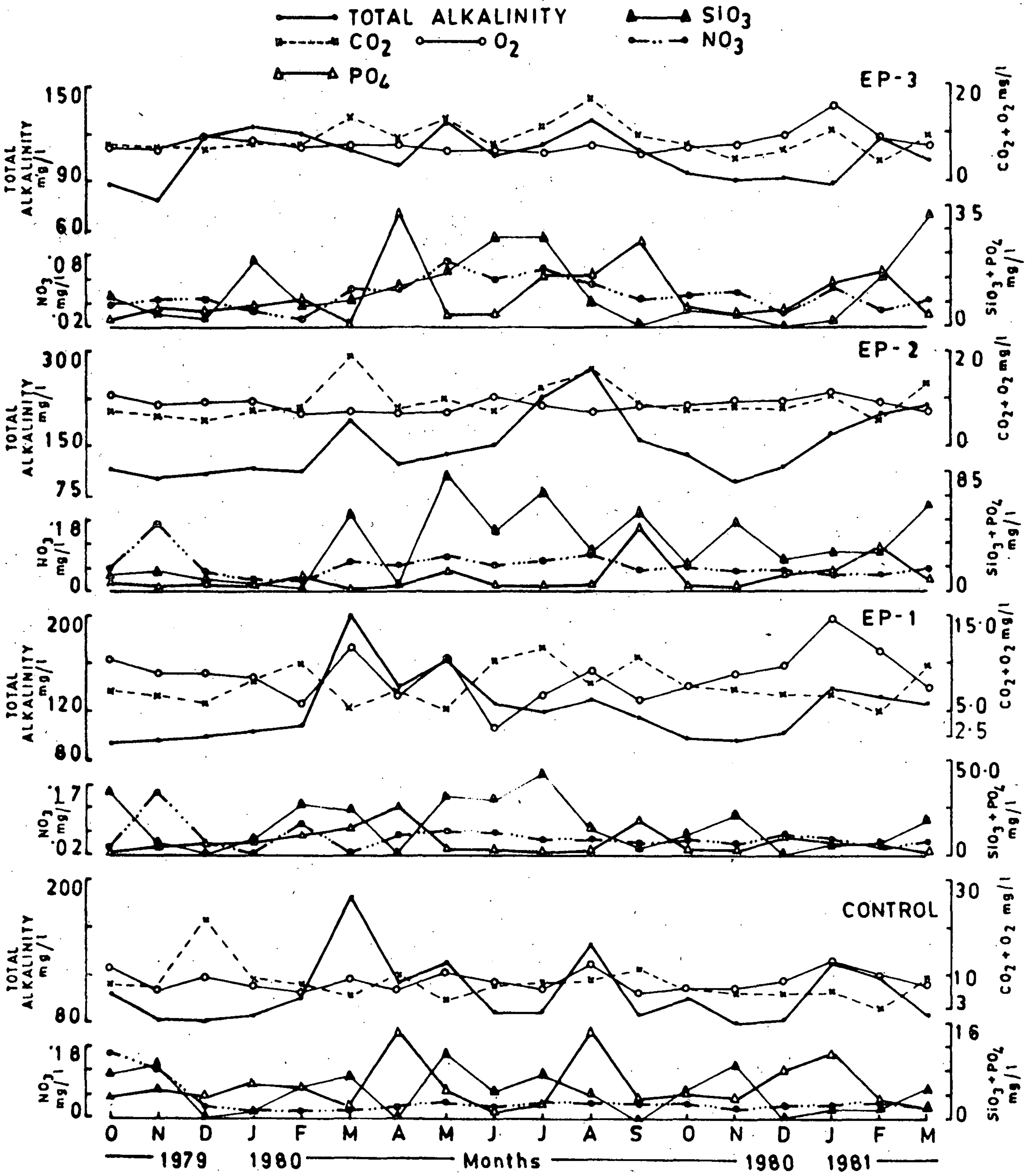
<u>EXPERIMENTAL FISH POND-2</u> : It revealed higher values of alkalinity and that too significantly, over all the other ponds. The minimum was recorded in November with 99.5 mg/l and the maximum peak of nearly 272.0 mg/l was observed in August during the first annual cycle. November and March recorded the minimum and maximum with 95.0 mg/l and 210.0 mg/l during the second cycle respectively. It was seen that the months of March, July and February also recorded smaller peaks, while their falls were observed in April and October during both the cycles in addition to the maximum and minimum recorded. The winter minima in the seasonal trend of fluctuation as observed in the other ponds was also seen here, though the maxima was in summer (Fig. 3).

<u>EXPERIMENTAL FISH POND-3</u> : The total alkalinity ranged between 80.0 mg/l recorded in November as minimum, to a maximum of 128.0 mg/l in

Fig. 3 - Showing the seasonal rhythmicity of
the physico-chemical parameters in
the Control and Experimental Fish Ponds.

EP = Experimental Fish Ponds.

EXPERIMENTAL FISH PONDS



August during the first annual cycle. In the second cycle, the maximum and minimum ranges were almost consistent to that of the first cycle with 88.0 mg/l in January and 116.0 mg/l in February. Besides, the maximum and minimum ranges recorded, it further showed peaks of almost equal magnitude in January and May, while their falls were registered in April, June and November during the study period. A similar trend of an overall seasonal fluctuation as observed in the other ponds for this factor was seen here also (Fig. 3).

Carbon-dioxide

CONTROL POND : The next factor was carbon-dioxide which recorded a minimum in May with 5.0 mg/l and in February with 3.3 mg/l during first and second cycles respectively. The maximum recorded for both the cycles were in December and March with a concentration of 22.0 mg/l and only 9.0 mg/l respectively. It was further observed that smaller peaks in carbon-dioxide concentration were encountered in the months of April, July, September and January, while the falls were registered in January, March, May and November in addition to the maximum and minimum recorded for the entire period (Fig. 3).

EXPERIMENTAL FISH POND-1 : In the experimental pond-1, the range of variations for CO_2 were not so apparent as in the control pond. The minimum of 5.0 mg/l was recorded in May and in February during both the cycles. The maximum was recorded in July and March with nearly 10.0 mg/l during both the cycles respectively. The fluctuations further revealed smaller peaks in addition to the maximum and minimum, in the months of October, January, April, June and September and their falls in December, March, May, August and October for both the cycles (Fig. 3).

EXPERIMENTAL FISH POND-2 : The carbon-dioxide concentration in the experimental pond-2, was more or less similar to that of pond-1, however, with a slight increase in both the minimum and maximum values. The lowest values of 6.0 and 6.5 mg/l was seen in December and February during the first and second cycles respectively, while a maximum of 19.0 and 13.0 mg/l was recorded in March during both the cycles. In addition to the maximum and minimum recorded, carbon-dioxide concentration showed smaller peaks in May, August, November and January while they fell in April, June and October during both the cycles. In any case this pond like the other abiotic factors, for carbon-dioxide also was seen to be maximum in comparison to all the other ponds undertaken (Fig. 3).

EXPERIMENTAL FISH POND-3 : It recorded the maximum and minimum carbon-dioxide values in August and December with 17.0 and 6.5 mg/l during the first annual cycle respectively. The second cycle recorded 10.0 mg/l in January as maximum and 4.0 mg/l in February as the minimum values. In addition to the peak values recorded, smaller peaks of magnitude were also observed in the months of January, March, May and March, while their falls were registered in April, June, September and November during both the cycles (Fig. 3).

Dissolved oxygen

CONTROL POND : Dissolved oxygen as the next abiotic factor revealed a range of fluctuation from 6.0 to 13.0 mg/l in the control pond. During the first annual cycle the months of August and September recorded maximum and minimum with 12.0 and 6.2 mg/l respectively. In the next cycle January recorded 13.0 mg/l as maximum and October with 7.4 mg/l as the minimum. The fluctuation of dissolved oxygen in addition to their maxima showed peaks of lower magnitudes in the months of October, December, March and May (Fig. 3).

EXPERIMENTAL FISH POND-1 : In this experimental pond-1, the maximum values were seen to be almost equal to that of the control pond, yet the minimum recorded in June was just 3.0 mg/l during the first annual cycle and 7.5 mg/l in March during the next cycle. The maximum values in both the cycles were 12.0 mg/l in March and 15.0 mg/l in January. In addition to the peak recorded, the months of October, May, August and December revealed smaller peaks (Fig. 3).

EXPERIMENTAL FISH POND-2 : It revealed that the minimum and maximum values of oxygen variations were the least in comparison to other ponds observed. It recorded a maximum in October with 10.8 mg/l and minimum in April with 7.0 mg/l during the first annual cycle. The next cycle showed 11.4 mg/l in January as the maximum and 7.6 mg/l in March as the minimum oxygen values. Besides these, smaller peaks were observed in the months of June and November only (Fig. 3).

EXPERIMENTAL FISH POND-3 : In this experimental pond-3, the range during the first annual cycle was minimal as it was seen to be between 6.0 mg/l and 9.0 mg/l, the former values as the minimum recorded in September and the latter as the maximum in December. However, the range in the second cycle was quite significant in that the minimum of 7.0 mg/l was recorded in October, while it was nearly 16.0 mg/l in January as the highest values recorded (Fig. 3).

After these abiotic factors, the seasonal fluctuation of the three major nutrients were analysed. These nutrients were Silicate, Nitrate and Phosphate.

Silicate

CONTROL POND : Silicate in the control pond was seen to vary between nil values and 10 mg/l. These nil values were recorded in December, April and September during the first annual cycle and December of the second cycle. The maximum values of silicate in the control pond were observed in May and November with 10.7 mg/l and 9.12 mg/l during the first and second cycles respectively. The seasonal trend of fluctuation showed a summer maxima and a winter minima (Fig. 3).

EXPERIMENTAL FISH POND-1 : The silicate values in this experimental pond-1 was never below 0.2 mg/l as recorded in December and April during the first annual cycle and in December during the next cycle. The maximum of nearly 43.0 and 21.0 mg/l was recorded in July and November during the first and second cycles respectively. The trend of seasonal fluctuation revealed a summer maxima and winter minima (Fig. 3).

EXPERIMENTAL FISH POND-2 : In this experimental pond-2, highly significant values of Silicate were obtained. Though, in one instance a minimum of only 2.0 mg/l was recorded in February during the first cycle, it was 18.0 mg/l in October during the next cycle. The maximum values obtained were in May and March with 83.0 mg/l and 63 mg/l during the first and second cycles respectively. These were undoubtedly high and obviously recorded the highest values in comparison to all the other ponds. The seasonal trend of fluctuation was similar to pond-1 (Fig. 3).

EXPERIMENTAL FISH POND-3 : The experimental pond-3 had comparatively low Silicate values but was more or less like that of pond-1. The minimum values were 0.5 mg/l or nil as seen in September and December during the first and second cycles respectively. The maximum values were 26.0 mg/l in June, while it was 33.0 mg/l in March during the first and second cycles respectively. The seasonal trend of fluctuation was similar to the other ponds (Fig. 3).

Phosphate

CONTROL POND : The next major nutrient analysed was Phosphate, which ranged between 1.0 mg/l and 15.0 mg/l. These as minimum and maximum values were recorded in June and August respectively during the first annual cycle in this control pond. Similarly, during the second cycle, the minimum of 2.0 mg/l and a maximum of 12.0 mg/l was seen in March and January respectively. In addition to the maximum peaks recorded during the entire period, peaks of smaller magnitudes were registered in the months of January, April and December, while they fell during the months of June, September and February (Fig. 3).

EXPERIMENTAL FISH POND-1 : In experimental pond-1, the minimum value of Phosphate dropped low and recorded 0.5 mg/l in October during the first annual cycle, but was nearly 4.0 mg/l in March during the next cycle. The maximum was however 25.0 mg/l in April, but it was only 10.0 mg/l in December during the first and second cycles respectively. Apart from the peaks recorded, smaller peaks were seen in the months of September and December, while their falls were prominently seen in May, October and February during the entire period (Fig. 3).

EXPERIMENTAL FISH POND-2 : The experimental pond-2 showed the maximum values of Phosphate. The minimum value however touched nearly 2.0 mg/l in February during the first annual cycle and was nearly 6.0 mg/l in November during the next cycle. A maximum of 46.0 mg/l was recorded in September and 32.0 mg/l in February during the first and second cycles respectively. The fluctuation of Phosphate over the seasons showed additional peaks in February, May and January and falls in March, June, October and March (Fig. 3).

EXPERIMENTAL FISH POND-3 : In experimental pond-3, Phosphate showed the minimal values of 0.5 mg/l in the first annual cycle as seen in March, while it was nearly 4.0 mg/l again in March during the second cycle. The maximum however, was recorded in April with 32.0 mg/l and in February with 16.0 mg/l during the first and second cycles respectively. Further, the trend of fluctuation in addition to the maximal value recorded, smaller peaks were registered in February, August and January, while the decreasing values were seen in March, May, October and March during both the cycles (Fig. 3).

Nitrate

The last major nutrient undertaken was Nitrate. It was found that the fluctuation of this nutrient throughout the period of study was considerably less and mostly oscillated around the minimal values recorded, irrespective of the different ponds undertaken.

CONTROL POND : The nitrate values in the control pond ranged between 0.02 and 0.16 mg/l and was found to oscillate more on the minimal side during the first annual cycle. In the next cycle the nitrate values oscillated between 0.032 and 0.039 mg/l. Except for the peak in October no significant increase or decrease in nitrate concentration was observed in the control pond (Fig. 3).

EXPERIMENTAL FISH POND-1 : A similar observation was also seen in experimental pond-1, in that the values ranged between 0.02 to 0.15 mg/l and the nitrate levels oscillated around the minimal values throughout the period of study. With the exception of the peak in November and a smaller one in February during the first annual cycle (Fig. 3).

EXPERIMENTAL FISH POND-2 : In the experimental pond-2 a similar trend of fluctuation in the nitrate levels was observed though the minimum and maximum levels recorded were a little higher. Further, these were also the maximal records among the other ponds under consideration. It ranged between 0.03 to 0.17 mg/l, the former being the minimum level recorded in February and the latter as the maximum recorded in November during the first annual cycle. During the second cycle the nitrate levels were almost consistent with a minimum of 0.04 mg/l in January and the maximum of 0.06 mg/l in October. In addition to the peak values recorded, there was a trend of increase though on smaller magnitudes in the months of March, May and August during the first annual cycle while the next cycle did not give any significant increase in nitrate levels (Fig. 3).

EXPERIMENTAL FISH POND-3 : The experimental pond-3 revealed the least nitrate level of all the ponds, with the range between 0.02 and 0.07 mg/l. The maximum nitrate level was recorded in May and the minimum in February during the first annual cycle. The next cycle recorded the maximum and minimum in January and December with 0.05 and 0.03 mg/l respectively. It was further observed that a trend of fluctuation on the increase was seen in the months of March, July, November and March during the entire study period (Fig. 3).

Circular Plastic Pools : Temperature

The air temperature for both the cycles revealed a more or less similar trend of fluctuation. A maximum of 34°C and a minimum of 18.3°C in the months of September and January respectively during the first annual cycle was recorded. During the next cycle a maximum of 27.3°C and a minimum of 18.5°C was recorded in October and January respectively. The water temperature also revealed a similar pattern of fluctuation, following closely the air temperature with a variation of ±1.0 and normally oscillating on the positive side. The maximum was recorded in September with 35°C and a minimum with 20.5°C in January during the first annual cycle. In the next cycle October recorded the maximum with 28.3°C and January with 19.5°C as the minimum (Fig. 4).

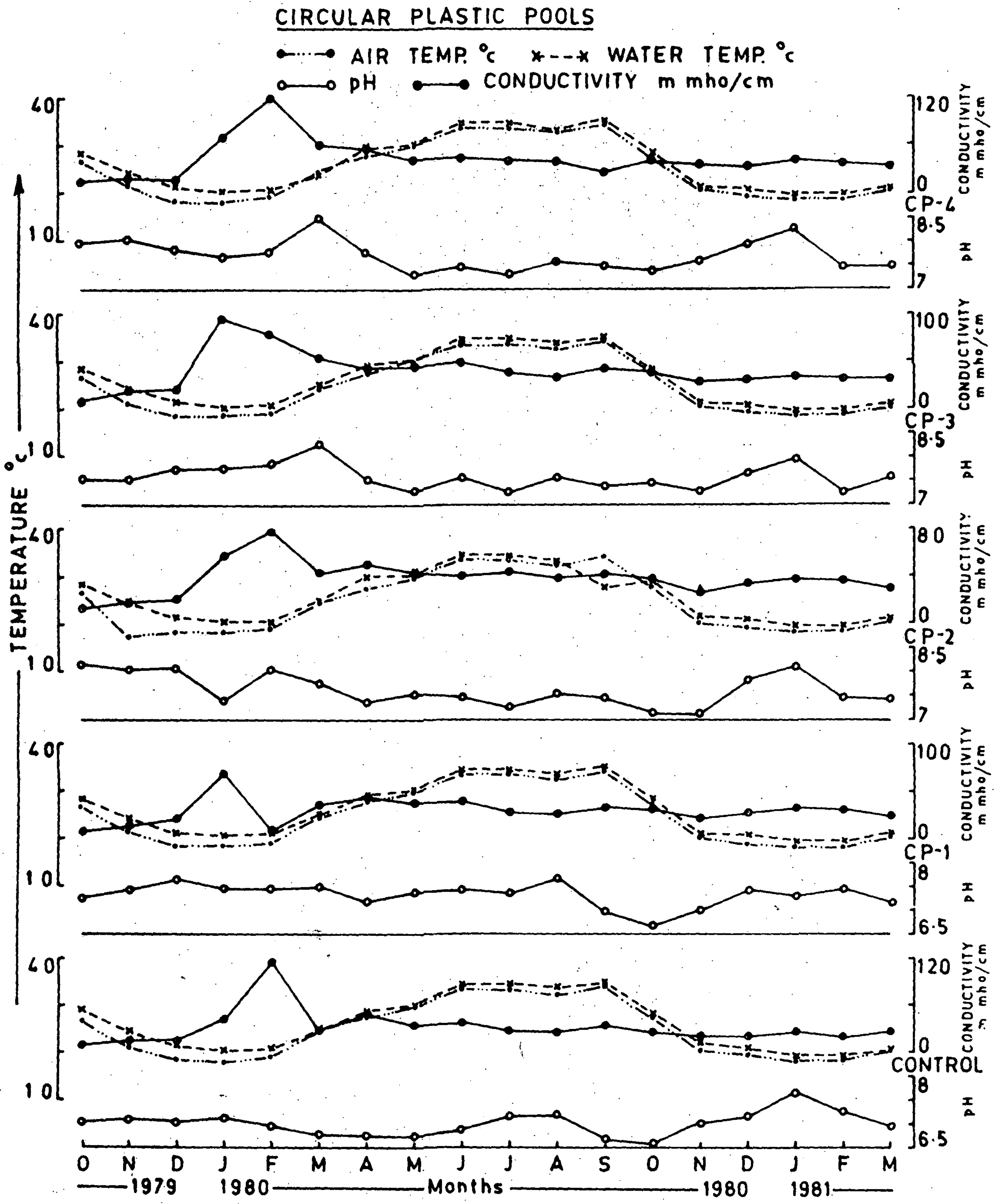
CONTROL POOL : pH

The next abiotic factor analysed was pH which was mostly on the alkaline side in all the pools. In the control pool, pH fluctuated around 7.0 units. The month of August recorded the maximum with 7.1 units and the minimum of 6.6 units in September during the first annual cycle. In the next cycle January recorded the maximum with 7.6 units, while October recorded the minimum with 6.5 units. An overall picture of the fluctuation, showed a winter and summer maxima and spring minima (Fig. 4).

CIRCULAR PLASTIC POOL-1 : The maximum pH recorded was in August registering 7.6 units and the minimum with 7.1 units in April during the first annual cycle. October recorded the minimum of 6.6 units and a maximum of 7.4 units in February during the second cycle. The pH

Fig. 4 - Showing the seasonal rhythmicity of the physico-chemical parameters in the Control and Circular Plastic Pools.

CP = Circular Plastic Pools.



CIRCULAR PLASTIC POOLS
AIR TEMP. °c
WATER TEMP. °c
pH
CONDUCTIVITY m mho/cm
TEMPERATURE °c
CONDUCTIVITY m mho/cm
pH
CP-4
CP-3
CP-2
CP-1
CONTROL
O N D J F M A M J J A S O N D J F M
1979 1980 Months 1980 1981

variations in this pool was very insignificant, however it oscillated around 7.0±0.4 throughout the period of investigation. The trend of seasonal fluctuations was similar to that of the control pool (Fig.4).

CIRCULAR PLASTIC POOL-2 : The pH variations in pool-2 fluctuated between 7.0 and 8.0 units. This pool recorded the maximum with 8.1 units in October and the minimum with 7.2 units in July during the first annual cycle. During the next cycle the maximum of 8.1 units was recorded in January while in November the minimum record of 7.1 units was observed. The seasonal trend of fluctuation revealed a spring maxima and winter minima during the first cycle while the maxima was recorded in winter with autumn minima during the second cycle (Fig.4).

CIRCULAR PLASTIC POOL-3 : pH in the circular plastic pool-3, oscillated around 7.2±0.3 throughout the period of study, with the month of March recording the maximum of 8.2 units while July recorded the minimum with 7.2 units during the first annual cycle. In the next cycle January recorded the maximum with 7.9 units and October as the minimum with 7.4 units. The seasonal fluctuations revealed a winter maxima and summer minima in this pool (Fig. 4).

CIRCULAR PLASTIC POOL-4 : pH fluctuated between 7.5 and 8.5 units during the entire period of investigation. The maximum was recorded in March with 8.4 units which was also the highest for all the other pools and the minimum was 7.2 in May during the first annual cycle. In the next cycle the maximum recorded was in January with 8.2 units and the minimum in October with 7.3 units. The seasonal fluctuation was similar to that of pool-3 (Fig. 4).

CONTROL POOL : Conductivity

Conductivity as the next abiotic factor analysed. The control pond recorded a minimum of 8.9 mmhos/cm in October which steadily increased till February to record the maximum of 116.7 mmho/cm during the first annual cycle. In the next cycle, however, it recorded a maxima though of lower magnitude with only 29.0 mmho/cm and a minimum of 21.6 mmho/cm in March and February respectively. The trend of seasonal fluctuations revealed more or less a winter maxima and summer minima (Fig. 4).

CIRCULAR PLASTIC POOL-1 : The circular plastic pool-1 recorded a minimum in October with 8.5 mmho/cm which thereafter increased gradually to record a maximum in January with 68.5 mmho/cm during the first annual cycle. However, in the second cycle, the maximum in January was only 31.5 mmho/cm and minimum in November with 24.0 mmho/cm. The trend of fluctuations of conductivity oscillated between the minimum record, but never exceeded beyond 39.3 mmho/cm with the only exception of the maximum recorded for the entire study period. The trend of seasonal fluctuation was also like that of the control pond (Fig. 4).

CIRCULAR PLASTIC POOL-2 : Conductivity in pool-2 recorded minimum in October with 13.6 mmho/cm which thereafter increased gradually to attain the maximum in February with 76.9 mmho/cm. However, during the remaining periods of the first annual cycle the fluctuations oscillated between 35.7 to 48.7 mmho/cm. In the next cycle it ranged between 27.6 mmho/cm recorded in November as minimum and 38.7 mmho/cm as maximum in January. In this pool the trend of seasonal fluctuation was similar to that of the control pool (Fig. 4).

CIRCULAR PLASTIC POOL-3 : Conductivity values likewise recorded a minimum in October with 8.8 mmho/cm in the pool-3 also. It thereafter followed a pattern of increase till it recorded a maximum in January with 94.7 mmho/cm and followed a trend of decrease fluctuating between 31.0 and 49.0 mmho/cm during the first annual cycle. The fluctuation recorded during the second cycle ranged between 28.6 mmho/cm in November as the minimum and 39.6 mmho/cm in October as the maximum.

This pool also revealed the same pattern of seasonal fluctuations like that of the control pool (Fig. 4).

CIRCULAR PLASTIC POOL-4: The minimum conductivity recorded was in October with 13.5 mmho/cm, which thereafter increased to register a rise in trend with 70.0 mmho/cm in January and the following month of February recorded the maximum with 116.5 mmho/cm for the first cycle. Thereafter, it fluctuated between 24.0 and 59.0 mmho/cm during the remaining period of the first annual cycle. In the next cycle the range of fluctuation was more or less uniform, oscillating around 33.6 mmho/cm as minimum and 41.0 mmho/cm as maximum, in December and October respectively. The phenomenon of seasonal fluctuation trend as observed in the control pool was also seen here (Fig. 4).

CONTROL POOL : Total Alkalinity

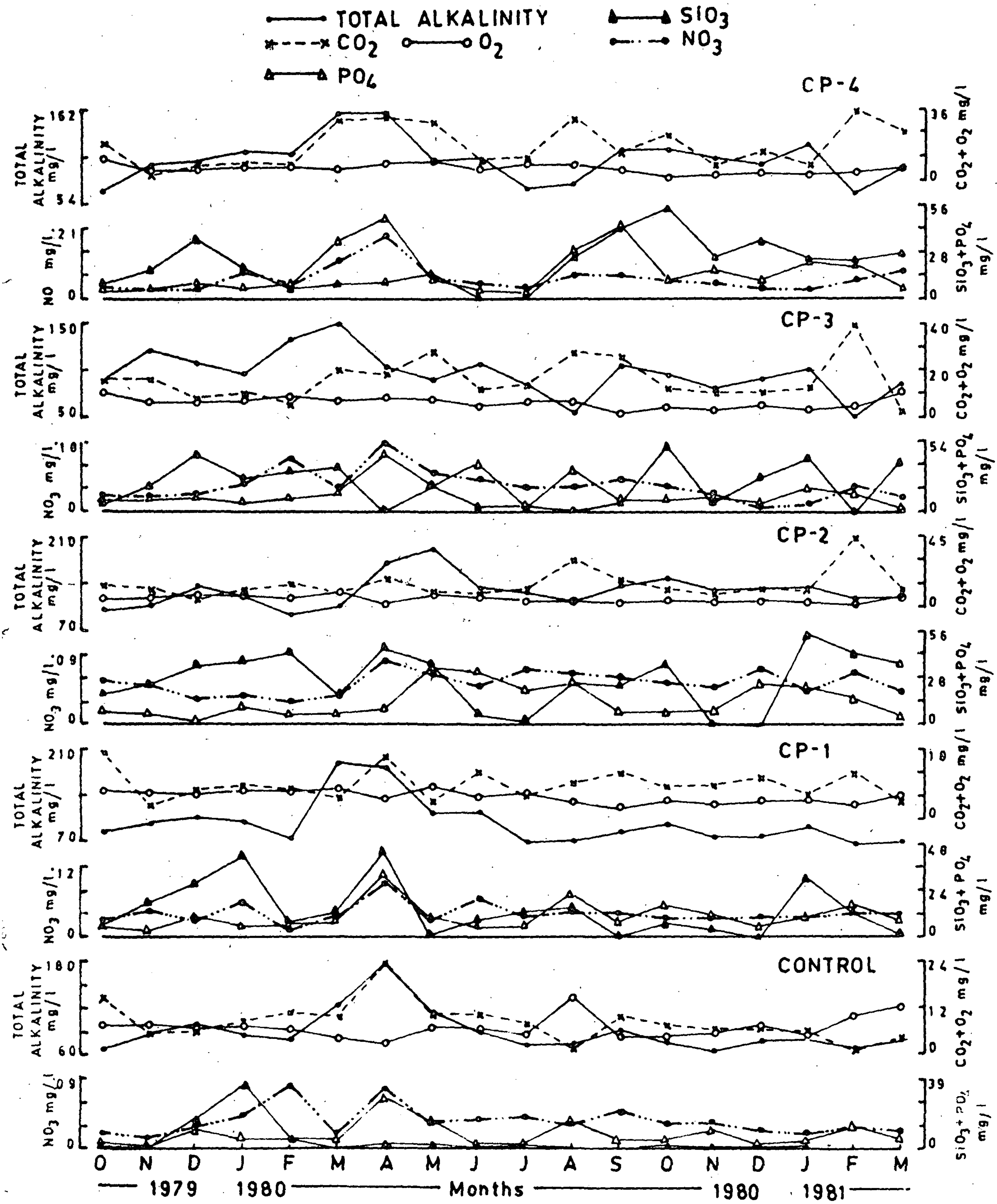
The next abiotic factor analysed was total alkalinity. In the control pool, total alkalinity was recorded as minimum in October and maximum in April recording 68.6 mg/l and 176.0 mg/l respectively during the first annual cycle. In the next cycle, March recorded the maximum and November as minimum with 86.0 mg/l and 66.0 mg/l respectively. The fluctuation of total alkalinity further revealed smaller peaks in the months of December, September and January and showed a seasonal trend of fluctuation with spring maxima and autumn minima (Fig. 5).

CIRCULAR PLASTIC POOL-1 : The total alkalinity ranged between 70.0 and 188.0 mg/l throughout the period of study. In this pool, the minimum was seen in February with 79.0 mg/l while almost two peaks of equal magnitude were recorded in March and April with 188.0 mg/l and 184.0 mg/l respectively during the first annual cycle. In the next cycle however, the maximum was only 99.0 mg/l and minimum with 70.0 mg/l in October and November respectively. In addition to the maximal and minimal values recorded in this pool, the fluctuation

Fig. 5 - Showing the seasonal rhythmicity of the physico-chemical parameters in the Control and Circular Plastic Pools.

CP = Circular Plastic Pools.

CIRCULAR PLASTC POOLS



further recorded peaks of smaller magnitudes in the months of April, June and January (Fig. 5).

<u>CIRCULAR PLASTIC POOL-2</u> : The fluctuation in total alkalinity levels during the first annual cycle ranged from 82.0 mg/l to 200.0 mg/l. The maximum and minimum levels were recorded in May and February respectively. In the next cycle the maximum was seen in October with 114.0 mg/l and minimum in February with 84.6 mg/l. In addition to the maximum and minimum recorded, the fluctuation further registered smaller peaks in the months of December and April. The trend of fluctuation seasonally revealed a spring and autumn maxima and winter minima (Fig. 5).

<u>CIRCULAR PLASTIC POOL-3</u> : The total alkalinity encountered in circular plastic pool-3 revealed a wide range of fluctuation in that the lowest was 56.0 mg/l in August and the maximum in March with 150,0 mg/l during the first annual cycle. In the next cycle the minimum was in February with 52.0 mg/l and the maximum in January with 109.0 mg/l. In addition to these values recorded in this pool, the fluctuations further revealed smaller peaks in November, June and January. The seasonal trend of fluctuation more or less revealed a spring maxima and summer minima (Fig. 5).

<u>CIRCULAR PLASTIC POOL-4</u> : It also showed a similar pattern of fluctuation to that of the pool-3 and ranged between 70.0 mg/l and 158.0 mg/l. The minimum and maximum were recorded in July and April respectively during the first annual cycle. During the second cycle, February recorded the minimum with 66.0 mg/l and the maximum in January with nearly 124.0 mg/l. The fluctuations in the alkalinity levels in this pool further recorded peaks of smaller magnitudes in the months of March and September. The seasonal fluctuation revealed a spring and autumn maxima and summer minima (Fig. 5).

Carbon-dioxide

CONTROL POOL : Carbon-dioxide in the control pool was observed to fluctuate between 1.6 mg/l and 23.5 mg/l throughout the study period. During the first annual cycle the maximum and minimum were recorded in April and August with 23.5 mg/l and 2.0 mg/l respectively. During the second cycle the carbon-dioxide level was more or less consistent, oscillating around the maximum as seen in October with 8.0 mg/l with the exception of the minimum record in February with 1.6 mg/l. In addition to the peaks and minima recorded, the fluctuation showed smaller peaks in October, February and March with a drop in November, May and December for the entire period. The trend of seasonal fluctuations revealed a more or less spring and autumn maxima and winter and summer minima (Fig. 5).

CIRCULAR PLASTIC POOL-1 : The carbon-dioxide level was maximum in October recording nearly 18.0 mg/l and the minimum with only 4.0 mg/l in November during the first annual cycle. In the next cycle February recorded 12.0 mg/l as the maximum, while 6.0 mg/l was the minimum in March. Further, smaller peaks were recorded in April, June, September and December and a fall in March, May and October in addition to the maximum and minimum levels recorded. The seasonal trend of fluctuations revealed a more or less spring and autumn maxima and winter minima in this pool.(Fig. 5).

CIRCULAR PLASTIC POOL-2 : In relation to all the other pools under consideration, this pool recorded the highest carbon-dioxide levels which touched 45.0 mg/l while the minimum was only 6.5 mg/l during the entire period of investigation. The month of August recorded 32.0 mg/l as maximum and December as the minimum with only 6.5 mg/l during the first annual cycle. In the next cycle a maximum of 45.0 mg/l was recorded in February and the minimum in November with only 9.0 mg/l. The fluctuations of carbon-dioxide further revealed smaller peaks in the months of February and April while they fell in May, October and March. The trend of seasonal fluctuations more or less revealed a spring and summer maxima and winter minima in this pool (Fig. 5).

CIRCULAR PLASTIC POOL-3 : The carbon-dioxide level in pool-3 also revealed a similar trend of fluctuation to that of pool-2, though the maximal and minimal levels obtained during the first annual cycle was only 28.0 mg/l in May and 6.4 mg/l in February. It was in the second cycle that a maximum of nearly 40.0 mg/l was recorded in February and the minimum in March with only 3.4 mg/l. In addition to these values recorded, the fluctuations of this gas, showed peaks of smaller magnitudes in March, August and September and their falls in December, June and October throughout the study period. The trend of seasonality revealed a more or less spring and summer maxima and winter minima in this pool (Fig. 5).

CIRCULAR PLASTIC POOL-4 : In this pool two peaks of almost equal magnitude as maxima were registered in April and August with nearly 32.0 mg/l, while the minimum was seen in November with only 3.4 mg/l during the first annual cycle. During the next cycle the minimum level was 8.4 mg/l as recorded in January and the maximum in February with 36.0 mg/l. Furthermbre, smaller peaks were recorded in March, May and October and a drop in the months of July, September and March during both the cycles. The trend of seasonal fluctuations revealed a spring maxima and winter minima (Fig. 5).

CONTROL POOL: *Dissolved oxygen*

The dissolved oxygen content in the control pool recorded a maximum in August with 12.3 mg/l and a minimum in April with 3.3 mg/l during the first annual cycle. In the next cycle, March recorded 12.2 mg/l and October with 8.0 mg/l as the maximum and minimum levels respectively. In addition to the peaks recorded the seasonal trend of fluctuations revealed a summer maxima and winter minima (Fig.5).

CIRCULAR PLASTIC POOL-1 : It registered in the month of May as the maximum oxygen values with 8.4 mg/l and September as the minimum with only 3.6 mg/l during the first annual cycle. The month of March in the second cycle recorded 8.2 mg/l as maximum and the minimum was in November and February recording 4.7 mg/l. The seasonal trend of fluctuations revealed a summer maxima and winter minima (Fig. 5).

CIRCULAR PLASTIC POOL-2 : The month of March recorded the maximum peaks with 9.8 mg/l and 6.7 mg/l during both the first and second cycles. The months of April and February recorded the minimum with 2.8 mg/l and 3.1 mg/l respectively for both the cycles. In this pool, the fluctuations were not so apparent and was found oscillating mostly around the maximal range (Fig. 5).

CIRCULAR PLASTIC POOL-3 : The dissolved oxygen in pool-3 revealed that the values were normally on the maximum side as recorded in October with 10.0 mg/l. The minimum was only 2.05 mg/l recorded in September during the first annual cycle. In the next cycle the oxygen values ranged between 3.3 and 11.35 mg/l and the fluctuation was usually on the minimal range. The maximum and minimum were recorded in March and January respectively. The seasonal trend of fluctuation revealed a similar trend to that of pool-2 (Fig. 5).

CIRCULAR PLASTIC POOL-4 : This pool recorded a maximum in October with 11.3 mg/l and a minimum in June with 5.7 mg/l during the first annual cycle. In the second cycle the months of March and October recorded 6.6 mg/l and 1.7 mg/l as maximum and minimum. The trend of seasonal fluctuations revealed a more or less summer maxima and winter minima in this pool (Fig. 5).

The major nutrients analysed in these circular plastic pools were Silicate, Phosphate and Nitrate.

Silicate

CONTROL POOL : The control pool revealed very insignificant Silicate levels throughout the period of study, except in the month of January where a record maximum of 37.9 mg/l was observed. However, nil values were seen in March, June, August and September during the first annual cycle. In the next cycle silicate levels oscillated between 0.19 mg/l and nil values which was recorded in December, February and March. The trend of fluctuation revealed very slight increase during the spring seasons (Fig. 5).

CIRCULAR PLASTIC POOL-1 : This pool recorded maximum silicate levels in January with 43.6 mg/l and the minimum in September with only 0.2 mg/l during the first annual cycle. The trend of fluctuation in pool-1 was usually on the maximum range. During the second cycle silicate levels oscillated between a minimum range of 0.1 mg/l and 31.9 mg/l. The maximum and minimum were recorded in January and December respectively. The seasonal trend of fluctuations revealed winter maxima and summer minima (Fig. 5).

CIRCULAR PLASTIC POOL-2 : In this pool-2, maximum silicate level was recorded in April with 46.1 mg/l followed by a gradual decrease in the following months to record the minimum level in July with 7.1 mg/l during the first annual cycle. In the next cycle the maximum silicate level recorded was 54.7 mg/l in January and the minimum was seen to be in December with only 0.1 mg/l. The trend of seasonal fluctuation of silicate revealed a spring and winter maxima and summer minima in this pool (Fig. 5).

CIRCULAR PLASTIC POOL-3 : The silicate level in pool-3 recorded a maximum peak with 44.4 mg/l in December and recorded nil values in April during the first annual cycle. In the second cycle a peak was seen in October with 52.0 mg/l but a record of only 0.1 mg/l in

February was seen as the minimum. The seasonal analysis recorded winter and autumn maxima and summer minima (Fig. 5).

CIRCULAR PLASTIC POOL-4 : In this pool, the silicate levels registered during the first annual cycle a maximum of 42.6 mg/l in September and the minimum with only 0.1 mg/l in June. In the second cycle October recorded the maximum and February the minimum with 54.2 mg/l and 23.1 mg/l respectively. The trend in the seasonal fluctuations revealed an autumn maxima and winter minima (Fig. 5).

CONTROL POOL :

Phosphate

The next major nutrient analysed was phosphate. In the control pool, November recorded the minimum with 2.4 mg/l and April the maximum with 29.5 mg/l. It was however observed that the phosphate level oscillated usually on the minimal side during the first annual cycle. In the next cycle maximum was 14.3 mg/l in February and the minimum with 4.9 mg/l in December. An overall picture of the seasonal fluctuation of this nutrient revealed a spring maxima and winter minima (Fig. 5).

CIRCULAR PLASTIC POOL-1 : In pool-1 comparatively higher phosphate levels were recorded than the control. The maximum with 32.3 mg/l was recorded in April and the minimum was 4.2 mg/l in November during the first annual cycle. In the second cycle the phosphate level was more or less consistent normally oscillating around the maximum range that was recorded in February with 17.3 mg/l while the minimum was 6.6 mg/l in December. The trend of seasonal fluctuation in this pool also revealed a spring maxima and winter minima (Fig. 5).

CIRCULAR PLASTIC POOL-2 : The level of phosphate in this pool was higher than in pool-1. The minimum and maximum were recorded in December and May with 2.9 mg/l and 35.2 mg/l during the first annual cycle respectively. The month of March recorded the minimum with 6.7 mg/l and the maximum in December with 26.1 mg/l during the second cycle. The seasonal fluctuations revealed a more or less summer maxima and winter minima (Fig. 5).

CIRCULAR PLASTIC POOL-3 : It recorded a maximum and minimum of phosphate levels in the months of April and August recording 45.0 mg/l and 8.0 mg/l respectively during the first annual cycle. In the next cycle the maximum was in January with 18.6 mg/l and the minimum in March with 6.0 mg/l. The seasonal trend of fluctuations in this pool revealed a summer maxima and winter minima (Fig. 5).

CIRCULAR PLASTIC POOL-4 : The phosphate level in the pool-4 revealed a peak in April recording 48.6 mg/l and the minimum was seen to be 5.1 mg/l in October during the first annual cycle. It was observed that the phosphate ranged with the exception of the peak, between 5.1 mg/l and 13.9 mg/l. In the next cycle the maximum was recorded in January with 22.9 mg/l and the minimum was 8.2 mg/l in March. The trend of seasonal fluctuation in this pool revealed spring and early autumn maxima and winter minima (Fig. 5).

Nitrate

CONTROL POOL :

Finally, the last major nutrient analysed was Nitrate. The control pool recorded a maximum in February with 0.08 mg/l and the minimum in November with only 0.01 mg/l. In the next cycle the maximum and minimum levels were recorded in November and January with 0.03 and 0.02 mg/l during the second cycle respectively. An overall picture of the seasonal trend of fluctuation revealed a spring maxima and winter minima (Fig. 5).

CIRCULAR PLASTIC POOL-1 : The nitrate level in pool-1 recorded the maximum in April with 0.1 mg/l and the minimum in October with only 0.02 mg/l during the first annual cycle. In the next cycle the nitrate levels were maximum in February with 0.04 mg/l and the minimum with 0.03 mg/l in October. The seasonal trend of fluctuation revealed a spring maxima and winter minima (Fig. 5)

CIRCULAR PLASTIC POOL-2 : The minimum nitrate level was recorded in February with 0.03 mg/l and the maximum in April with 0.08 mg/l during the first annual cycle. The months of December and January recorded the maximum and the minimum nitrate levels respectively with 0.07 mg/l and 0.04 mg/l during the second cycle. The seasonal trend of fluctuation revealed a summer maxima and winter minima (Fig. 5).

CIRCULAR PLASTIC POOL-3 : The nitrate level in pool-3 revealed a peak in April recording 0.17 mg/l and the minimum in December with only 0.04 mg/l during the first annual cycle. In the next cycle the maximum was recorded in February and the minimum in January with 0.07 mg/l and 0.02 mg/l respectively. The trend of seasonal fluctuation revealed a spring maxima and winter minima during the first and second cycles (Fig. 5).

CIRCULAR PLASTIC POOL-4 : In this pool, the nitrate level was maximum in April with 0.19 mg/l and the minimum in December with only 0.03 mg/l during the first annual cycle. In the second cycle the maximum and minimum levels were recorded in March and January with 0.08 mg/l and 0.04 mg/l respectively. An overall picture of the seasonal fluctuation trend revealed a spring maxima and winter minima in this pool (Fig. 5).

DISCUSSION

Water in general has a twofold effect within it; (i) through it's physical properties acting as a medium for the locomotion of plants and animals and (ii) through it's chemical property as a bearer of nutrients producing from inorganic to organic, a basis of primary production setting a sequence of reactions for secondary or tertiary production useful to man.

It was, therefore, that the present investigation was undertaken to elucidate the resulting pattern of observations influencing in fundamental ways both physical and chemical cycles governing the production and utilization in natural systems like ponds and near to natural systems like plastic pools. Works in India and others throughout the world have helped us to take cognizance of the priorities needed for the present investigation even with the handicap of the remoteness of the region and the absence of essential facilities.

A total of ten physico-chemical parameters were undertaken for seasonal studies under the general physical and chemical aspects of these ponds and pools for one complete annual cycle and a half of the other. Temperature of the air and water were the physical factors along with pH and specific conductivity, the latter two to help in observing the buffering capabilities and ionic mobility respectively. Oxygen and carbon-dioxide were the gases undertaken, the latter reflecting the carbonate molecules also in terms of alkalinity and finally phosphate, silicate and nitrate were the nutrients analysed.

The atmospheric temperature being common for all the systems, both ponds and pools, was seen to play a direct effect on the water temperature. September or October was commonly observed to be levels of maximum of water temperature, while January the minimum.

pH as the next factor, reflecting the Hydrogen ion concentration of the environment is also useful for determining the hardness and softness of the water. The most important aspect of pH in such studies is that it varies with the concentration of carbon-dioxide. The changes in one affecting the other in a non-linearity of relationship between the two parameters is well documented (Verduin, 1956; Beyer and Odum, 1959, 1960; Lyman, 1961).

The pH in both the experimental fish ponds and circular plastic pools was maintained throughout the study period on the alkaline side. Even in the control systems of both, the values which touched the lower levels though acidic was very near to neutral. The buffering capability was very well documented in the present study in that irrespective of differential fertilization and in the different systems the values fluctuated between 7 or 8 $\pm$ 0.5 pH units. Further, the maximum records touched in all the systems were usually found to be in the winter months of December or January and probably extending to a little in spring. Similarly the least values observed were just after the peak summer periods, September, October and just before the onset of winter in a few instances like November. In any case experimental fish pond-2 and circular plastic pool-4 tended to oscillate always on the higher side.

This is understandable as not only pH and carbon-dioxide are interrelated but a more or less direct relationship exists between pH and oxygen. All these factors interplay with each other preventing wide fluctuation in pH as the waters in these hilly regions which tend to be acidic, react very well to fertilization keeping the waters just above the neutral simultaneously preventing the culmination of eutrophication indicative of the rise and fall of algal populations. This factor alone gives us an idea that fertilization levels at the rates as given in the present investigation could safely be administered as it helped in the total buffering capability of the system.

As warmer waters can dissolve less amounts of gases than a cooler one, the high temperature by turning out carbon-dioxide may be increasing the pH value. But the fall in pH value that invariably follows the vernal maximum is not accompanied by a similar fall in the temperature. In fact, when the pH is falling, the temperature may still be rising. Furthermore in the winter months when the pH recorded their peaks, the temperature invariably registered a fall. This clearly indicated that the temperature changes do not control, at least directly, the changes in the pH value.

Specific conductivity measured in terms of m mho/cm was definitely on the lower side in comparison to tropical situations. It ranged from as low as 17 m mho/cm to a little over 50 m mho/cm in the experimental fish ponds, while the range was much larger in the circular plastic pools where the lowest was around 8.0 m mho/cm and the peak value a little higher than 115 m mho/cm. In the experimental fish ponds, fertilization did not effect to a large extent the conductivity changes and were probably the same as for the control except in pond-2 which recorded the peak value. Similarly, it was more or less so, for the circular plastic pools and except for the peak value of the first annual cycle between the control and circular plastic pool-4. This pool-4 tended to possess higher conductivity values throughout in relation to the other pools, which were more or less similar to the control pool. The higher values in the experimental fish ponds were normally seen to be in spring and early summer seasons with the lowerfall in winter. This trend was however not clearcut in the pools where, though the peak values were in January, the least observed were either in October or November. It was therefore observed that no uniformity existed between the two systems in their seasonal fluctuations for this abiotic factor.

Specific conductivity as a factor is usually taken up as an indicator for assessing the trophic status of freshwater systems. As this is related to salts in the water, it is primarily a measure of resistance to electrical flow. In the present investigation the values could be attributed to that in meso-eutrophic situations (Vollenweider and Frei, 1953; Juday and Birge, 1933). This indicates that the ponds were reacting to fertilization just as the pH buffering capability and even for specific conductance was in equilibrium.

Total alkalinity as the next factor had more or less a spring or summer maxima and a definite winter minima irrespective of the systems and fertilizations. Such accumulation of large quantities of bicarbonates during summer may be possibly attributed to the liberation of carbon dioxide in the process of decomposition of the bottom deposits. This is understandable, as such a phenomenon would result in the conversion of insoluble carbonates of calcium into soluble bicarbonates. In any case the higher values do not indicate a true tropical situation of eutrophication. This aspect is interesting as the ponds and pools situated at lower altitude in the present investigation with fertilization measures of management and especially that of phosphate and nitrates should have boosted the values of the total alkalinity, which in these cases do not show significant increases as in no case it exceeded 300 mg/l and with the other higher values operating between 100 mg/l to 200 mg/l. The maintenance of such a constancy of values irrespective of differential fertilization could be attributed possibly to the buffering capability of the system indicative of the pH as seen in the present investigation to have very minor fluctuation of values in their seasonality. Again Experimental Fish Pond-2 and Circular Plastic Pool-2 similarly showed fluctuation at higher total alkalinity levels.

Wallen (1955) considers the importance of alkalinity in view of its relationship with available carbon-dioxide for photosynthesis and because of its use as an indicator of productivity. The values of total alkalinity of 100 to 300 mg/l indicated the ponds to be nutrient rich and of hard water type and according to Barrett (1953) such waters are often the best fish producers.

As that of alkalinity, carbon-dioxide also followed a similar pattern. This is typical between the relationship of alkalinity and carbon-dioxide and possibly to the inverse relationship of pH. Mostly the summer months showed an increase in values while winter the lower records. In contrast to the control pond the fertilized ponds were more steady in their carbon-dioxide levels and again Experimental Fish Pond-2 showed maximal levels in relation to the others except possibly for the highest record in the control pond. In contrast, the circular plastic pools had a wider range of fluctuation and the peak values obtained in fertilized pools were nearly two to three times higher that observed in the fertilized fish ponds. The control pool was more or less similar to that of the control pond. A similar summer increase with a winter decrease was also seen in these pools with circular plastic pool-2 showing higher magnitudes of fluctuation.

The free carbon-dioxide in waters formed carbonic acid (H_2CO_3) which results in a change of pH. In the present investigation the increases in summer months could also be attributed to the increased metabolic rate of phytoplankton and probably reflecting their respiration at the decomposition level though not taken up in the present study. Both these criteria relating to its depletion or build up is probably reflective of the oxygen values. It has been well understood that oxygen depletion in the bottom and Carbon dioxide accumulation are the results of eutrophication. Stum and Morgan (1962) stated that with mounting anaerobiosis of the hypolimnetic waters, the shift to a greater degree of eutrophy is speedily effected. However, the fluctuations seemed to maintain a steady state in the systems studied for this abiotic factor.

Dissolved oxygen in either the experimental fish ponds or circular plastic pools revealed a typical tropical situation showing an inverse relationship to carbon dioxide, in that the higher values were obtained in winter and the lower records in summer. In fact a near to mirror image was obtained between these two abiotic factors. The values obtained were definitely lower than that would be expected in saturated conditions as 15 mg/l was the highest record to be obtained. In fact the lower values were much below 2.0 mg/l as in the case of circular plastic pools. One observation is that a clear decrease in value was seen due to fertilization both in the ponds and pools in contrast to the control systems. Further, in the ponds the values were just a little lower than that of the control systems but a definite drop in values were seen in the fertilized circular plastic pools. The mirror image between carbon dioxide and oxygen becomes more clear cut as in the experimental fish ponds the values were more or less the same for both the abiotic factors but in the circular plastic pools, carbon dioxide values were prominently high in contrast to the oxygen values.

Low oxygen concentration is usually associated with higher organic matter. Changes in dissolved oxygen are intimately associated with biochemical changes and are brought about primarily by the oxidation of organic matter accumulated (Streeter and Phelps, 1925;

Butcher *et.al.*, 1927; Wiebe, 1927; Blum, 1957; Pettet, 1959; Oliff, 1960; and Foldats, 1962). In the present investigation it appears that the oxidizable organic matter go more or less hand in hand with the water temperature as is evidenced by the inversely proportionate values of water temperature to the dissolved oxygen. According to Klein,(1957) when a rise in temperature occurs and especially in such investigations as the present one where accumulation of organic matter is aided by the addition of fertilizers both organic and inorganic, there is not only dissappearance of oxygen due to the lower solubility of this gas at higher temperature but also there is an increased rate of utilization of dissolved oxygen by the various biochemical reaction which proceeds much faster at higher temperatures. The increase in oxygen during the winter months could be attributed definitely to the lower temperature and in addition to the prolific growth of phytoplanktonic algae. Sreenivasan (1966) and Sahai and Sinha (1969) working on different freshwater bodies lend support to this view. In fact oxygen deficit is known to be a characteristic feature of any productive lake, especially in the tropics, and it would be all the more so in the fertilized fish ponds and circular plastic pools (Sreenivasan, 1970; and Timms, 1970). Though these were the general abiotic factors of prime importance in such studies, the identification of the relevance of chemical factors and in particular the major nutrients is more essential. One of these is silicate which is usually present in the form of amorphous silicon or polymerised silicic acid. It is known that once it is solidified and deposited, the amorphous silicon does not act as a source supply during deficiency (Lewis, 1961). However, as soon as the cells particularly of diatoms, die, silicic acid begins to leach out and is utilized therefrom. In the fertilized experimental fish ponds, the silicate values showed drastic increases in contrast to the control pond. This was all the more evident as seen in Experimental Fish Pond-2 which was nearly six to eight times that of the control, while the other two ponds were just two or three times that of the control system. The disappearance of silicate during certain times recorded as nil could possibly be attributed to the earlier mentioned phenomena for this nutrient. However, in the Circular Plastic Pools the difference in the concentration of silicate among the fertilized systems as opposed to the control was not as significant as seen for the ponds. There was no consistency in their seasonality of fluctuation though revealing more or less peak values in summer months, with winter as the least record in the case of the ponds whereas it was January and November respectively for the pools. Such biological utilization could be attributed to the lack of stratification in the water column, low temperature and low light levels during winter. Kinetics of reactive silicon utilization for freshwater (Kilham, 1975) and marine (Harrison, 1974) diatoms follow Michaelis-Menten Kinetics. At low ambient reactive silicon concentration, the growth rate of a diatom species can be described by a hyperbolic function (Parker <u>et.al.</u>, 1977a). Lund (1969) used the decrease of dissolved silica content of water for assessing production. Also Kilham (1971) while proposing his hypothesis concerning silica and the freshwater planktonic diatoms suggested a strong correlation between dominance of specific diatoms and the silica content of water. Zafar (1967) and Singh (1960) reported that silica did not become a limiting factor in their studies. However, some measure of silica demand could be used as an index of increasing environmental enrichment on eutrophication. From the present study it was very clear that the rate of dissolved silica release was much greater during the warmer temperature (Tessenow, 1966) though the dissolution of this nutrient was greatly accelerated by the disruption of diatom frustules by zooplankton (Beklemishev, 1961; and Tessenow, 1966) possibly around the same time.

The next major nutrient was phosphate and the importance of this nutrient need not be overemphasized (Stewart and Rohlich, 1967; Vollenweider, 1968; Shanon and Brezonick, 1972; and Golterman, 1975). It's role in fish ponds particularly is all the more important as with fertilization, the disappearance of this nutrient into the sediments, the movement to and from sediments in addition to the mineralization process of the aquatic organisms all seem to play an integrated role towards the enhancement of fish growth. In the present investigation the values obtained were significantly high as would normally be expected for eutrophicated fish ponds in contrast to the low values obtained in both the different control systems. Though a clear cut seasonality did not emerge in their fluctuations, yet generally they seemed to show a summer maxima and winter minima irrespective of differential fertilization. It was once again observed that experimental fish pond-2 seemed to possess higher levels of phosphate and circular plastic pool-4 similarly though the latter did not have higher values than the former system.

This large amount of phosphate getting stored in the sediment and as in the present investigation even under strong anoxic conditions relatively small amounts get released. This however represents a potential danger as far as eutrophication processes are concerned if it is not simultaneous with the feeding of fish. Rigler (1972) states that there might possibly be three mechanisms for the return of phosphate phosphorus to solution- (i) direct release of phosphate by ultraplankton, (ii) excretion of phosphate by zooplankton and (iii) enzymatic hydrolysis of organic phosphate compounds excreted by organisms or produced by autolysis or decomposition of dead plankton.

Phosphorus is assumed to be recycled rapidly and continued additions of these nutrients are not necessary to sustain high levels of primary production. However, due to its rapid loss in the bottom mud even in highly fertile fish ponds, high level of photosynthesis depend upon periodic addition of phosphorus.

The last nutrient analysed in these systems was nitrate. This is indicative of the nitrogen richness in any aquatic system and is primarily attributed to animal origin (Thresh et. al., 1944). The nitrate values obtained in these systems were quite low and there was hardly any significant difference between the higher or lower records. This was true not only between the ponds and the pools, but also between themselves irrespective of fertilization with very little significant changes of either increase or decrease from that of the control. The pattern of fluctuation was more or less similar to that of phosphate though not very clear cut. In the ponds and pools the low nitrate content without great magnitude of fluctuation could probably be related to the low average oxygen concentration which is not sufficient to oxidize biologically the ammonia produced which is one possibility of increasing the nitrates in water. This probably seems to be in accordance with the observation of Butcher et. al., (1927, 1928), Berg (1943), Ganapati (1943) and Zafar (1964). In fact Ganapati (1943) and Zafar (1964) have recorded low nitrate content in deficient oxygen tropical waters. Further, increase of nitrate metabolism due to seasonal increase in standing crops of autotrophic organisms have been determined to cause a decreased nitrogen (Atkins, 1932; 1933; Taylor and Welch, 1970).

On a general analysis these physico-chemical parameters analysed revealed that the amount of fertilizers used was probably the optimum levels irrespective of the combination. This was certainly indicated by the marked buffering capability with significant increases of carbon-dioxide levels and lower values of oxygen. It seemed that a steady state equilibrium was maintained with the factors showing a magnitude of fluctuation which is known to be conducive for fish. Among the nutrients also phosphate was possibly the only one to reveal levels of significance if at all and therefore controlling the biota as it were by maintaining their levels around a threshold value. In comparison among themselves however most of these values were seen to be always on the higher side in Experimental Fish Pond-2 and Circular Plastic Pool-4. It seems therefore that supplementary feeding in addition to both organic and inorganic fertilization does play a role in affecting the abiotic components of such systems. In the present investigation Experimental Fish Pond-2 and Circular Plastic Pool-4 had all these three combinations (organic and inorganic fertilizers and supplementary feed) while in the others it was only one or two of these.

REFERENCES

Aberg, B. & W. Rodhe	1942	Uber die Milieufactoren in einigen Sudschwedischen Seen. Symbolae Botanicae Upsalienses, 5:1-256.
Alfred, J.R.B. & N.T. Chellappa	1977	Absence of primary production in a shallow oligotrophic pond. Verh. Internat. Verein. Limnol. 20:2737-2742.
______________, S. Kaur & M.P. Thapa	1978	The role of nutrients and their effects on the biota in freshwater lentic systems. Int. Confer. of Water Poll. Res. Bangkok; Wat. Poll. Res., 1:133-139.
Allen, H.L. & B.T. Ocevski	1977	Limnological studies in a large, deep, oligotrophic lake (Lake Ohrid, Yugoslavia). A summary of nutritional radiobioassay responses of the pelagial phytoplankton. Hydrobiologia, 53:49-54.
A.P.H.A.	1965	Standard methods for the examination of water and wastewater, 12th ed.
Atkins, W.R.G.	1925	Seasonal changes in phosphate content of sea water in relation to the growth of the algal plankton during 1923 and 1924. J. Mar. Biol. Ass. U.K. 13, 700-720 (p. 719).
______________	1932, 1933	The chemistry of sea water in relation to productivity of the sea. Science progr., XXVII :298-312.
Bardach, J.E., J.H. Ryther & W.O. McLarny.	1972	Aquaculture: The farming and husbandry of freshwater and marine organisms. Wiley Inter-Science. New York, N.Y. 868 P.P.
Beklemishev,C.W.	1961	Superfluous feeding of the marine herbivores zooplankton. Rapp. P.-V. Reun., Cons. Int. Explor. Mer., 153:108-113.
Berg, K.	1943	Physiographical studies on the River Susaa. Folia limnol. Scand., 1:1-174.
Berret, P.H.	1953	Relationship between alkalinity and absorption and regeneration of added phosphorus in fertilized trout lakes. Trans. Amer. Fish. Soc., 82:78-79.
Beyers, R.J. & H.T. Odum	1959	The use of carbon-dioxide to construct pH curves for the measurement of productivity. Limnol. Oceanogr., 4:499-502.
______________ & ______________	1960	Differential titration with strong acids or bases Vs. CO_2 water for productivity studies. Limnol. Oceanogr., 5:229-230.

Blinn, D.W. T. Tompkins & A.J. Stewart	1976	Seasonal light characteristics for a newly formed reservoir in south-western U.S.A. Hydrobiologia, 51:77-84.
Blum, J.L.	1957	An ecological study of the algae of the saline River, Michigan. <u>Hydrobiologia</u> 9(4) 361-408.
Butcher, R.W., F.T.K. Pentelow & J.W.L. Woodley	1927	The diurnal variation of the gaseous constituents of river waters. Biochem. J., 21:945-957.
________, ________ & ________	1928	The diurnal variation of the gaseous constituents of river waters. Part III. Biochem. J., 22:1035-1047.
Casperi, W.A.	1910	Deposits of the Scottish freshwater lochs. In Murray and Pullar's Bathymetrical Survey of the Scottish Fresh-water Lochs, 1:261-274.
Chen, R.L., D.R. Keeney & J.G. Konrad	1972	Nitrification in sediments of selected Wisconsin lakes. J. Environ. Qual., 1:151-154.
Cheng, D.M.H. & P.A. Tyler	1976	Nutrient economics and trophic status of Lakes Sarell and Crescent, Tasmania. Aust. J. Mar. Freshwater Res., 27:151-163.
Colt, T.J. & G.Tchobanoglous	1978	Chronic exposure of channel catfish, <u>Ictalurus punctatus</u>, to ammonia. Effect on growth and survival. Aquaculture 15:353-372.
Deevey, E.S.	1940	Limnological studies in Connecticut. V. Contribution to Regional Limnology. Am. Jour. Sci., 238:717-741.
DePasse, P.	1956	Monographie piscicole de la province orientale. Bull. Agric. Congo. Belge. XVII, No.4.
Dillon, P.J., D.S. Jeffries, W.Snyder, R.Reid, N.D. Yan, D.Evans, J.Moss & W.A.Scheider	1978	Acidic precipitation in South-Central Ontario: recent observations. J. Fish. Res. Bd. Can., 35:809-815.
Edmondson, W.T.	1948	Ecological applications of Lansing's physiological work on longevity in <u>Rotatoria</u>. Science, 108:123-126.
Foldats, E.	1962	La concentracion de oxigeno disuelta en lass aguas negras. Acta. biol. Venezuel. 3(10): 149-159.
Forel, F.A.	1892	Le Leman: Monographie Limnologique. Tome I. Geographie, Hydrographie, Geologie, Climatologie. Hydrologie. Lausanne, F. Rouge, 543 pp.
________	1895	Le Leman: Monographie Limnologique. Tome II. Mecanique, Hydraulique, Thermique, Optique, Acoustique, Chemie. Lausanne, F.Rouge, 651 pp.

Ganapati, S.V. 1940 The ecology of a temple tank containing a permanent bloom of Microcystis aeruginosa (Kutz) Henfr. J. Bom. Nat. Hist. Soc., 42: 65-77.

__________ 1941 Seasonal changes in the physical and chemical conditions of a garden pond containing abundant aquatic vegetation. J. Mad. Univ., 13: 55-69.

__________ 1943 An ecological study of a garden pond containing abundant zooplankton. Proc. Acad. Sci., 17:41-58.

__________ 1955 Diurnal variations in dissolved gases, hydrogen ion concentration and some of the important dissolved substances of biological significance in three temporary rock pools in stream bed at Mettur Dam. Hydrobiologia, 7: 285-303.

__________ 1959 Ecology of tropical waters. Proc. Symp. on Algology, New Delhi (ICAR) 200-218.

Garith, A. 1976 Seston dynamics and Tripton sedimentation in the pelagic zone of a shallow eutrophic lake. Hydrobiologia, 51(3):225-231.

Goldman, C.R. 1960 "Molybdenum as a factor limiting primary productivity in Castle Lake, California". Science 132:1016-1017.

Golterman, H.L., ed. 1969 Methods for Chemical Analysis of Fresh Waters. Int. Biol. Program Handbook 8. Oxford, Blackwell Scientific Publications, 172 pp.

__________ 1975 Physiological Limnology, An approach to the Physiology of Lake Ecosystems. Elsevier, Amsterdam. 489 pp.

__________ & R.S. Clymo. 1968 Methods for Chemical Analysis of Freshwaters. IBP Handbook No. 8. Blackwell Scientific Publications, Oxford.

Gonzalves, E.E. & D.B. Joshi 1947 Fresh water algae near Bombay. I. The seasonal succession of the algae in a tank at Bandra. J. Bombay nat. Hist. Soc., 46(1): 154-176.

Gulati, R.D. & G. Wurtz-Schulz 1980 Remarks on the present status of limnology in India based mainly on the Indian Publications in Hydrobiologia and suggestions for future approach. Hydrobiologia, 72:211-222.

Harrison, P.J. 1974 Continuous culture of the marine diatom Sketetonema costatum (Grev) Cleve under silicate limitation, Ph.D. Thesis, Univ. Washington, Seattle 140 p.

Hussainy, S.V. 1967 Studies on the Limnology and primary production of a tropical Lake. Hydrobiologia, 30 (3-4): 335-352.

Hutchinson, G.E. 1938 On the relation between oxygen deficit and the productivity and typology of lakes. Int. Rev. Gesamten Hydrobiol. Hycrogr., 36:336-355.

________ 1957 "A treatise on Limnology. Vol.I. Geography, physics and chemistry. John Wiley and Sons, Inc., New York, N.Y. 1015p.

James, H.R. & E.A. Birge 1938 A laboratory study of the Absorption of light by Lake Waters. Trans. Wis. Acad. Sci., Arts, Let., 31:1-154.

Jhingran, V.G. 1980 Fish and fisheries of India. Hindustan Publishing Corporation, New Delhi (India).

Juday, C. & E.A. Birge 1933 The transparency, the color and the specific conductance of the lake waters of northeastern Wisconsin. Trans. Wisconsin Acad. Sci., Arts and lett. 28:205-259.

Kalff, J. 1970 "Nutrient limiting factors in an arctic tundra pond". Ecology 52:655-659.

Keeney, D.R. 1973 The nitrogen cycle in sediment-water systems. J. Environ. Quality, 2:15-29.

Kemmerer, G., J.F. Bovard & W.R. Boorman 1923 Northwestern Lakes of the United States: Biological and Chemical Studies with Reference to Possibilities in Production of Fish. Bull. U.S. Bur. Fish., 39:51-140.

Kerr, P.C. D.F. Paris & D.L. Brockway 1970 The interrelationship of carbon and phosphorus in regulating heterotrophic and autotrophic populations in aquatic ecosystems. U.S. Gov. Print. Off., Washington D.C. 53 p.

Keup, L.E. 1968 Phosphorus in flowing waters. Water Res., 2:373-386.

Kilham, P. 1971 A hypothesis concerning silica and the freshwater planktonic diatoms. Limnol. Oceanogr. 16:10-18.

Kilham, S.S. 1975 Kinetics of silicon-limited growth in the freshwater diatom Asterionella formosa. J. Phycol. 11:396-399.

King, D.L. 1970 The role of carbon in eutrophication. J.Water Pollut. Contr. Fed., 42:2035-2051.

Klein, L. 1957 Aspects of river pollution. Butterworths Scientific Publications. London, 621 pp.

Komarovsky, B. 1953 A comparative study of the phytoplankton of several fish ponds in relation to some of the essential chemical constituents of the water. Bull. Res. Counc. Israel, 11(4):379-410.

Kusnetzow, S.I. G.S. Karzinkin 1931 Direct Method for the Quantitative Study of Bacteria in Water and Some Consideration on Causes which produce a zone of oxygen-minimum in Lake Glubokoji. Zentralbl. f. Bakt., Parasit. u. Infektionskr., 83:169-174.

Lange, W. 1970 Cyanophyta-Bacteria systems: Effects of added carbon compounds or phosphate on algal growth at low nutrient concentrations. J. Phycol., 6:230-234.

Lasenby, D.C. 1975 Development of oxygen deficits in 14 southern Ontario lakes. Limnol. Oceanogr., 20(6): 993-999.

Lauff, G.H. 1953 A contribution to water chemistry and phytoplankton relationships of Rogers Lake, Slathead Country, Montana. Proc. Montana Acad. Sci., 13:5-19.

Lewin, J.C. 1961 The dissolution of silica from diatom walls. Geochim. Casmochim. Acta., 21:182-195.

Lund, J.W.G. 1969 Phytoplankton-In. "Eutrophication causes, consequences, correctives-National Academy of Sciences, Washington.

________, F.J.H. Mackereth & C.H. Mortimer 1963 Changes in depth and time of certain chemical and physical conditions and of the standing crop of <u>Asterionella formosa</u> Hass. in the north basin of Winderemere in 1947. Phil. Trans. R. Soc. Lond. Ser. B 246:255-290.

Lundqvist, G. 1927 Boderrablagerungen und Entwicklungstypen der Seen. Die Binnengewasser, Bd. II, 124 pp.

Lyman, J. 1961 Changes in pH and total CO_2 in natural waters. Limnol. Oceanogr., 6:80-82.

Mackereth, F.J.H. 1963 <u>Some methods of water analysis for Limnologists</u>. Scientific Publication No.21, Freshwater Biol. Assoc., Ambleside. 70 pp.

Michael, R.G. 1969 Seasonal trends in physico-chemical factors and plankton of a freshwater fish pond and their role in fish culture. Hydrobiologia, 33:144-160.

________ 1980 A historical resume of Indian limnology. Hydrobiologia, 72:15-20.

Mortimer, C.H. 1942 The exchange of dissolved substances between mud and water in lakes. J. Ecol., 29:280-329.

Moyle, J.B. 1946 Some indices of lake productivity. Trans. Amer. Fish. Soc., 76:322-334.

Muttkowski, R.A. 1918 The Fauna of Lake Mendota - A Qualitative and Quantitative Survey with Special Reference to the Insects. Trans. Wis. Acad. Sci., Arts, Let., 19:374-482.

Ohle, W. 1952 Die hypolimnische kohlendioxydrakkumulation als produktionsbiologischer Indikator. Arch. Hydrobiol., 46:153-285.

Oliff, W.D. 1960 Hydrobiological studies on the Tugela River systems. Part 1. The main Tugela River. Hydrobiologia XLV(3-4):281-385.

Parker, C.B., R.C. Hochn, R.A. Paterson, J.A. Craft, L.S.Lane, R.W. Stavros, H.G. Sugg, J.T. Whitehurst, R.D.Fortner & B.L. Weand. (1977) Changes in dissolved organic matter, photosynthetic production and microbial community composition in Lake Bonney, South Victoria Land, Antarctica. In "Adaptations within Antartic ecosystems. Ed. G.A. Llano: 873-890. Proceedings of the third S.C.A.R. Symposium on Antarctic biology. Smithsonian Institution, Washington.

Pettet, A.E.J. 1959 Pollution and the oxygen content of river waters. Proc. Linn. Soc. Lond.,170(2):170.

Pruthi, H.S. 1933 Studies on the bionomics of freshwaters in India. I. Seasonal changes in the physical and chemical condition of the waters of the tank in the Indian Museum Compound. Int. Rev. ges. Hydrobiol. Hydrogr. 28:46-47.

Rigler, F.H. 1972 A dynamic view of the phosphorus cycle in lakes, p.539-568. <u>In</u> E.J. Griffith <u>et.al</u>., (ed.) The Environmental Phosphorus Handbook.

Russo, R.C. & R.V. Thurston 1977 The acute toxicity of nitrite to fishes Pages 118-131 in R.A. Tubb, ed. Recent advances in fish toxicology. U.S. Environ. Prot. Agency Ecol. Res. Ser. EPA-600/3-77-085, Corvallis, Oregon.

Ruttner, F. 1931 Hydrographische und hydrochemische Beabachtungen auf Java, Sumatra, und Bali. Arch. Hydrobiol. Suppl. 8:197-454.

Sahai, R. & A.B. Sinha 1969 Investigations on bio-ecology of inland waters of Gorakhpur (U.P.), India. I. Limnology of Ramgarh Lake. Hydrobiologia, 34:433-447.

Schindler, R.W. 1977 Evolution of phosphorus limitation in lakes. Science 195:260-262.

Serruya, C., U. Pollingher & M. Gophen 1975 N and P distribution in Lake Kinneret (Israel) with emphasis on dissolved organic nitrogen. Oikos, 26:1-8.

Shanon, E.E. & P.L. Brezonik | 1972 | Relationships between lake trophic state and nitrogen and phosphorus loading rates. Environ. Sci. Technol. 6:719-725.

Shapiro, J. | 1960 | The cause of a metalimnetic minimum of dissolved oxygen. Limnol. Oceanogr., 5:216-227.

Singh, V.P. | 1960 | Phytoplankton ecology of the inland waters of Uttar Pradesh. Proc. Symp. Algology, ICAR. New Delhi, 243-271.

Sreenivasan, A. | 1966 | Fish production in some rural demonstration ponds in Madras (India) with an account of the chemistry of water and soil. FAO Fish. Rep., (44). Vol. 3:179-197.

________ | 1970 | Limnology of tropical impoundments: A comparative study of the major reservoirs in Madras State (India). Hydrobiologia, 36(3-4): 443-469.

________ | 1975 | J. Mar. biol. Assoc., India 7:1.

Stewart, K.M. & G.A. Rohlich | 1967 | Eutrophication- A Review - A Report to the State Water Quality Control Board, California, No. 34, 188 pp.

Streeter, H.W. & E.B. Phelps | 1925 | A study of the pollution and natural purification of the Ohio River. III. Factors concerned in the phenomena of oxidation and reaeration, U.S. Publ. Hlth. Serv., Publ. Hlth. Bull. No. 146:1-75.

Strom, K.M. | 1931 | Feforvatn: A physiographic and biological study of a mountain lake. Arch. Hydrobiol., 22: 491-536.

Stromsten, F.A. | 1927 | Lake Okobiji as a Type of Aquatic Environment. Univ. Iowa Studies in Nat. Hist., 12:3-52.

Stumm, W. & J.J. Morgan | 1970 | Aquatic Chemistry - Wiley, Interscience.583p.

Swingle, H.S. | 1957 | Relationships of pH of pond water to their suitability for fish culture. 9th pac. Sci. Congr. Bangkok, Thailand.

Tan, T.L. & J. Overbeck | 1973 | Okolgische Untersuchungen uber nitratreduzierende Bakterien im Wasser des Pluss-secs (Schleswig-Holstein). Z. Allg. Mikrobiol., 13:83-94.

Taylor, M.P. & E.B. Welch | 1970 | Morris Reservoir Study: Part II, Effects of thermal stratification and nutrient availability on the production of reservoir phytoplankton. 34p.

Tessenow, U. | 1966 | Untersuchungen uber den Kieselsaurehaushalt der Binnengewasser. Arch. Hydrobiol. Suppl., 32:1-136.

Thresh, J.C., E.V. Suckling & J.F. Beale 1944 The examination of water supplies. Ed. Taylor, E.W., 1949

Timms, B.V. 1970 Chemical and zooplankton studies of lentic habitats in north eastern New South Wales. Aust. J. Mar. Fresh Wat. Res., 21:11-33.

Tomasso, J.R., B.A. Simco & K.B. Davis 1979 Chloride inhibition of nitrite-induced methemoglobinemia in channel cat fish (Ietalurus punctatus). J. Fish. Res. Board Can. 36: 1141-1144.

Tucker, D.S. 1958 The distribution of freshwater invertebrates in ponds in relation to annual fluctuations in the chemical composition of the water. J. Anim. Ecol., 27:105-123.

Vallentyne, J.R. 1957 Principles of Modern Limnology. Amer. Scientist, 45:218-244.

Verduin, J. 1956 Energy fixation and utilization by natural communities in Western Lake Erie. Ecology, 37:40-50.

Vijayaraghavan, S. 1971 Studies on the diurnal variations in physico-chemical and biological factors in Teppakulam Tank. Proc. Ind. Acad. Sci., 44B:63-73.

________________, P.Navaneethakrishnan & R.G. Michael. 1969 Diel cycle of dissolved carbonhdrates in two freshwater ponds. Proc. Ind. Acad. Sci., 70B:157-168.

Villadolid, D.V., P.Rangoniban & T.G. Megia 1954 The role of pH in pond fertilization. Proc. Indo-Pac. Fish. Coun. 5th meeting Technical paper-3.

Vollenweider, R.A. 1968 Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication. Organization for economic cooperation and development publication: DAS/CSI/68-27 Paris, France. 182 pp.

________________ & M. Frei 1953 Vertikale und zeitliche Vertellung der Leitfahig keit einn eutrophen Gewasser WaBrend der sommer stagnation. Scheiz. A. Hydrol., 15:158-167.

Wallen, I.E. 1955 Some limnological considerations in the productivity of Oklahoma farm ponds. J. Wildlife Mgmt., 19(4):450-462.

Welch, P.S. 1948 Limnological Methods. Philadelphia, 381 pp.

Wetzel, R.G. 1966 Variations in productivity of Goose and hypereutrophic sylvan Lakes, Indiana. Invest. Indiana Lake streams 7.

Wetzel, R.G. 1975 Limnology - W.B. Saunders Co.; Philadelphia. 743 pp.

Wiebe, A.H. 1927 Biological survey of upper Mississipi with *special reference to pollution.* Bull. U.S. Bur. Fish., 43(2):137-167.

——— 1930 Investigation on plankton on fish ponds. Bull. U.S. Bureau of Fisheries, 46:137-176.

Worthington, E.B. & L.C. Beadle 1933 Thermoclines in Tropical Lakes. Nature, 129: 55-56.

Zafar, A.R. 1964 On the ecology of algae in certain fish ponds of Hyderabad, India. II. Distribution of unicellular and Colonial forms. Hydrobiologia, 24:556-566.

——— 1967 On the ecology of certain fish ponds of Hyderabad, India. III. The periodicity. Hydrobiologia, 30:96-112.

PHYTOPLANKTON AND ZOOPLANKTON

INTRODUCTION

It was not till the middle of the last century that the existence of plankton in aquatic systems was known. Studies in the oceans were the earliest available works on plankton. In fact the usage of the term "plankton" has come down over the century since the time of Hensen (1887, 1895) who was an Oceanographer, attributing all heterogenous assemblages of minute organisms under this term. The earliest Indian work was on rotifers by Anderson (1889). Apstein (1896) was probably the first to study the plankton in freshwaters in particular the inland lakes. Schrater and Kirchner (1896) introduced the term pleuston to designate the whole biological communities associated with air-water interface. The knowledge of the presence of a range in the size of these planktonic organisms was discovered by Kofoid (1897). Daday (1898) described many new species of Cladocera, Copepoda and Rotifera from oriental regions.

Since then, works all over the world took an impetus and various theories were propounded such as the floatation theory after Wesenberg-Lund (1900) and its contradiction by Lauternborn (1900). The idea of a genetically related phenomena for cyclomorphosis particularly in Daphnia was shown by Waltereck (1908, 1909, 1913 and 1928). The effect of environmental factors also contributed to such phenomena was outlined by Ostwaldt (1902). Lohmann (1908), showed the existence of the smallest group of plankton referred to as "nannoplankton". Naumann (1917) introduced the term neuston to designate the assemblage of microorganisms associated with surface film of the waters.

The geographical distribution, diurnal movements, the effect of light, the seasonal variations and organic matter as a factor, all responsible for either the growth, the reproduction and distribution were initiated in the very early part of this century (West and West, 1912; Dice, 1914; Ruttner, 1914; Prasad, 1916; Jennings, 1918).

The idea of the trophic status of plankton, the feeding behaviour of zooplankton and studies on the feeding apparatus of some major groups were also done in the early 1900's (Naumann, 1921, 1923 and 1929; Nordquist, 1921; Birge and Juday, 1922; Storch, 1924, 1925; Schmidt, 1928; Utermohl, 1925). Around the same time the importance of nutrients and temperature as limiting factors on the growth of plankton were done by Pearsal (1923), Strom (1924), Mac Arthur and Baille (1925), Coker and Addlestone (1938). Such works continued in various regions and latitudes of the world (Krastz, 1931; Krogh and Berg, 1931; Ruttner, 1931; Sewell, 1934; Seymour-Swell, 1934; Van Oye, 1934; Gunther, 1936; Hauer, 1937 and 1938; Rosenburg, 1939; Ganapathi, 1941). It was only Hutchinson in the year 1941 who first revealed the concept of ecosystem based on all these studies that physical and chemical and biological processes have an inter-relationship both temporally and spatially.

It was then that subsequent works were aimed at finding out the causative factor or factors responsible for the growth and sustenance of groups of phytoplankton or zooplankton, their interpretation for the rise and fall of population, in particular the algal blooms and the intricate relationship between the species of phytoplankton and zooplankton with the idea and rate of both colonization and succession (Edmondson, 1944; 1945 and 1946; Hutchinson, 1944; Pennak, 1944; Brooks, 1947; Nygaard, 1949; 1955; Plew and Pennak, 1949; Gerloff <u>et. al.</u>, 1950; 1952).

All the above studies were done on natural freshwater systems and interpretation based purely on observations as occurring in nature. It was therefore felt by workers that due to the complicated phenomena of natural ecosystem, it would be ideal to set up near-to-natural experiments and to identify one factor and its effects on another. Such a thinking took a great stride in the subsequent two decades along with the general observations in other systems (Canter and Lund, 1951; Welch, 1952; Ganapati et. al.,1953; Ruttner, 1953; Vaas and Sachlan, 1953; Villadolid et. al., 1954; Nelson and Edmondson, 1955; Fogg, 1956; Rigler, 1956; Rodhe et. al., 1956; Edmondson, 1957; Gerloff and Skoog,1957a,b; Pennak, 1957; Banforth, 1958; Provasoli, 1958; Kuznetsov, 1959; Shroder, 1959; Vaas and Vaas-Van Oven, 1959; Golterman, 1960; Parker, 1960; Michael, 1962 and 1964; Pomeroy et. al., 1962; Steeman Nielsen, 1962; Steeman Nielsen and Jorgensen, 1962; Venkataraman, 1962; Strauskraba, 1963, 1965 and 1967; Hobbie, 1964; Zafar, 1964; Fogg, 1965; Wetzel, 1965, 1966 and 1972; Hbracek and Hbrackoba-Esslova, 1966; Gilbert, 1967; Vijayaraghavan, 1967; Corjunova, 1968; Stagenberg, 1968; Vollenweider, 1968; Castenholz, 1969; M c Queen, 1969; Michael,1969; Butler et. al., 1970; Munawar, 1970; Vijayaraghavan, 1970; Wojcik, 1970).

The last decade beginning in 1970, though, has been a period of intensive limnological work all over the globe, yet, it was primarily directed towards the understanding of pollution in aquatic systems. In this respect, works on plankton done in oligotrophic systems in contrast to eutrophic ones, the identification of indicator species, the effect of manipulation in terms of addition of nutrients and in particular fertilizers in fish ponds, the life history patterns and the developmental stages in relation to abiotic factors, the effect of acidification and most of all, the influence on the biota, particularly phytoplankton and zooplankton in relation to the nature of effluents from the establishment of industries, the accumulation and biological magnification in groups of plankton by pesticides, were all part of the general limnological studies (Fitzgerald, 1971; Fogg, 1971; Folt, 1971; Hagedorn, 1971; Kristiansen, 1971; Navaneethakrishnan and Michael, 1971; Reynolds, 1971; Abeliovich and Shilo, 1972; Green, 1972; Kryuchkova, 1972; Saunders, 1972; Sorokin and Paveljeva, 1972; Burgis, 1973; Fogg et.al., 1973; Pennak, 1973; Shapiro, 1973; Tilzer, 1973; Wolk, 1973; Droop, 1974; Hutchinson, 1975; Lewkowicz and Lewkowicz, 1975; Reynolds and Walsby, 1975; Wetzel, 1975; Begg, 1976; Burns, 1976; Ferrante, 1976; Green, 1976; Jacobson and Comita, 1976; Munawar and Munawar, 1976; Zaret et.al., 1976; Brown and Sibert, 1977; Hbracek, 1977; Alfred et.al., 1978; Boers and Carter, 1978; Vincent, 1978; Yan and Stokes, 1978; Venkataraman and Job, 1979; Zagorodnyaya, 1979; Cooney and Gehrs, 1980; Fallon and Brock, 1980; Fernando, 1980; Gilbert, 1980; Lei and Armitage, 1980; McCracken et.al., 1980; Pourriot et.al., 1980; Swar and Fernando, 1980; Venkataraman and Job, 1980.

Though Indian works and especially Indian authors working on freshwater systems in India have come in the above mentioned literature in various aspects, the review of Gulati and Wurtz (1980) and Michael (1980) cover a detailed account of the Indian works in this field. The foregoing literature though includes the works on the general population dynamics of phyto- and zooplankton in freshwater ponds and also their role in fish ponds, particularly with the addition of fertilizers, yet certain works stand out as significant contributions. Moreover, the understanding of these biota in fish ponds, with known quantities of nutrient additions either in terms of inorganic or organic fertilizers, and their interrelationships with a possible increase in fish yield is quite well documented (Swingle and Smith, 1939; Ball and Tanner, 1951; Nelson and Edmondson, 1955; McIntire and Bond, 1960; Hall et. al., 1970; Yao-Sungling, 1976; Oglesby, 1977; Boyd and Sowles, 1978; Shroeder, 1978; Willemsen, 1980; Boyd, 1981 ; Boyd et. al., 1981. The Indian works where phyto- and zooplankton dynamics related to various abiotic factors along with fertilization levels and fish production have been documented conclusively in the compilations by Jhingran (1980).

MATERIALS AND METHODS

Water samples for phyto- and zooplankton were collected only from the surface at the four experimental ponds and five circular plastic pools. The periodicity of collection was weekly and done always in the morning hours (0600-0900 hrs). At each station samples were collected by filtering a volume of 50 litres of water from the experimental ponds and 25 litres from the circular plastic pools, through a bolting silk net of mesh size 25 μ. These were brought to 50 ml and 25 ml respectively and preserved in 4% formalin.

Such weekly samples from all the ponds and pools were collected for one and a half annual cycle (October 1979 - March 1981). A well shaken sample from the 50 ml and 25 ml preserved collection was drawn with the help of a wide-mouthed pipette and transferred into a counting cell (Sedgwick-Rafter Plankton counting cell) of a 1 ml capacity graduated into 1000 squares. After covering it with a large rectangular coverslip, counts were made after "Utermohl" (1958) of all organisms present at random in 100 squares. Individuals and colonies were counted as such, while filamentous algae were counted by their approximate length being kept uniform. All these were presented numerically upto the genus level and placed under the appropriate family and class. Three such counts were done for each weekly sample and an average count evolved. Such weekly sample counts were determined as monthly averages.

The generic identification of phyto- and zooplankton were done with the help of Smith (1950), Pennak (1953), Edmondson (1959), Needham and Needham (1962).

The computation for the numbers of phyto- and zooplankton per litre at different experimental fish ponds and circular plastic pools was evaluated by the formula -

$$n = \frac{(a \times 1000)\ C}{1}$$

where n = number of plankton per litre of original water

a = average number of plankton in all counts in Sedgwick Rafter cell.

C = volume of original concentration in ml.

1 = volume of original water expressed in litres.

RESULTS

The biota taken for detail investigations in the four experimental fish ponds and in the five circular plastic pools can be broadly classed into Phytoplankton and Zooplankton. In all the ponds irrespective of the fertilization, six classes of phytoplankton were represented. The class Chlorophyceae comprised of the families Chlamydomonaceae which had only one genus, Chlamydomonas, Scenedesmaceae comprising of Scenedesmus and Actinastrum, Oocystaceae represented by Ankistrodesmus, Tetraedron, Selenastrum, Cerasterias and Pachycladon, Desmidiaceae by Cosmarium, Closterium, Staurastrum, Docidium and Anthrodesmus, Dictyosphaeriaceae comprised of a single genus Dictyosphaerium, Ulotricaceae by Ulothrix, Zygnemataceae by Spirogyra, Volvocaceae represented by two genera Volvox and Pandorina, Hydrodictyaceae with a single genus Pediastrum and similarly the family Protococaceae with Protococcus and Coelastraceae with Coelastrum.

The next class Euglenophyceae comprised of two families Euglenaceae represented by two genera Euglena and Phacus and the family Peranemaceae with Urcoelus. The class Bacillariophyceae comprised of two families Naviculaceae represented by three genera Navicula, Frustulia and Pinnularia and Fragillariaceae represented by a single genus Synedra. The class Xanthophyceae comprised of two families Xanthophyceae and Tribonemataceae with a single genus each, Botryococcus and Tribonema respectively. Dinophyceae was represented by three families Ceratiaceae, Gymnodiaceae and Glenodiaceae. Each of these families comprised of only one genus, Ceratium, Gymnodinium and Glenodinium respectively. Though these are the general phytoplankton of the ponds, yet all genera were not present together and only some genera occurred and dominated at the different ponds during the study period.

Of the six classes, Chlorophyceae represented the largest number of families as seen in all the four experimental fish ponds irrespective of differential fertilization.

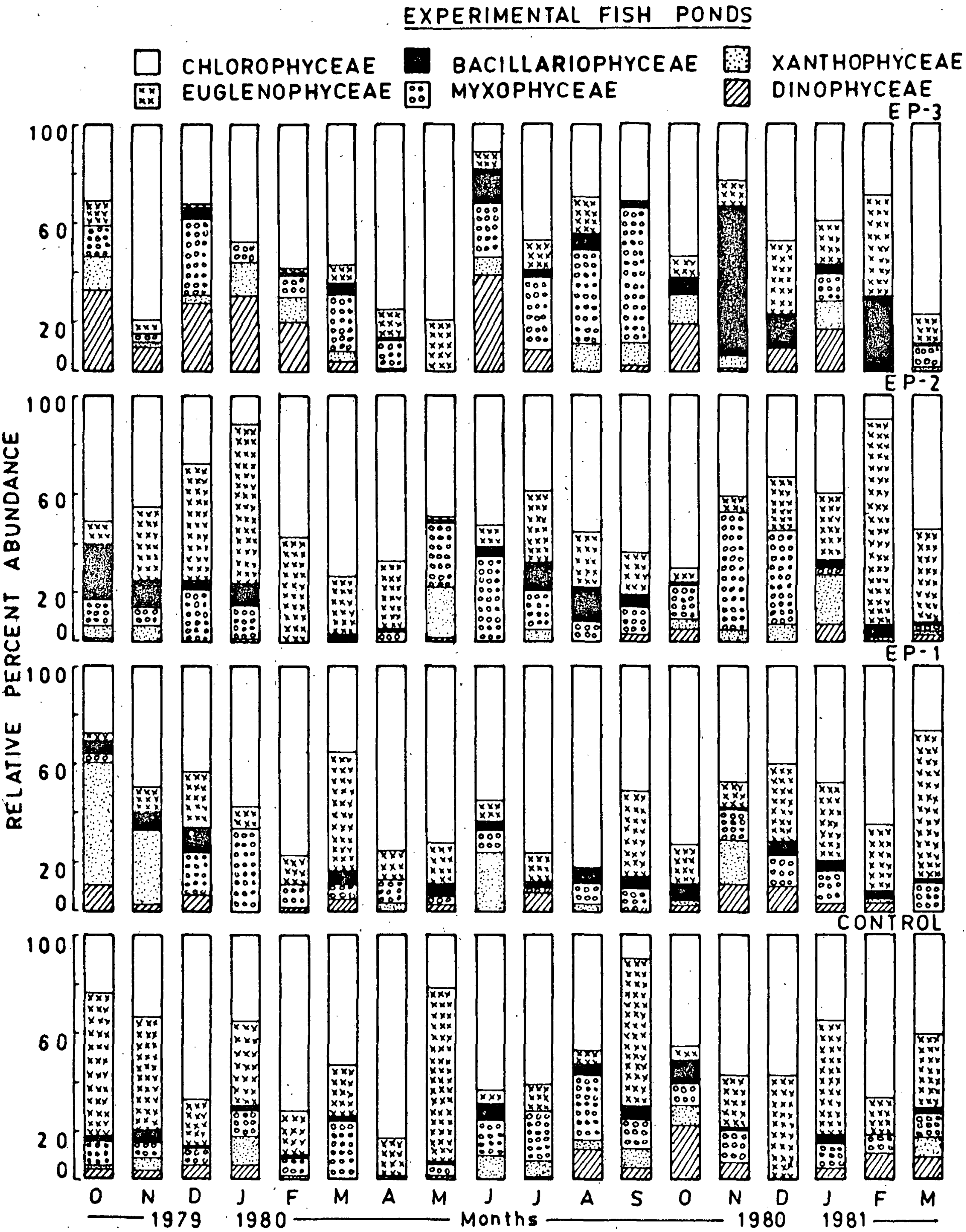
CONTROL POND : In the control pond, the class Chlorophyceae during the first annual cycle, showed a maximal peak in the month of December recording nearly 20,500 units/litre and a minimum of 4,800 units/litre in June. During the second cycle the maximum occurred in December recording 12,328 units/litre and a minimum of 3,420 units/litre in November When this class Chlorophyceae was seen as a relative percentage among the different classes, it indicated a maximum of nearly 83.4% in April during the first annual cycle, and nearly 68% in the month of February during the second cycle. Even though the actual numbers for both the cycles indicated the month of December as maximum yet as a relative percentage they were only 66-56% respectively (Fig. 6).

In the same control pond when the class Chlorophyceae was broken down into families, it was seen to comprise of eleven families. These families were Chlamydomonaceae, Scenedesmaceae, Oocystaceae, Desmidiaceae, Dictyosphaeriaceae, Ulotricaceae, Zygnemataceae, Volvocaceae, Hydrodictyaceae, Protoccocaceae and Coelastraceae.

The family Chlamydomonaceae represented by a single genus Chlamydomonas revealed a peak of 9,800 units/litre in February and recorded nil values during June, July, September in the first annual cycle. In the next cycle it recorded 5,600 units/litre in January as the maximum and nil value in December. The family Scenedesmaceae in the control pond recorded a maximum of 4,880 units/litre in April and with nil value in September during the first annual cycle. The month of December during the second cycle

Fig. 6 - Showing the histograms representing the seasonality of the relative percent abundance of the major phytoplanktonic groups in the Control and Experimental fish Ponds.

EP = Experimental fish Ponds.



EXPERIMENTAL FISH PONDS
CHLOROPHYCEAE
BACILLARIOPHYCEAE
XANTHOPHYCEAE
EUGLENOPHYCEAE
MYXOPHYCEAE
DINOPHYCEAE
EP-3
EP-2
EP-1
CONTROL
RELATIVE PERCENT ABUNDANCE
100
60
20
0
O N D J F M A M J J A S O N D J F M
1979 1980 Months 1980 1981

showed a maximum of 5,928 units/litre which dropped to nil value in October. In the first annual cycle, a tendency to increase was seen in December and a subsequent fall the following month, with a steady increase till April and then a fall to nil values. A similar trend was also seen during the second cycle. The genus Scenedesmus recorded peaks of abundance in April with 4,880 units/litre and December with 5,800 units/litre and minimum in October with 200 units/litre and January with 860 units/litre during the first and second cycles respectively. Actinastrum revealed peaks in March with 2,040 units/litre and November recording 480 units/litre during the first and second cycle. The months of June and December recorded 200 units/litre and 128 units/litre as the minimum during the first and the second cycle.

The next family Oocystaceae showed a trend of increase similar to Scenedesmaceae in its bimodality with December and April showing maximum peaks during the first annual cycle, with the exception that December had a larger peak of nearly 5,560 units/litre, while April revealed a little lower than 4,000 units/litre. Nil value was recorded in the month of September in the first annual cycle. A peak of 2,200 units/litre in December and a minimum value of 440 units/litre was observed during the second cycle. Ankistrodesmus revealed peaks of abundance in April with 3,760 units/litre and in December 1,400 units/litre during the first and second cycle. The minimum was recorded in November with 200 units/litre and March with 320 units/litre and was absent for six months during both the cycles. Tetraedron recorded maximum in November and January with 800 units/litre and 1,420 units/litre during the first and second cycles. The month of December with 20 units/litre and October with 80 units/litre recorded the minimum during the first and second cycle and was absent for seven months during both the cycles.

Selenastrum revealed December as the maximum with 3,320 units/litre and minimum in February representing 160 units/litre during the first annual cycle. During the second cycle it was present only in the months of November and February registering 120 units/litre and 280 units/litre respectively. *Pachycladon* was present only in the month of October with 33 units/litre and November with 400 units/litre during both the cycles.

The family Desmidiaceae recorded small peaks of abundance in November and December representing 2,500 units/litre each followed by a second maximum peak with nearly 5,800 units/litre in March. The lowest value of 100 units/litre was recorded in January during the first annual cycle. In the second cycle, November recorded nil values. This was followed by a sudden increase in December to 1,400 units/litre, a subsequent fall the next month and a rise thereafter to form a peak in March with nearly 1,680 units/litre. The genus *Cosmarium* was recorded only once in October with 60 units/litre and was totally absent during the remaining periods of both the cycles. The genus *Closterium* revealed peaks of abundance in April registering 2,400 units/litre and minimum in August recording 50 units/litre during the first annual cycle. In the next cycle a maximum was recorded in March with 1,000 units/litre and a minimum in February with 440 units/litre and was absent in November. *Staurastrum* recorded peaks of abundance in the month of March registering 3,960 units/litre and 680 units/litre during the first and second cycle and a minimum in October with 106 units/litre and January with 160 units/litre. It was absent for seven months during both the cycles.

The family Dictyosphaeriaceae represented by a single genus *Dictyosphaerium* was absent throughout the period of investigation with only an exception during the second cycle when it recorded

1,020 units/litre in October. The family Ulotricaceae was also represented by a single genus Ulothrix which occurred only four times throughout the study period, with the month of January recording a peak of 400 units/litre.

The family Zygnemataceae represented by Spirogyra occurred only twice, in the first annual cycle. This genus recorded less than 100 units/litre on both occassions.

Volvocaceae as the next family occurred during the first cycle with 1,000 units/litre in October but fell to a value of 10 times lower the following month. It thereafter disappeared from the system to reoccur only in the month of May and steadily increased to reach a peak in August with 1,100 units/litre. During the second cycle it occurred only in October and February with the latter month recording 160 units/litre. The family Volvocaceae was represented by two genera, Volvox and Pandorina. The genus Volvox was recorded only in May with 440 units/litre during the first annual cycle. In the next cycle October and February were the only months to register their occurrence recording 60 units/litre and 160 units/litre respectively. The genus Pandorina showed a peak in August with 1,100 units/litre and a minimum in November registering 100 units/litre and was absent from December to May during the first annual cycle. In the next cycle they were entirely absent.

Hydrodictyaceae represented by a single genus Pediastrum was present throughout the period of investigation. During the first annual cycle, two peaks were registered a small one in December with nearly 2,860 units/litre and a larger peak in April recording 3,200 units/litre. In the second cycle, a maximum peak of 2,800 units/litre was recorded in December. The minimum counts were

160 units/litre and 400 units/litre in March and November during the first and second cycles, respectively.

The family Protococcaceae represented by Protoccaceae occurred in the system only on two occassions during the first annual cycle, registering a consistent number of 1,400 units/litre each in November and December.

The last family under the class Chlorophyceae was Coelastraceae also represented by a single genus Coelastrum which occurred only on one occassion in the month of August with 50 units/litre and was totally absent during the remaining period of investigation (Table-III).

The class Euglenophyceae recorded a peak of abundance in May registering 24,760 units/litre and a minimum in June with 360 units/litre during the first annual cycle. In the second cycle, the month of October recorded the minimum density with 560 units/litre and thereafter increased gradually to record a peak in January representing 13,120 units/litre (Table-III).

The relative percent abundance of the class Euglenophyceae followed a trend more or less similar to their actual numbers. The months of May and June recorded the maximum and minimum with 72% and 5.0% respectively during the first annual cycle. In the next cycle a maximum of 46.0% was recorded in January and a minimum of 6.6% in October (Fig. 6).

Euglenophyceae was represented by two families, Euglenaceae with three genera, Euglena, Phacus and Trachelomonas and the family Peranemaceae by a single genus Urcoelus. The family Euglenaceae recorded a maximum peak of abundance in May representing 24,760 units/litre and a minimum in July with only 120 units/litre during the

TABLE-III

Seasonal abundance of phytoplankton, their classes, families, respective genera and the total phytoplankton (units/litre) in the Control pond.

(A) CHLOROPHYCEAE

1. Chlamydomonaceae/*Chlamydomonas*
2. Scenedesmaceae
3. *Scenedesmus*
4. *Actinastrum*
5. Oocystaceae
6. *Ankistrodesmus*
7. *Tetraedron*
8. *Selenastrum*
9. *Pachycladon*
10. Desmidiaceae
11. *Cosmarium*
12. *Closterium*
13. *Staurastrum*
14. Dictyosphaeriaceae/*Dictyosphaerium*
15. Ulotricaceae/*Ulothrix*
16. Zygnemataceae/*Spirogyra*
17. Volvocaceae
18. *Volvox*
19. *Pandorina*
20. Hydrodictyaceae/*Pediastrum*
21. Protococcaceae/*Protococcus*
22. Coelastraceae/*Coelastrum*

(B) EUGLENOPHYCEAE

23. Euglenaceae
24. *Euglena*
25. *Phacus*
26. *Trachelomonas*
27. Peranemaceae/*Urceolus*

(C) BACILLARIOPHYCEAE

28. Naviculaceae
29. *Navicula*
30. *Frustulia*
31. *Pinnularia*
32. Fragillariaceae/*Synedra*

(D) MYXOPHYCEAE

33. Oscillatoriaceae
34. *Spirulina*
35. *Phormidium*
36. Rivulariaceae/*Rivularia*
37. Chroococcaceae
38. *Coelosphaerium*
39. *Merismopedia*
40. Nostocaceae
41. *Anabaena*
42. *Nostoc*

(E) XANTHOPHYCEAE

43. Xanthophyceae/*Botryococcus*
44. Tribonemataceae/*Tribonema*

(F) DINOPHYCEAE

45. Ceratiaceae/*Ceratium*
46. Gymnodiaceae/*Gymnodinium*

TABLE - III

	1979-80												1980-81					
Sl.No.	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
(A)	5058	8000	20500	10540	15320	14460	10320	7400	4800	6800	7110	1960	3760	3420	12520	10020	4560	7700
1.	420	600	4120	4200	9800	2160	2320	1060	0	0	810	0	180	640	0	5600	1120	1240
2.	426	770	4020	2680	3720	4720	4880	1740	2400	2800	2160	0	0	1720	5928	860	1080	1820
3.	200	530	4020	2680	3400	2680	4880	1300	2200	2240	1770	0	0	1240	5800	860	920	1820
4.	226	240	0	0	320	2040	0	440	200	560	390	0	0	480	128	0	160	0
5.	899	1540	5560	600	160	1600	3760	1700	360	960	1500	0	440	660	2200	1240	800	600
6.	346	270	2220	0	0	360	3760	1000	360	0	320	0	360	0	1400	0	520	320
7.	520	800	20	0	0	120	0	0	0	640	410	0	80	140	800	1420	0	360
8.	0	470	3320	600	160	1120	0	620	0	320	850	0	0	120	0	0	280	0
9.	33	0	0	0	0	0	0	0	0	0	0	0	0	400	0	0	0	0
10.	953	2600	2520	100	520	5880	4160	1400	200	320	900	360	620	0	1400	680	720	1680
11.	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0	0
12.	847	1610	980	100	520	1840	2400	800	200	320	50	360	960	0	800	520	440	1000
13.	106	990	1540	0	0	3960	1760	600	0	0	850	0	0	0	600	160	280	680
14.	0	0	0	0	0	0	0	0	0	0	0	0	1020	0	0	0	0	0
15.	40	0	20	400	0	0	0	0	0	0	280	0	0	0	0	0	0	0
16.	93	0	0	0	0	0	0	0	0	0	0	80	0	0	0	0	0	0
17.	1800	100	0	0	0	0	0	440	440	400	1100	840	60	0	0	0	160	0
18.	0	0	0	0	0	0	0	440	0	0	0	0	60	0	0	0	160	0
19.	1000	100	0	0	0	0	0	0	440	400	1100	840	0	0	0	0	0	0
20.	1227	1070	2860	2480	1120	160	3200	1060	1400	1520	1230	680	1440	400	2800	1460	680	2360
21.	0	1400	1400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0
(B)	13353	11470	5640	10800	4020	6040	3360	27760	360	1080	840	12680	560	1270	9600	13120	900	5720
23.	13353	11470	5640	10800	4020	6040	3360	24760	360	120	540	12680	560	1240	7000	12860	900	5720
24.	420	1670	2900	3800	3500	4720	2400	24760	0	0	400	12320	560	680	3800	12000	220	5200
25.	267	1870	1220	3100	0	1320	960	0	360	120	140	1200	0	560	3200	860	680	520
26.	0	0	0	0	0	0	0	0	0	0	0	160	0	0	0	0	0	0
27.	12666	7930	1520	3900	520	0	0	0	0	960	300	0	0	30	2600	260	0	0
(C)	233	1150	40	700	160	640	0	660	560	0	640	1040	680	80	0	1040	0	400
28.	233	800	40	700	160	640	0	300	560	0	550	920	520	80	0	1040	0	400
29.	233	800	40	700	160	640	0	300	360	0	410	120	0	0	0	1040	0	0
30.	0	0	0	0	0	0	0	0	200	0	140	520	520	80	0	0	0	240
31.	0	0	0	0	0	0	0	0	0	0	0	280	0	0	0	0	0	160
32.	0	350	0	0	0	0	0	360	0	0	90	120	160	0	0	0	0	0
(D)	2707	1620	2600	3400	2120	6440	280	1460	1080	1960	4110	2680	880	880	0	2900	640	1700
33.	667	170	0	400	0	0	280	0	600	520	1390	0	320	0	0	0	0	0
34.	667	170	0	0	0	0	280	0	600	320	690	0	0	0	0	0	0	0
35.	0	0	0	480	0	0	0	0	0	200	700	0	320	0	0	0	0	0
36.	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37.	507	620	0	3000	1760	6440	0	0	480	1440	1450	720	0	480	0	1300	0	680
38.	507	300	0	2700	1760	4200	0	0	480	1440	590	0	0	480	0	960	0	680
39.	0	320	0	300	0	2240	0	0	0	0	860	720	0	0	0	340	0	0
40.	1533	750	2600	0	360	0	0	1460	0	0	1270	1960	560	320	0	1600	640	1020
41.	1533	750	1240	0	360	0	0	940	0	0	1270	1800	560	320	0	1600	520	1020
42.	0	0	1360	0	0	0	0	520	0	0	0	160	0	0	0	0	120	0
(E)	400	930	0	3500	0	0	0	0	760	640	500	1640	580	0	0	0	0	1920
43.	400	380	0	3500	0	0	0	0	760	0	500	1640	400	0	0	0	0	1520
44.	0	550	0	0	0	0	0	0	0	640	0	0	180	0	0	0	0	0
(F)	967	680	2180	1400	160	0	0	140	0	140	1800	870	2020	400	0	1400	640	1840
45.	967	370	2180	200	160	0	0	0	0	0	0	520	1660	400	0	1400	640	1840
46.	0	310	0	1200	0	0	0	140	0	140	1800	350	360	0	0	0	0	0
TOTAL	22718	23930	30960	30340	21780	27560	21980	34420	7560	9820	15000	20870	8400	5970	21928	28480	6740	18960

first annual cycle. In the second cycle, January recorded the maximum and October as the minimum registering 12,860 units/litre and 560 units/litre respectively. The family Peranemaceae revealed a peak in October with 12,666 units/litre and minimum in August with 300 units/litre. However, this family was absent in the months of March, April, May, June and September during the first annual cycle. The months of December and November recorded the maximum and minimum abundances representing 2,600 units/litre and 30 units/litre respectively during the second cycle. This family was absent during October, February and March of the second cycle.

The genus Euglena showed maximum peaks of abundance in May recording 24,760 units/litre and a minimum in August with only 400 units/litre during the first annual cycle. In the second cycle January recorded the maximum with 12,000 units/litre and a minimum in February with 220 units/litre. Phacus recorded a peak of abundance in January with 3,100 units/litre and July as the minimum with 120 units/litre and absent in the months of February and May during the first annual cycle. Trachelomonas was absent in both the cycles except in the month of September recording 160 units/litre. As only one genus Urocoelus was present under family Peramanaceae, hence the seasonality trend of the family and the genus was the same (Table-III).

The class Bacillariophyceae recorded peaks of abundance in November and January both recording 1,150 units/litre and 1,040 units/litre during the first and second cycles respectively. The months of December recorded 40 units/litre as minimum and was absent in April and July during the first annual cycle. The next cycle recorded minimum values of 80 units/litre in November and was absent in December and February (Table-III). The percentage abundance of this class Bacillariophyceae recorded maximum in June with 7.4% and minimum in December with 0.2% during the first annual cycle. In the next cycle maximum and minimum percent abundance was recorded as 8.1% and 1.3% in October and November respectively (Fig.6).

The class Bacillariophyceae was represented by two families Naviculaceae, represented by three genera, Navicula, Frustulia and Pinnularia and the family Fragillariaceae by a single genus Synedra. The family Naviculaceae recorded a maximum peak of abundance in September with 920 units/litre and January with 1,040 units/litre during the first and second cycles. The minimum was recorded in December with 40 units/litre and November with 80 units/litre and was absent in April, July, December and February during both the cycles. The family Fragillariaceae recorded maximum in May with 360 units/litre and minimum in August with 90 units/litre during the first annual cycle. In the next cycle, the family Fragillariaceae was recorded only in October. The genus Navicula constituted the most dominant forms under this class and recorded peaks in November and January representing 800 units/litre and 640 units/litre respectively during the first annual cycle. The minimum was recorded in December with only 40 units/litre, and was absent during April and June. In the next cycle, February recorded 1,040 units/litre and was absent during the remaining periods. The genus Frustulia was absent almost throughout the entire first half of the first annual cycle, appearing only in June and recorded a peak in September representing 520 units/litre. In the next cycle, October recorded 520 units/litre as maximum with the minimum in November as 80 units/litre and absent in December, January and February. Pinnularia was recorded only once in the month of September during the first annual cycle and in the next cycle only in March. As Synedra was the only genus under the family Fragillariaceae, it followed the same trend (Table-III).

The class Myxophyceae had a maximum peak of abundance recording 6,440 units/litre in March and a minimum in April with 280 units/litre during the first annual cycle. In the second cycle a maximum was recorded in January with 2,900 units/litre and a minimum in February with 640 units/litre and was absent in December (Table-III). When the class Myxophyceae as a percentage of total phytoplankton was seen, the month of August recorded the maximum with 27.4% and minimum in April with only 1.3% during the first annual cycle. In the second cycle the maximum and minimum were recorded in November and January with 13.4% and 5.1% respectively (Fig. 6).

Four families were represented under this class viz. Oscillatoriaceae, Rivulariaceae, Chroococceae and Nostocaceae. The family Oscillatoriaceae recorded a maximum peak of abundance in August with 1,390 units/litre and a minimum in April recording 280 units/litre during the first annual cycle. In the second cycle it was recorded only in October with 320 units/litre. The family Chroococcaceae recorded peaks of abundance in the month of January recording 3,000 units/litre and 1,300 units/litre during both the first and second cycles respectively. They recorded a minimum in June and November with 480 units/litre each and was absent for six months in both the cycles. Rivulariaceae and its single genus Rivularia was recorded only once in November with 80 units/litre throughout the period of study. The family Nostocaceae recorded a peak of abundance in December with 2,600 units/litre and minimum in February recording 360 units/litre during the first annual cycle. In the second cycle January and November recorded the maximum and minimum with 1,600 units/litre and 320 units/litre respectively and was absent in December (Table-III).

The genera Spirulina and Phormidium of the family Oscillatoriaceae recorded peaks of abundances in August recording 690 units/litre and 700 units/litre respectively. Spirulina in the second cycle was totally absent while Phormidium was recorded only in October with 320 units/litre. The genera Coelosphaerium and Merismopedia of the family Chroococcaceae recorded peaks of abundances with 4,200 units/litre and 2,240 units/litre respectively in the month of March during the first annual cycle. Coelosphaerium again recorded a peak in January with 960 units/litre and Merismopedia was recorded only once in the month of January during the second cycle. Anabaena constituted the major form under the family Nostocaceae and recorded a maximum of 1,800 units/litre in September and 1,600 units/litre in January during the first and second cycles respectively. Nostoc was present only on four occassions, of which December recorded 1,360 units/litre and February recorded 120 units/litre (Table-III).

The class Xanthophyceae registered a peak of abundance in January recording 3,500 units/litre and was absent in December, February, March, April and May and reappeared in June to form a smaller peak with 1,640 units/litre in September during the first annual cycle. In the second cycle it recorded a maximum in March with 1,520 units/litre. When the relative percent abundance of this class was seen it followed more or less a similar trend to their actual numbers (Table-III and Fig. 6).

The class Xanthophyceae was represented by two families, Xanthophyceae by a single genus Botryococcus, which recorded a maximum and minimum in January and October recording 3,500 units/litre and 400 units/litre respectively during the first annual cycle. In the second cycle a peak was registered in March with 1,520 units/litre and was absent in November, December, January and February. The family Tribonemataceae was also represented by one genus

Tribonema recorded only in November, July and October during both the cycles (Table-III). The relative percent abundance of this class Xanthophyceae revealed a maximum and a minimum of 11.5% and 1.7% in January and October during the first annual cycle and in the next cycle recorded a maximum and minimum registering 8.0% and 6.8% in March and October respectively (Fig. 6).

The class Dinophyceae revealed peaks of abundance in December and March recording 2,180 units/litre and 2,020 units/litre respectively during the first and second cycles. A minimum of 140 units/litre was recorded in May and July and was absent in March, April and June during the first annual cycle. In the next cycle, November recorded 400 units/litre as minimum and was absent in December (Table-III). When the relative percent abundance of the class Dinophyceae was seen, the maximum was recorded in August with 12.0% and October with 23.8% respectively during the first and second cycles respectively. A minimum of 0.5% and 4.9% was recorded in May and January respectively during the first and second cycles (Fig. 6). The single genus Ceratium of the family Ceratiaceae formed a major portion under this class. The months of December and March recorded the maximum peaks of abundance representing 2,180 units/litre and 1,840 units/litre during the first and second cycles respectively. A minimum of 160 units/litre was recorded in February and was absent in March to August during the first annual cycle. In the next cycle November recorded the minimum with 400 units/litre and was absent in December. Gymnodinium of the family Gymnodiaceae recorded a peak in August with 1,800 units/litre and a minimum in July with 140 units/litre and was absent for six months during the first annual cycle. In the next cycle October was the only month to register a count of 360 units/litre and was absent there after. When the total phytoplankton and its seasonal abundance was seen, it revealed a winter maxima and summer minima (Table-III).

EXPERIMENTAL FISH POND-1

The class Chlorophyceae like the control pond constituted the major bulk of phytoplankton in the experimental fish pond-1. The class recorded maximal peaks in August and February representing nearly 31,200 units/litre and 34,000 units/litre during the first and second cycles. The minimum values were recorded in December and November registering nearly 4,000 units/litre and 6,800 units/litre during both the cycles respectively (Table-IV).

When this class Chlorophyceae was calculated for the relative percent abundance it followed more or less a similar pattern to their actual numbers, in that, the month of August revealed 82.1% abundance while October revealed 72.2% abundance during both the cycles. However, October and March registered the minimum percent abundance represented by 26.6% and 27.3% during the first and second cycles respectively (Fig. 8).

The class Chlorophyceae when broken into families, was seen to be represented by eight families. These families were Chlamydomonaceae, represented by a single genus Chlamydomonas, Scenedesmaceae by two genera Scenedesmus and Actinastrum, Oocystaceae by seven genera, Ankistrodesmus, Tetraedron, Selenastrum, Pachycladon, Kirchneriella, Chodetella and Cerasterias. The family Desmidiaceae was represented by Cosmarium, Closterium and Staurastrum, while Dictyosphaeriaceae by a single genus Dictyosphaerium and Ulotric aceae with Ulothrix, the family Volvocaceae had two genera Volvox and Pandorina, while the last family Hydrodictyaceae was represented again by a single genus Pediastrum.

The family Chlamydomonaceae represented by a single genus Chlamydomonas recorded maximal peaks in the month of March represented by 8,660 units/litre and 2,700 units/litre during the first and

TABLE-IV

Seasonal abundance of phytoplankton, their classes, families, respective genera and the total phytoplankton (units/litre) in the Experimental fish pond-1.

(A) CHLOROPHYCEAE

1. Chlamydomonaceae/*Chlamydomonas*
2. Scenedesmaceae
3. *Scenedesmus*
4. *Actinastrum*
5. Oocystaceae
6. *Ankistrodesmus*
7. *Tetraedron*
8. *Selenastrum*
9. *Pachycladon*
10. *Kirchneriella*
11. *Chodatella*
12. *Cerasterias*
13. Desmidiaceae
14. *Cosmarium*
15. *Closterium*
16. *Staurastrum*
17. Dictyosphaeriaceae/*Dictyosphaerium*
18. Ulotricaceae/*Ulothrix*
19. Volvocaceae
20. *Volvox*
21. *Pandorina*
22. Hydrodictyaceae/*Podiastrum*

(B) EUGLENOPHYCEAE

23. Euglenaceae
24. *Euglena*
25. *Phacus*
26. *Trachelomonas*
27. Peranemaceae/*Urceolus*

(C) BACILLARIOPHYCEAE

28. Naviculaceae
29. *Navicula*
30. *Frustulia*
31. *Pinnularia*
32. Fragillariaceae/*Synedra*

(D) MYXOPHYCEAE

33. Oscillatoriaceae
34. *Spirulina*
35. *Phormidium*
36. Rivulariaceae/*Rivularia*
37. Chroococaceae
38. *Coelosphaerium*
39. *Merismopedia*
40. Nostocaceae
41. *Anabaena*
42. *Nostoc*

(E) XANTHOPHYCEAE

43. Xanthophyceae/*Botryococcus*
44. Tribonemataceae/*Tribonema*

(F) DINOPHYCEAE

45. Ceratiaceae/*Ceratium*
46. Gymnodiaceae/*Gymnodinium*
47. Glenodiaceae/*Glenodinium*

TABLE - IV

Sl.No.	1979-80 OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	1980-81 OCT	NOV	DEC	JAN	FEB	MAR
(A)	4740	6880	4000	25920	8500	21620	16000	19560	9080	11340	31200	2800	10080	6800	7120	10100	34400	9740
1.	360	0	600	0	560	8660	280	4200	2780	2800	3200	0	800	720	1040	2140	0	2700
2.	2660	2320	1760	9600	2120	5380	1200	5620	2060	1400	8800	0	0	3640	2560	2760	21000	0
3.	2660	2320	1440	7040	1380	3380	1040	4940	1900	920	8800	0	0	3640	1840	2360	21000	0
4.	0	0	320	2560	740	2000	160	680	160	480	0	0	0	0	720	400	0	0
5.	0	960	520	2560	1480	1260	10280	3980	920	1720	3760	240	60	160	2720	1140	0	1260
6.	0	0	0	0	1360	1100	9040	2520	920	560	0	0	60	0	1120	420	0	0
7.	0	480	520	2560	120	160	680	480	0	700	1200	240	0	0	1040	560	0	740
8.	0	0	0	0	0	0	360	980	0	460	2000	0	0	0	560	0	0	280
9.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	0	240
10.	0	0	0	0	0	0	0	0	0	0	560	0	0	160	0	0	0	0
11.	0	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.	0	0	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0
13.	460	0	0	5760	960	2000	2400	1900	940	680	4000	1280	7340	680	0	1520	0	2400
14.	0	0	0	0	0	0	0	0	0	0	0	0	140	0	0	0	0	0
15.	460	0	0	5760	740	740	1720	720	240	680	2560	960	7200	680	0	116	0	1760
16.	0	0	0	0	220	1260	680	1180	700	0	1440	320	0	0	0	360	0	640
17.	0	0	0	0	0	2300	0	480	0	0	3840	0	0	0	0	0	0	760
18.	0	1680	0	0	0	0	80	0	0	240	0	0	0	80	0	0	0	0
19.	0	1440	0	0	2220	0	0	0	220	880	0	120	0	480	0	1060	400	0
20.	0	0	0	0	2160	0	0	0	0	0	0	120	0	0	0	280	400	0
21.	0	1440	0	0	60	0	0	0	220	880	0	0	0	480	0	780	0	0
22.	1260	480	1120	8000	1160	2020	1760	3380	2160	3620	7600	1160	1880	1040	1200	1480	13000	2620
(B)	540	1380	2200	4160	1500	30400	2880	4500	1340	1980	0	1880	2280	1500	1040	6620	14040	21300
23.	540	560	1480	4160	1500	20800	2120	3140	80	1980	0	1880	2280	1260	1040	6620	13600	21300
24.	540	0	0	4160	1500	20480	960	2500	80	0	0	1760	2280	920	0	6620	13600	21300
25.	0	560	920	0	0	320	1160	640	0	1980	0	0	0	340	1040	0	0	0
26.	0	0	560	0	0	0	0	0	0	0	0	120	0	0	0	0	0	0
27.	0	720	720	0	0	9600	760	1360	1260	0	0	0	0	240	0	0	440	0
(C)	880	1120	840	0	0	3960	0	1180	460	460	2560	280	1020	160	320	900	1600	80
28.	880	480	520	0	0	3200	0	1180	460	380	2560	280	1020	160	320	900	1600	80
29.	760	480	520	0	0	3200	0	1180	260	100	960	0	720	160	320	900	1600	80
30.	120	0	0	0	0	0	0	0	0	160	1600	280	0	0	0	0	0	0
31.	0	0	0	0	0	0	0	0	200	120	0	0	300	0	0	0	0	0
32.	0	640	320	0	0	760	0	0	0	80	0	0	0	0	0	0	0	0
(D)	640	0	1520	15680	1040	2960	1800	1160	1560	160	3040	480	300	1660	6640	2740	0	4500
33.	480	0	160	0	0	0	0	0	1560	0	3040	480	0	0	0	0	0	220
34.	0	0	160	0	0	0	0	0	840	0	1600	0	0	0	0	0	0	220
35.	480	0	0	0	0	0	0	0	720	0	1440	480	0	0	0	0	0	0
36.	160	0	0	0	0	0	0	0	0	0	0	0	0	800	320	0	0	0
37.	0	0	1360	15680	980	2320	1800	1120	0	0	0	0	0	720	5040	2500	0	1000
38.	0	0	440	7040	640	1560	960	480	0	0	0	0	0	0	2720	1520	0	600
39.	0	0	920	8640	340	760	840	640	0	0	0	0	0	720	2320	980	0	400
40.	0	0	0	0	60	640	0	1040	0	160	0	0	300	140	1280	240	0	3280
41.	0	0	0	0	60	640	0	1040	0	160	0	0	300	0	1040	240	0	3280
42.	0	0	0	0	0	0	0	0	0	0	0	0	0	140	240	0	0	0
(E)	8580	4240	0	0	0	0	760	0	4120	1000	1200	0	0	2700	0	0	280	0
43.	0	4240	0	0	0	0	760	0	4120	1000	0	0	0	1380	0	0	0	0
44.	8580	0	0	0	0	0	0	0	0	0	1200	0	0	1320	0	0	280	0
(F)	2400	480	680	0	80	2500	0	720	0	0	0	0	280	1420	2640	560	2160	0
45.	2080	480	680	0	80	920	0	0	0	0	0	0	280	1180	2640	560	1600	0
46.	320	0	0	0	0	1580	0	0	0	0	0	0	0	0	0	0	0	0
47.	0	0	0	0	0	0	0	720	0	0	0	0	0	240	0	0	560	0
TOTAL :	17780	14100	9240	45760	11120	61440	21440	27120	16560	14940	38000	05440	13960	14240	17760	20920	52480	35620

second cycles respectively. However, it recorded nil values in November, January and September during the first annual cycle and February of the second cycle.

The next family Scenedesmaceae which was mainly constituted by the genus Scenedesmus registered a maximal peak representing 9,600 units/litre in January, while it recorded nil values in September during the first annual cycle. Nil values were recorded again in October and March with a maximal peak of a higher magnitude recorded in February representing 21,000 units/litre.

The family Oocystaceae was mainly represented by the genera Ankistrodesmus, Tetraedron and Selenastrum, while the other genera mentioned earlier appeared sparsely and insignificantly. The maximal peak of this family Oocystaceae was recorded in April registering 10,280 units/litre of which the major bulk was constituted by the genus Ankistrodesmus, however it recorded nil values in October during the first annual cycle. During the second cycle nil value was recorded in February and the maximal peak was recorded in December representing 2,720 units/litre. The genus Ankistrodesmus recorded a peak of abundance in April with 9,040 units/litre and a minimum in July representing 560 units/litre and was absent in October to January, August and December during the first annual cycle. In the next cycle the maximum was registered in December recording 1,120 units/litre and a minimum in October with 60 units/litre and was absent in November, February and March. Tetraedron recorded a maximum in January with 2,560 units/litre and a minimum in February representing 120 units/litre and was absent in the months of October and June during the first annual cycle. In the second cycle, December and January recorded the maximum and minimum representing 1,040 units/litre and 560 units/litre respectively and was absent in October, November and February. Selenastrum had a peak of abundance in August with 2,000 units/litre and a minimum in April recording 360 units/litre and was absent from October to March, June and September during the first cycle. The months of December and March recorded 560 units/litre and 280 units/litre as maximum and minimum during the second cyole and was absent in October, November and February.

The family Desmidiaceae was represented mainly by two genera Closterium and Staurastrum. The maximal peak was constituted by Closterium alone recording nearly 5,760 units/litre in January while the other months were well represented by both the genera Closterium and Staurastrum though the latter genus constituted the major bulk. Nil values were recorded in November and December during the first annual cycle. Similarly during the second cycle, a maximal peak of 7,340 units/litre was represented in October by two genera Cosmarium and Closterium of which the latter contributed the largest number in October and the family recorded nil in December and February. Cosmarium was totally absent during the first cycle and was present only in October with 140 units/litre during the second cycle. Closterium recorded a peak in January and a minimum in June representing 5,760 units/litre and 240 units/litre during the first annual cycle and was absent in November and December. During the second cycle October recorded a maximum with 7,220 units/litre and a minimum in November registering 680 units/litre and was absent in December and February. Staurastrum recorded peaks of abundance in August and March representing 1,440 units/litre and 640 units/litre respectively during the first and second cycles. The months of February with 220 units/litre and January with 360 units/litre was recorded as the minimum. It was absent from October to January, July, October to December and February during both the cycles.

The family Dictyosphaeriaceae which was represented by a single genus Dictyosphaerium occurred in the system only on three occasions, March, May and August of which 3,840 units/litre represented the maximal peak in August during the first annual cycle. In the second cycle it was absent throughout the period of study except in March which registered 760 units/litre.

Similarly the family Ulotricaceae represented by a single genus Ulothrix occurred sporadically with insignificant numbers except for the month of November which recorded 1,680 units/litre as the maximum and was absent totally during the other periods with the exception in April and July during the first annual cycle. During the second cycle however, it was totally absent, except in November registering only 80 units/litre.

The family Volvocaceae was represented by two genera Volvox and Pandorina, of which the latter was more abundant numerically. However, the maximal peak during the first annual cycle was contributed by Volvox representing nearly 2,220 units/litre while the other periods were mainly constituted by Pandorina. However, during the second cycle, Pandorina mainly attributed the maximal peak recording nearly 1,060 units/litre in January and recorded nil values for seven months during the first annual cycle and October, December and March during the second cycle.

The last family Hydrodictyaceae encountered under the class Chlorophyceae in this experimental fish pond-1 was represented by a single genus Pediastrum, which numerically formed the second major constituent of the phytoplankton and was well represented throughout the period of investigation. The maximal peak was recorded in January registering nearly 8,000 units/litre and a minimum of 480 units/litre in November during the first annual cycle. The maximal peak was recorded in February with nearly 13,000 units/litre and a minimum in

November registering 1,040 units/litre during the second cycle (Table-IV).

The next class Euglenophyceae constituted the second largest phytoplankton among the other classes. The maximal peak was recorded in March registering 30,400 units/litre and in August nil value was recorded during the first annual cycle, whereas during the second cycle the month of March registered the maximum with 21,300 units/litre and December recorded 1,040 units/litre as the minimum (Table-IV).

When the class Euglenophyceae was seen as a relative percent abundance it followed more or less a similar pattern to their actual numbers with March registering 49.5%, while March again of the second cycle recorded 59.8% (Fig. 6). This class comprised of two families Euglenaceae represented by three genera Euglena, Phacus and Trachelomonas and the family Peranemaceae by a single genus Urcoelus. The family Euglenaceae recorded a maximum peak of abundance in March representing 20,800 units/litre and a minimum in June with 80 units/litre and was absent in the month of August during the first annual cycle. In the next cycle the maximum and minimum were recorded in March with 21,300 units/litre and 1,040 units/litre in December. The family Peranemaceae recorded a peak in March with 9,600 units/litre and was absent for six months during the first annual cycle. In the second cycle it was recorded only in November and January with 240 units/litre and 440 units/litre respectively (Table-IV).

Euglena constituted the dominant genus. The maximal peak was in March with 20,480 units/litre but was recorded nil in November, December, July and August during the first annual cycle. During the second cycle, however, the genus Euglena alone formed the peak in March with 21,300 units/litre and recorded nil in December. The genus Phacus recorded a maximum of 1,980 units/litre in July and recorded nil in October, January, February, June, August and September during the first annual cycle. The months of November and December of the second cycles were the only two occasions to record their occurrence (Table-IV).

The class Bacillariophyceae registered a maximal peak in March recording 3,960 units/litre and recorded nil in January, February and April during the first annual cycle. The class was present throughout the second cycle with the month of February as the maximal peak (1,600 units/litre) and the subsequent month of March registered the minimum with only 80 units/litre (Table-IV).

When the relative percent abundance of this class Bacillariophyceae was seen, it recorded a maximum of 9.1% and a minimum of 2.8% in December and June during the first annual cycle. In the next cycle October and March recorded the maximum and minimum with 7.3% and 0.3% respectively (Fig. 6). The class Bacillariophyceae comprised of two families Naviculaceae, which recorded a maximum peak of abundance in March with 3,200 units/litre and a minimum in September with only 280 units/litre during the first annual cycle. In the second cycle, February and March recorded the maximum and minimum with 1,600 units/litre and 80 units/litre respectively. The family Fragilariaceae was represented by a single genus Synedra which recorded a peak of abundance in March with 760 units/litre and a minimum in July with 80 units/litre and was absent in October, January, February, April, May, June, August and September during the first annual cycle. In the second cycle they registered a total absence (Table-IV).

The genus Navicula during the first cycle rose to a maximal peak in March representing 3,200 units/litre. Similarly in the second cycle Navicula recorded the maximal peak in February registering 1,600 units/litre. The genus Frustulia and Pinnularia were sporadically represented throughout the study period. The former genus recorded a maximum of 1,600 units/litre in August and occurred only in July September and October of the first annual cycle and was totally absent during the second cycle. The latter genus Pinnularia occurred only in June and July registering 200 units/litre and 120 units/litre respectively and was absent during the rest of the first cycle. In the next cycle October was the only occasion to record its occurrence with 300 units/litre (Table-IV).

The next class Myxophyceae recorded a peak in January representing nearly 15,680 units/litre and nil in November during the first annual cycle. In the next cycle, nil value was recorded in February and a maximum peak in December representing 6,640 units/litre (Table-IV). The class Myxophyceae when observed as a relative percent abundances in relation to all the other classes present, it followed a similar pattern to their actual numbers with January and December recording a maximum of 34.3% and 37.4% during the first and second cycles (Fig. 6). Undar this class four families were recorded, Oscillatoriaceae represented by two genera, Spirulina and Phormidium; Rivulariaceae by a single genus Rivularia; Chroococcaceae by two genera, Coelosphaerium and Merismopedia and finally Nostocaceae also with two genera, Anabaena and Nostoc. The family Oscillatoriaceae recorded peaks of abundance in August and March recording 3,040 units/litre and 220 units/litre respectively during the first and second cycles. The minimum values were recorded in December with 160 units/litre and nil from October to February in the second cycle. The family Rivulariaceae with its single genus Rivularia was recorded only once during the first annual cycle in October and in the second cycle, November recorded a maximum with 800 units/litre and was absent in October, January, February and March. The family Chroococcaceae revealed a maximum peak of abundance in January with 15,680 units/litre and was absent in October, November, June to September during the first annual cycle. In the second cycle a peak was recorded in December with 5,040 units/litre and was absent in October and February. The family Nostocaceae recorded maximum in May with 1,040 units/litre and a minimum with 60 units/litre in February and was absent from October to January, April, June, August and September during the first annual cycle. In the next cycle a peak was registered in March representing 3,280 units/litre and a minimum with 140 units/litre in November and was absent in February (Table-IV).

The two genera Spirulina and Phormidium of the family Oscillatoriaceae appeared and disappeared intermittently. The maximum were recorded in the same month of August registering 1,600 units/litre and 1,440 units/litre respectively for both cycles. The family Chrococcaceae represented by two genera Coelosphaerium and Merismopedia revealed maximum peaks in January representing 7,040 units/litre and and 8,640 units/litre respectively. Both genera were absent in October, November, June to September during the first annual cycle. Similarly during the second cycle, Coelosphaerium and Merismopedia rose to a peak in December recording 2,720 units/litre and 2,320 units/litre respectively.

Anabaena and Nostoc under the family Nostocaceae occurred sporadically throughout the period of study. Anabaena was more dominant in comparison to Nostoc. Anabaena registered a maximum peak with 1,040 units/litre in May and was recorded only in February, March and July. However, the genus Nostoc was absent throughout the first annual cycle. During the second cycle Anabaena revealed a maximum peak of abundance in March with 3,280 units/litre, while Nostoc recorded a maximum in December with 240 units/litre (Table-IV).

The class Xanthophyceae revealed a maximal peak of abundance in October recording 8,580 units/litre and was absent in December, January to March, May and September in the first cycle. The maximal peak in the second cycle was registered in November with 2,700 units/litre and was present only in February (Table-IV).

The class Xanthophyceae recorded maximum relative percent abundance in October with 48.3% and November with 18.9% and the minimum in August with 3.2% and February with 0.5% during the first and second cycles respectively (Fig. 6). Under this class two families were recorded, Xanthophyceae represented by Botryococcus and Tribonemataceae represented by Tribonema.

The genus Botryococcus recorded maximum in November with 4,240 units/litre during the first annual cycle. However, it occurred only once during the second cycle in November representing 1,380 units/litre. Triboenma occurred in October and August, the latter recording 1,320 units/litre (Table-IV).

The class Dinophyceae showed a peak in March with 2,500 units/litre and was absent in January, April, June to September during the first annual cycle and March during the second cycle. The month of December revealed the maximum with 2,640 units/litre and minimum in October with 280 units/litre (Table-IV). When the class Dinophyceae was analysed for their relative percent abundance it followed a trend similar to their actual numbers. The months of October and December recorded maximum of 13.5% and 14.9% respectively and the minimum in February and October with 0.7% and 2.0% during the first and second cycles respectively (Fig. 6).

The class Dinophyceae comprised of theee families, Ceratiaceae represented by a single genus Ceratium, Gymnodiaceae by Gymnodinium and Glenodiaceae by Glenodinium. The family Ceratiaceae revealed a maximum and minimum in the months of October with 2,080 units/litre and February with 80 units/litre during the first annual cycle. In the second cycle December and October recorded the maximum and minimum with 2,640 units/litre and 280 units/litre respectively. The family Gymnodiaceae was only recorded in the months of October and March and was entirely absent for the rest of the study periods. Similarly the family Glenodiaceae was recorded only in May with 720 units/litre during the first annual cycle and in the second cycle November and February recorded their presence in this pond. As each family were represented by a single genus, the trend was same.

A spring and summer maxima with a winter minima was observed in the present pond, when the total phytoplankton in this system was observed (Table-IV).

EXPERIMENTAL FISH POND-2

In the experimental fish pond-2 the same six classes of Phytoplankton were represented. Of these classes Chlorophyceae was the most important group both in numbers and percent abundance in the present pond. The population displayed a bimodal pattern of fluctuation with October recording a small peak of 63,600 units/litre which then gradually decreased and thereafter increased to reach a maximal peak of abundance of 3,98,715 units/litre in March and persisted till June. It then fell down to register the minimal peak of 3,040 units/litre in July during the first annual cycle. The population thereafter increased their numbers to reach a peak again in March recording 24,780 units/litre with the previous month of February recording the minimum of 6,240 units/litre (Table-V).

When the relative percent abundance of this class was seen in relation to the others for both the cycles, Chlorophyceae revealed a maximum of 72.2% abundance in March and the minimum was recorded in January with only 11.0%. Though July was the minimum count in numbers, yet it registered a higher percent abundance as 38.6% during the first annual cycle. October of the second cycle recorded the maximum with 70.5% abundance though the maximum numbers were in March which showed only 54.7%. The minimum was registered in the month of February as 10.0% (Fig. 6).

The class Chlorophyceae constituted the largest number of families and genera. Ten families represented by a total of eighteen genera were present in this class alone. The family Chlamydomonaceae and its single genus *Chlamydomonas* recorded a peak of abundance in March and a minimum in July representing 3,75,645 units/litre and 760 units/litre respectively during the first annual cycle. In the next cycle a peak was registered in March with 20,020 units/litre

TABLE-V

Seasonal abundance of phytoplankton, their classes, families, respective genera and the total phytoplankton (units/litre) in the Experimental fish pond-2.

(A) CHLOROPHYCEAE
1. Chlamydomonaceae/*Chlamydomonas*
2. Scenedesmaceae
3. *Scenedesmus*
4. *Actinastrum*
5. Oocystaceae
6. *Ankistrodesmus*
7. *Tetraedron*
8. *Selenastrum*
9. *Cerïasterias*
10. *Pachycladon*
11. Desmidiaceae
12. *Cosmarium*
13. *Closterium*
14. *Staurastrum*
15. Dictyosphaeriaceae/*Dictyosphaerium*
16. Ulotricaceae
17. *Ulothrix*
18. *Hormidium*
19. Hydrodictyaceae/*Pediastrum*
20. Volvocaceae/*Pandorina*
21. Coelastraceae/*Coelastrum*
22. Protococcaceae/*Protococcus*

(B) EUGLENOPHYCEAE
23. Euglenaceae
24. *Euglena*
25. *Phacus*
26. *Trachelomonas*
27. Peranemaceae/*Urceolus*

(C) BACILLARIOPHYCEAE
28. Naviculaceae
29. *Navicula*
30. *Frustulia*
31. *Pinnularia*
32. Fragillariaceae/*Synedra*

(D) MYXOPHYCEAE
33. Oscillatoriaceae
34. *Spirulina*
35. *Oscillatoria*
36. *Phormidium*
37. Rivulariaceae/*Rivularia*
38. Chroococcaceae
39. *Merismopedia*
40. *Coelosphaerium*
41. Nostocaceae
42. *Anabaena*
43. *Nostoc*

(E) XANTHOPHYCEAE
44. Xanthophyceae/*Botryococcus*
45. Tribonemataceae/*Tribonema*
46. Chlorothiciaceae/*Ophiocytium*

(F) DINOPHYCEAE
47. Ceratiaceae/*Ceratium*
48. Gymnodiaceae/*Gymnodinium*
49. Peridiniaceae/*Peridinium*

TABLE - V

Sl.No.	1979-80 OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	1980-81 OCT	NOV	DEC	JAN	FEB	MAR
(A)	62600	19260	4280	5600	196800	39875	36600	19267	15894	3040	26800	18480	15760	7640	12200	7020	6240	24780
1.	8200	3800	1000	1600	193000	375645	17360	9149	10968	760	7800	7600	5400	1840	2600	1620	2560	20028
2.	21900	5100	160	640	800	4146	6700	342	3870	680	8200	7600	2560	3920	0	580	2320	2200
3.	21900	4400	0	640	800	2052	5880	285	3878	680	8200	7600	2560	3920	0	80	2320	2200
4.	0	700	160	0	0	2394	820	57	0	0	0	0	0	0	0	500	0	0
5.	400	440	120	1160	0	12654	4800	5472	726	520	3840	640	960	1240	1800	800	160	520
6.	0	0	0	0	0	11970	2208	5472	0	0	0	0	600	720	1800	800	0	360
7.	400	40	0	560	0	0	0	0	0	520	960	640	360	520	0	0	160	160
8.	0	400	120	0	0	0	2600	0	726	0	2880	0	0	0	0	0	0	0
9.	0	0	0	600	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.	0	0	0	0	0	684	0	0	0	0	0	0	400	0	0	0	0	0
11.	1620	1440	0	1840	2400	4218	3940	86	330	320	1920	800	1120	320	2400	120	1040	1080
12.	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13.	1520	800	0	1520	840	3192	2520	29	0	0	480	0	320	0	2400	120	880	360
14.	100	600	0	320	1560	1026	1420	57	330	320	1440	800	800	320	0	0	160	720
15.	0	1500	0	0	0	0	2180	0	0	0	0	0	0	0	0	1680	160	0
16.	0	80	0	0	0	0	0	0	990	0	0	0	200	320	0	0	0	0
17.	0	0	0	0	0	0	0	0	990	0	0	0	200	320	0	0	0	0
18.	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19.	9840	6900	3000	360	600	1368	1620	80	0	760	4080	1840	4640	0	3600	900	0	960
20.	0	0	0	0	0	684	0	4138	0	0	0	0	0	0	1800	600	0	0
21.	0	0	0	0	0	0	0	0	0	0	960	0	0	0	0	800	0	0
22.	20640	0	0	0	0	0	0	0	0	0	0	0	480	0	0	0	0	0
(B)	10460	12800	7760	32960	144040	142518	15220	713	3060	2200	11040	4400	1480	1120	8200	4560	52360	18520
23.	10100	11300	7760	31520	144040	142518	15220	713	3060	840	6720	3440	1480	1120	8200	4560	50440	18520
24.	2800	5300	7000	29000	4040	25008	3620	0	0	0	0	1600	0	0	4600	3600	3440	14928
25.	7300	6000	760	2520	140000	117510	8800	713	1260	840	6720	1840	1480	1120	2800	960	47000	3600
26.	0	0	0	0	0	0	2800	0	1800	0	0	0	0	0	800	0	0	0
27.	360	1500	0	1440	0	0	0	0	0	1360	4320	960	0	0	0	0	1920	0
(C)	27800	4900	320	4360	0	2622	520	86	800	880	6920	1160	480	0	0	660	2800	800
28.	27000	4900	320	4360	0	2622	520	86	800	880	5000	1160	400	0	0	660	2800	800
29.	25520	1200	160	2760	0	912	520	86	800	0	560	520	400	0	0	660	960	220
30.	2880	2400	0	1600	0	1710	0	0	0	880	4440	640	0	0	0	0	1840	120
31.	0	1300	160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	360
32.	0	0	0	0	0	0	0	0	0	0	1920	0	0	0	0	0	0	0
(D)	12840	3320	3400	7680	0	5850	1860	10216	10710	1400	3360	2920	2960	8840	14200	600	800	320
33.	100	0	0	0	0	0	0	1528	3120	0	0	1040	200	0	0	0	800	320
34.	100	0	0	0	0	0	0	0	0	0	0	720	0	0	0	0	0	0
35.	0	0	0	0	0	0	0	0	1320	0	0	0	0	0	0	0	0	320
36.	0	0	0	0	0	0	0	1528	1800	0	0	320	200	0	0	0	800	0
37.	0	0	0	0	0	0	0	252	0	0	0	0	0	0	0	0	0	0
38.	12740	3320	1600	7280	0	5890	1860	7752	7590	1400	3360	1880	2160	1040	1800	0	0	0
39.	920	0	0	1600	0	378	0	0	0	680	0	0	1360	1040	1800	0	0	0
40.	18820	3320	1600	5680	0	5472	1860	7752	7590	720	3360	1880	800	0	0	0	0	0
41.	0	0	1800	400	0	0	0	684	0	0	0	0	600	7800	12400	600	0	0
42.	0	0	1800	0	0	0	0	684	0	0	0	0	600	7800	12400	600	0	0
43.	0	0	0	400	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(E)	8640	2200	0	0	0	0	0	8991	0	360	0	0	600	880	2400	3200	0	360
44.	0	2200	0	0	0	0	0	8892	0	0	0	0	0	0	2400	0	0	0
45.	0	0	0	0	0	0	0	99	0	0	0	0	600	880	0	3200	0	360
46.	8640	0	0	0	0	0	0	0	0	360	0	0	0	0	0	0	0	0
(F)	960	0	0	200	0	2394	0	252	0	0	0	480	1000	0	0	1160	0	480
47.	960	0	0	200	0	2394	0	252	0	0	0	0	800	0	0	1160	0	480
48.	0	0	0	0	0	0	0	0	0	0	0	480	0	0	0	0	0	0
49.	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	0	0	0
TOTAL :	123300	42480	15760	90800	340840	552099	54200	39525	30464	7880	48120	27440	21800	18400	37000	17200	62200	45260

with a minimum in January with 1,620 units/litre. The family Scenedesmaceae recorded a peak in October with 21,900 units/litre and a minimum in December with 160 units/litre during the first annual cycle. In the next cycle November recorded the maximum with 3,920 units/litre and January as the minimum with 580 units/litre and was absent in December. Scenedesmaceae was represented by two genera Scenedesmus and Actinastrum. Scenedesmus was more prevalent and constituted a maximum peak in October with 21,900 units/litre which thereafter fell to 160 units/litre as minimum in December during the first cycle. Similarly in the second cycle it was maximum in November (3,920 units/litre) and minimum with 80 units/litre in January. It was absent in December. The genus Actinastrum was very infrequent in their occurrence. Their presence were confined only to the months of November, December and March with the latter recording a maximum of 2,394 units/litre and April and May, while January was the only month with nearly 500 units/litre during the next cycle. The family Oocystaceae recorded a peak in March with 12,654 units/litre and a minimum with 120 units/litre in December during the first annual cycle. In the next cycle December recorded the maximum and February the minimum with 180 units/litre and 160 units/litre respectively (Table-V).

The family Oocystaceae was represented by Ankistrodesmus, Tetraedron, Selenastrum, Cerasterias and Pachycladon. Ankistrodesmus was the most abundant and recorded March as the maximal peak with 11,970 units/litre. December of the second cycle recorded the maximal peak of 1,800 units/litre and was absent from October to February, June to September during both the cycles. Tetraedron recorded peaks in August and November with 960 and 520 units/litre during the first and second cycles. Selenastrum recorded two peaks one in April and the other in August, the latter with 2,880 units/litre as maximum during the first annual cycle. The genus was not represented during the second cycle. Ceriasterias and Pachycladon appeared only once in January and March during the first cycle only and with the exception of October of the second cycle which recorded 400 units/litre for Pachycladon (Table-V).

The family Desmidiaceae recorded maximum in March with 4,218 units/litre and in December with 2,400 units/litre during the first and second cycles respectively. May recorded 86 units/litre and January with 120 units/litre as the minimum for both the cycles.

The family Desmidiaceae was represented by three genera Cosmarium, Closterium and Staurastrum. Of these Closterium and Staurastrum constituted the major bulk, whereas Cosmarium was recorded only in November (40 units/litre) throughout the entire period of study. The family Desmidiaceae recorded a maximal peak in March (4,218 units/litre) that persisted till April and then fell to 8,611 units/litre in May which was the minimum and was absent in December. However, during the second cycle, December registered 2,400 units/litre as maximum and dropped to 120 units/litre in January as minimum. The genera Closterium and Staurastrum recorded maximal peaks of abundance in March and February representing 3,192 units/litre and 1,560 units/litre respectively during the first annual cycle. During the next cycle, the genus Closterium recorded a maximum of 2,400 units/litre in December and a minimum of 120 units/litre in January. Staurastrum during the same period showed a maximum in October (800 units/litre) and 160 units/litre as minimum. The family Dictyosphaeriaceae was recorded only in the months of November, April, January and February. Similarly the family Ulotricaceae was present only in November, June, October and November during both the cycles.

The family Dictyosphaeriaceae represented by only Dictyosphaerium was recorded only four times throughout the study period. It recorded 2,180 units/litre as maximum in April and 1,600 units/litre in January during the first and second cycles besides November of the first cycle and February of the second cycle when they occurred with less numbers. Similarly the family Ulotricaceae represented by <u>Ulothrix</u> and <u>Hormidium</u> had September and October as the only two occasions to register their presence. The family Hydrodictyaceae recorded peaks of abundance in October with 9,840 units/litre and minimum in May with 80 units/litre and was absent in June during the first annual cycle. In the second cycle October recorded the maximum peak with 4,640 units/litre and January with 900 units/litre as the minimum and was absent in November and February.

The family Volvocaceae was present only on two occasion each during both the cycles. May recording 4,138 units/litre and December with 1,800 units/litre in the first and second cycles respectively. Coelastraceae was recorded only in August with 960 units/litre and 800 units/litre in January during the first and second cycles respectively. Finally the family Protococcaceae was recorded in the months of October for both the cycles with 20,640 units/litre and 480 units/litre.

<u>Pandorina</u> of the family Volvocaceae, <u>Coelastrum</u> of Coelastraceae and <u>Protococcus</u> of Protococcaceae occurred only sporadically during the study period and formed a meagre population percentage. The exception was <u>Pandorina</u> and <u>Protococcus</u> which recorded 4,138 units/litre and 20,640 units/litre in May and October of the first cycle (Table-V).

The next class Euglenophyceae showed a maximum peak of abundance in February recording 1,44,040 units/litre which persisted till April though in decreasing order and recorded the minimum in May representing only 713 units/litre in the first cycle. During the second cycle it revealed a steady increase in numbers to touch a maximal peak in February recording 52,360 units/litre and with November recording a minimum of 1,120 units/litre (Table-V). When this class Euglenophyceae was seen for their relative percent abundance in relation to the other classes, a maximum of 64.9% abundance was recorded in January while the peak month of February recorded only 42.3% which constituted the largest number of individual counts. May recorded 1.8% as minimum during the first cycle. The second cycle followed a similar trend to their actual numbers (Fig. 6)

The class Euglenophyceae in this pond-2 was constituted by two families, Euglenaceae represented by Euglena, Phacus and Trachelomonas and the family Peranemaceae represented by a single genus Urcoelus. The family Euglenaceae followed a trend similar to its class for the first cycle. In the second cycle a peak of 50,440 units/litre was recorded in February and a minimum in November with 1,120 units/litre. The family Peranemaceae and its single genus Urcoelus recorded a peak in August with 4,320 units/litre and a minimum of 360 units/litre in October. In the next cycle February was the only month to record the presence of the family with 920 units/litre (Table-V).

The genus Phacus recorded a maximal peak of abundance in February with 1,40,000 units/litre and a minimum in May with only 713 units/litre during the first annual cycle. In the next cycle February recorded the maximum peak with 47,000 units/litre and a minimum in November with 1,120 units/litre. The genus Euglena revealed a maximum density in January and March representing 29,000 units/litre and 14,920 units/litre respectively during both the cycles. Nil values were recorded in May, June, July and August during the first annual cycle and November of the second cycle. Trachelomonas occurred only in April with 2,800 units/litre and June with 1,800 units/litre during the first annual cycle. December of the second cycle was the only month of its occurrence (800 units/litre) (Table-V).

The next class Bacillariophyceae recorded a maximum density in October registering 27,800 units/litre which fell to a minimum of 86 units/litre in May and recorded nil value in February during the first cycle. However, February of the second cycle recorded a maximum peak with 2,800 units/litre and minimum in October with 400 units/litre and was absent in November and December (Table-V).

When this class Bacillariophyceae was analysed for their relative percent abundance it followed more or less a similar pattern as their actual numbers. October and February recorded 22.5% and 4.5% as maximum during the first and second cycles respectively (Fig. 6).

The class Bacillariophyceae comprised of two families, Naviculaceae represented by three genera Navicula, Frustulia and Pinnularia and Fragilariaceae by a single genus Synedra. The family Naviculaceae recorded peaks of abundance in October and February representing 27,800 units/litre and 2,800 units/litre respectively during the first and second cycles. The months of May and January represented the minimum with 86 units/litre and 660 units/litre during the first and second cycles respectively. The family Fragilariaceae was recorded only once in August with 1,920 units/litre during the entire period of investigation (Table-V). Navicula constituted the most dominant genus under this family Naviculaceae. October registered the maximal density representing 225 units/litre and February registered 960 units/litre respectively during the first and second cycles. Frustulia recorded maximum in August and February recording 4,440 units/litre and 1,840 units/litre respectively during both the cycles. Pinnularia occurred only three times during the entire period (Table-V).

The next class Myxophyceae was made up of the second largest number of families and genera. It was represented throughout the period of study with the exception of February. The class recorded its maximal density in October representing 12,840 units/litre with another smaller peak in June recording 10,710 units/litre during the first annual cycle. During the second cycle it gradually increased to touch a maximal peak in December recording 14,200 units/litre and fell to a minimum of 320 units/litre in March (Table-V).

The class Myxophyceae in respect of their relative percent abundance among the other classes, showed a maximum of 35.2% in June whereas the peak month October revealed only 10.4% abundance and the minimum was in March with only 1.1% during the first cycle. In the next cycle a maximum and minimum were recorded in November with 48.0% and February 1.3% respectively (Fig. 6).

The class Myxophyceae was comprised of four families and eight genera. Of these families and genera, the family Chroococcaceae constituted the largest. Under this family the genus Coelosphaerium was more dominant than Merismopedia. The family revealed a peak in October recording 12,740 units/litre and minimum in July with 1,400 units/litre during the first annual cycle. January, February and March of the second cycle recorded nil, while the maximum was in December with 1,800 units/litre represented by only Merismopedia. The family Oscillatoriaceae recorded a peak in June and a minimum in October representing 3,120 units/litre and 100 units/litre respectively during the first annual cycle. In the second cycle February recorded a maximum of 800 units/litre and October with 200 units/litre as minimum. The family Rivulariaceae was present only in May with 252 units/litre and was absent otherwise. The family Chroococcaceae recorded peaks of abundance in October with 12,740 units/litre and October with 2,160 units/litre during the first and second cycles. The minimum was recorded in December with 1,600 units/litre and November 1,040 units/litre during the first and second cycles respectively. The family Nostocaceae recorded a peak in December with 1,800 units/litre and January as minimum with 400 units/litre and was absent in October, November, February to April, June, September during the first annual cycle. In the second cycle a peak was registered in December with 12,400 units/litre and recorded absent in February and March (Table-V).

The family Nostocaceae was represented by two genera Anabaena and Nostoc. Anabaena revealed infrequent occurrences during the first cycle registering in December 1,800 units/litre and 684 units/litre in May. Their occurrences were recorded during the major part of the second cycle with December recording 12,400 units/litre and were absent in February and March. The genus Nostoc was present only once in January recording 400 units/litre and was totally absent during the second cycle. The family Rivulariaceae represented by a single genus Rivularia occurred only in May (252 units/litre) throughout the period of study. The family Oscillatoriaceae was represented by three genera Spirulina, Oscillatoria and Phormidium. Of these genera, Phormidium constituted the dominant genus with a maximum record in June representing 1,800 units/litre which fell to 320 units/litre in September as minimum during the first annual cycle. During the second cycle they were present only in October and February recording 200 and 800 units/litre respectively. Oscillatoria was present only in June with 1,320 units/litre and March (320 units/litre) during the first and second cycles. The genus Spirulina was recorded only in September with 720 units/litre (Table-V).

The class Xanthophyceae was present only on four occasions during the first cycle and recorded two peaks of maximal abundence one in October registering 8,640 units/litre and then a higher peak in May recording 8,991 units/litre. During the second cycle however, they were well represented throughout except February. It was observed that their numbers increased steadily till January revealing a maximum density of 3,200 units/litre (Table-V).

When the class Xanthophyceae was seen as a relative percent abundance in comparison to the other six classes encountered in this experimental pond-2 it followed a trend more or less similar to their actual numbers with May and January registering maximal percent abundance of 22.7% and 18.6% during the first and second cycles respectively. The minimum percent abundance were recorded in July (4.6%) and March (0.8%) during both the cycles (Fig. 6).

Three families were encountered under this class. The family Xanthophyceae was represented by Botryococcus, Tribonemataceae by Tribonema and Chlorothiaciaceae by Ophiocytium. The family Xanthophyceae with its single genus Botryococcus during the first annual cycle and recorded only in November and May representing 2,200 units/litre and 8,892 units/litre respectively. In the second cycle it was recorded only in the month of December with 2,400 units/litre. The family Tribonemataceae again with its single genus Tribonema was absent throughout the first annual cycle with the exception of the month of May recording 99 units/litre. In the second cycle a maximum of 3,200 units/litre was registered in January, and March recorded the minimum with 360 units/litre and was absent in December and February. The family Chlorothiaciaceae and its single genus Ophiocytium recorded a peak of 8,640 units/litre in October and a count of 360 units/litre in July during the first annual cycle and in the next cycle it was totally absent (Table-V).

The last class encountered in this pond was Dinophyceae. It recorded maximal density in March representing 2,394 units/litre with a minimum reoord of 200 units/litre in January and was absent for seven months during the first cycle. During the second cycle, January recorded maximum with nearly 1,160 units/litre and also a smaller peak in October with nearly 1,000 units/litre. March recorded minimum counts representing only 480 units/litre and was absent during the other periods (Table-V).

When their relative percent abundance was seen, September recorded the maximum with 1.7% abundance, though they were constituted by a very low number of individual counts in comparison to the peak month of March which recorded a percent abundance of only 0.4% during the first annual cycle. However, the second cycle followed a trend similar to their actual numbers with January recording maximum with 6.7% abundance (Fig. 6).

The class Dinophyceae was represented by three families with one genus each. The family Cer^tiaceae represented by Ceratium was the dominant form under this class and had a maximum in March recording 2,394 units/litre and was present only in October, January and May during the first annual cycle. In the next cycle January recorded the maximal peak with 1,160 units/litre and was present only in October and March. The genus Gymnodinium (Gymnodiniceae) and Peridinium (Peridiniaceae) registered their presence only once during both the cycles. Gymnodinum occurred in September recording 480 units/litre and Peridinium in October representing only 200 units/litre.

When the total phytoplankton was observed for its seasonal trend of fluctuations, irrespective of the genera present under them it revealed a spring maxima and winter minima during both the cycles (Table-V).

EXPERIMENTAL FISH POND-3

In this experimental fish pond-3, the class Chlorophyceae was also the most dominant phytoplankton and was constituted by eleven families represented by twentytwo genera. In terms of maximum numbers of abundance, November recorded the maximum (47,853 units/litre) and January (25,320 units/litre) during the first and second cycles respectively. The minimum was in January with 3,480 units/litre and February with 1,280 units/litre during both the cycles (Table-VI).

When the relative percent abundance of this class Chlorophyceae was observed it showed in the first cycle a maximum of 79.2% in November, though the month of May also showed a percentage of 79.1% abundance but were far less in numerical counts. March constituted 76.0% abundance which had a very low count of individuals than the peak month of January which showed only 39.7% abundance during the second cycle (Fig. 6).

The family Chlamydomonaceae and Scenedesmaceae recorded peaks of abundance in April and January during both cycles respectively. The former family recorded 2,240 units/litre and 5,600 units/litre, while the latter had 6,900 units/litre and 9,600 units/litre respectively during the first and second cycles. The family Chlamydomonaceae recorded a minimum in February with 40 units/litre and Scenedesmaceae in January with 300 units/litre during the first annual cycle. The minimum record was in the month of October with 680 units/litre and 320 units/litre for Chlamydomonaceae and Scenedesmaceae respectively

The family Oocystaceae recorded peaks of abundance in August with 5,000 units/litre and in November with 3,600 units/litre during the first and second cycles respectively. It recorded a minimum of 240 units/litre in January and 40 units/litre in March during both the cycles.

TABLE-VI

Seasonal abundance of phytoplankton, their classes, families, respective genera and the total phytoplankton (units/litre) in the Experimental fish pond-3.

(A) CHLOROPHYCEAE

1. Chlamydomonaceae/Chlamydomonas
2. Scenedesmaceae
3. Scenedesmus
4. Actinastrum
5. Oocystaceae
6. Ankistrodesmus
7. Tetraedron
8. Selenastrum
9. Cariasterias
10. Pachycladon
11. Desmidiaceae
12. Cosmarium
13. Closterium
14. Staurastrum
15. Desmidium
16. Docidium
17. Anthrodesmus
18. Dictyosphaeriaceae/Dictyosphaerium
19. Ulotriaceae/Ulothrix
20. Zygnemataceae/Spirogyra
21. Volvocaceae
22. Volvox
23. Pandorina
24. Hydrodictyaceae/Pediastrum
25. Protococcaceae/Protococcus
26. Coelastraceae/Coelastrum

(B) EUGLENOPHYCEAE

27. Euglenaceae
28. Phacus
29. Euglena
30. Peranemaceae/Urceolus

(C) BACILLARIOPHYCEAE

31. Naviculaceae
32. Frustulia
33. Pinnularia
34. Navicula
35. Fragilariaceae/Synedra

36

(D) MYXOPHYCEAE

36. Oscillatoriaceae
37. Spirulina
38. Phormidium
39. Rivulariaceae/Rivularia
40. Chroococcaceae
41. Merismopedia
42. Coelosphaerium
43. Nostocaceae
44. Anabaena
45. Nostoc

(D) XANTHOPHYCEAE

46. Xanthophyceae/Botryococcus
47. Tribonemataceae/Tribonema
48. Chlorothiciaceae/Ophiocytium

(F) DINOPHYCEAE

49. Ceratiaceae/Ceratium
50. Gymnodiaceae/Gymnodinium
51. Glenodiaceae/Glenodinium

TABLE - VI

Sl.No.	1979-80 OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	1980-81 OCT	NOV	DEC	JAN	FEB	MAR
(A)	6200	47853	12540	3480	13360	3547	12190	10380	6000	6540	11000	6240	1640	19440	16000	25320	1280	8795
1.	840	720	0	400	40	353	2240	500	0	1100	200	200	680	1520	0	9600	0	3495
2.	620	480	1580	300	800	584	6900	2420	6000	3280	4900	0	320	320	0	9600	0	3320
3.	620	0	1120	300	800	584	6780	2420	6000	3280	4900	0	0	0	0	9600	0	1400
4.	0	480	460	0	0	0	200	0	0	0	0	0	320	320	0	0	0	1920
5.	780	720	440	240	920	1179	580	1600	0	0	5000	1680	160	3600	3600	2120	0	40
6.	640	720	0	240	0	0	60	640	0	0	0	0	0	0	0	1600	0	0
7.	0	0	200	0	500	233	320	960	0	0	1000	240	160	3600	3600	520	0	40
8.	140	0	240	0	0	0	200	0	0	0	2000	1280	0	0	0	0	0	0
9.	0	0	0	0	180	280	0	0	0	0	1000	160	0	0	0	0	0	0
10.	0	0	0	0	240	666	0	0	0	0	1000	0	0	0	0	0	0	0
11.	1220	5000	1640	1000	3380	346	890	2360	0	460	900	240	480	3200	1600	0	0	400
12.	160	0	920	0	0	0	10	0	0	0	200	0	0	0	0	0	0	0
13.	160	5000	720	640	4060	73	600	700	0	360	700	40	320	640	0	0	0	160
14.	140	0	0	360	320	273	250	1660	0	100	0	200	0	1600	1600	0	0	0
15.	0	0	0	0	0	0	0	0	0	0	0	0	160	960	0	0	0	0
16.	760	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17.	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	240
18.	0	0	0	0	600	146	0	0	0	0	0	0	0	0	0	0	0	0
19.	260	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20.	420	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21.	160	280	360	0	900	720	0	0	0	200	0	2720	0	0	0	1600	0	420
22.	160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1600	0	0
23.	0	280	360	0	900	720	0	0	0	200	0	2720	0	0	0	0	0	420
24.	760	6400	460	760	5720	219	1520	2500	0	1500	0	0	0	10800	10800	6400	1280	1120
25.	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0
26.	1140	34253	8020	780	0	0	10	0	0	0	0	1400	0	0	0	0	0	0
(B)	2240	0	200	0	400	386	1710	2740	3200	1860	4900	0	280	10720	10400	11200	1840	1390
27.	1860	0	200	0	200	386	1710	2740	0	1620	4900	0	280	7520	7200	11200	760	1390
28.	1140	0	40	0	200	146	430	1060	0	120	2800	0	280	320	0	3600	0	1100
29.	720	0	160	0	0	240	1280	1680	0	1500	2100	0	0	7200	7200	7600	760	290
30.	380	0	0	0	200	0	0	0	3200	240	0	0	0	3200	3200	0	1080	0
(C)	0	3480	1800	0	40	292	50	0	6000	340	2600	400	240	52880	4800	2400	1360	60
31.	0	3480	1800	0	40	292	50	0	6000	340	2600	400	240	52880	3200	2400	680	60
32.	0	0	800	0	40	219	0	0	0	0	0	0	0	0	1600	2400	0	0
33.	0	0	0	0	0	0	0	0	0	0	1600	0	0	1600	0	0	0	0
34.	0	3480	1000	0	0	73	50	0	6000	340	1000	400	240	51280	0	0	0	60
35.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1600	0	680	0
(D)	2820	2080	12640	680	1976	1398	2200	0	10000	4040	14000	10840	0	0	0	7600	0	1140
36.	600	0	10200	240	800	0	0	0	0	0	3700	0	0	0	0	0	0	0
37.	600	0	10000	240	800	0	0	0	0	0	3700	0	0	0	0	0	0	0
38.	0	0	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39.	0	0	0	0	1040	0	0	0	0	0	0	6240	0	0	0	0	0	0
40.	2220	2080	1920	0	136	1398	2200	0	10000	4040	8400	4600	0	0	0	7600	0	1140
41.	1440	400	0	0	0	440	1040	0	6000	2520	4100	0	0	0	0	7600	0	0
42.	780	1680	1920	0	136	1158	1160	0	4000	1520	4300	4600	0	0	0	0	0	1140
43.	0	0	520	440	0	0	0	0	0	0	1900	0	0	0	0	0	0	0
44.	0	0	360	440	0	0	0	0	0	0	1900	0	0	0	0	0	0	0
45.	0	0	160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(E)	2860	880	920	1000	2040	360	0	0	3200	0	4300	1760	360	3280	0	6800	0	180
46.	2460	0	920	1000	2040	360	0	0	3200	0	4300	0	0	0	0	3200	0	180
47.	240	0	0	0	0	0	0	0	0	0	0	0	360	3280	0	3600	0	0
48.	160	880	0	0	0	0	0	0	0	0	0	1760	0	0	0	0	0	0
(F)	6300	6120	11020	2320	4840	313	200	0	16800	1000	0	320	560	1120	3200	10400	0	0
49.	2520	0	1900	860	600	313	200	0	7200	120	0	320	560	1120	0	5200	0	0
50.	3780	5280	8720	1460	4200	0	0	0	7200	840	0	0	0	0	3200	5200	0	0
51.	0	840	480	0	40	0	0	0	2400	40	0	0	0	0	0	0	0	0
TOTAL :	20420	60432	39120	7480	22656	6296	16350	13120	45200	13780	36800	19560	3080	87440	34400	63720	4480	11565

The family Desmidiaceae recorded peaks of abundance in the month of November during both the cycles representing 5,000 units/litre and 3,200 units/litre respectively. A minimum record of 240 units/litre and 400 units/litre were registered in September and March during the first and second cycles respectively.

The family Dictyosphaeriaceae was recorded only in the months of February and March during both the cycles.

The families Ulotricaceae and Zygnemataceae were also present only in the months of October and December during the entire period of study. The family Volvocaceae recorded peaks of abundance in September recording 2,720 units/litre and a minimum in October with 160 units/litre during the first annual cycle. In the next cycle January and March were the only months it was recorded.

The family Hydrodictyaceae revealed a maximum in November with 6,400 units/litre and a minimum in March with 219 units/litre during the first annual cycle. In the next cycle November and December recorded a maximum peak with 10,800 units/litre and a minimum in March with 1,120 units/litre. The family Protococcaceae was recorded only in April with 50 units/litre during both the cycles. The family Coelastraceae in the first cycle, revealed a peak of abundance in November with 34,253 units/litre and recorded a minimum in April with 10 units/litre and was totally absent during the second cycle (Table-VI).

Under the family Scenedesmaceae, <u>Scenedesmus</u> and <u>Actinastrum</u> were represented. <u>Scenedesmus</u> constituted the second largest form and recorded maximal peak in April (6,700 units/litre) and showed nil values in November and September during the first cycle. In the second cycle it occurred only on two occasions, January and March (9,600 units/litre) and (1,400 units/litre). The genus <u>Actinastrum</u> was represented very infrequently in November, December and April, with

November being the maximum (480 units/litre). Similarly during the second cycle, November, December and March recorded their presence, with March as the maximum with 1,920 units/litre.

The family Oocystaceae was represented by five genera, Ankistrodesmus, Tetraedron, Selenastrum, Cerasterias and Pachycladon. Of these genera, Tetraedron was the dominant genus which revealed a peak of abundance in August recording nearly 1,000 units/litre and a minimum of 200 units/litre in December. They were absent in October, November, January, June and July during the first cycle. During the second cycle, two equal peaks of abundances were registered in November and December both with 3,600 units/litre which was followed by a fall in March recording only 40 units/litre and was absent in February. The genus Ankistrodesmus occurred more during the first cycle than that of the second cycle. The peak of abundance was in November recording 720 units/litre which fell to 60 units/litre in April during the first cycle. January was the only month to register their presence throughout the second cycle. Selanostrum also had a similar trend of fluctuation with August registering the maximal peak of 2,000 units/litre and a minimum of 140 units/litre in October. During the second cycle they were totally absent. The genus Cerasterias and Pachycladon revealed peaks of nearly 1,000 units/litre in August during the first annual cycle and was totally absent during the second cycle.

The family Desmidiaceae was represented by Cosmarium, Closterium, Staurastrum, Desmidium, Docidium and Anthrodesmus. Of these genera, Closterium formed the largest number under this family with November showing the maximal peak of 5,000 units/litre and a smaller peak in February with 4,060 units/litre. This fell to a minimum of 40 units/litre in September and was absent in June during the first annual cycle. During the second cycle it steadily increased again to touch a peak (640 units/litre) in November and then recorded nil values, only to appear again in March with 160 units/litre. Staurastrum also had a similar trend of fluctuation with May recording maximum of 1,660 units/litre which declined to 100 units/litre in July during the first annual cycle. However, in the second cycle it registered two subsequent counts of 1,600 units/litre in November and December. Cosmarium was present only in October, December, April and August with the month of December showing a peak of abundance of 920 units/litre and the minimum with 10 units/litre in April. During the second cycle they were totally absent from this system. The genera Docidium and Anthrodesmus occurred on single occasions in October and April recording 760 units/litre and 30 units/litre respectively. The genus Anthrodesmus reappeared again in March recording 240 units/ litre during the end of the second cycle. Pandorina was found to occur infrequently and the month of September recorded a maximum with 2,720 units/litre and registered again only in March with 420 units/ litre during both the cycles. Volvox was registered only in October and January during the first and second cycles (Table-VI).

The next class after Chlorophyceae was Euglenophyceae which registered a maximal peak of abundance in August recording 4,900 units/litre and nil values in November and January. During the second cycle, however, they were present throughout the period with January and October recording the maximum and minimum abundance with 11,200 units/litre and 280 units/litre respectively (Table-VI).

When the class Euglenophyceae was seen in relation to their relative percent abundance among other classes, the month of May of the first cycle recorded 20.9% as maximum though numerically they constituted a very low count in comparison to the peak month of August which showed only 13.3%. Similarly the month of December showed a relative percent abundance of 30.2% while the peak value recorded in January revealed only 17.6%. The minimum percent abundance was recorded in December with 0.5% and October with 9.2% during the first and second cycles respectively (Fig. 6).

Under the class Euglenophyceae two families were represented, Euglenaceae by the genera Phacus and Euglena and Peranemaceae by a single genus Urcoelus. Of these genera, Euglena constituted the major bulk under this class. The family Euglenaceae recorded maximum peak of abundance in August with 4,900 units/litre and a minimum in December with 200 units/litre during the first annual cycle. In the next cycle, a peak was recorded in January with 11,200 units/litre and a minimum in October with 280 units/litre. The family Peranemaceae with its single genus Urcoelus recorded peaks of abundance in June with 3,200 units/litre and a minimum in February with 200 units/litre during the first annual cycle. In the second cycle two equal peaks were recorded in November and December registering nearly 3,200 units/litre (Table-VI). The genus Phacus recorded peaks of abundance in August and January with 2,800 units/litre and 3,600 units/litre respectively during the first and second cycles. They were absent in November, January, June and September during the first cycle and in December and February in the second cycle. Euglena revealed a peak in August registering 2,100 units/litre and a minimum in December with 160 units/litre and was absent in November, January, February, June and September during the first annual cycle. In the next cycle a peak was registered in January with 7,600 units/litre and nil in October (Table-VI).

Bacillariophyceae was the next class found in this experimental fish pond which showed a maximal peak of abundance in June recording 6,000 units/litre and February recorded the minimum of 40 units/litre. It was absent in October, January and May during the first cycle. In the next cycle they were present throughout the period of investigation. The month of November registered the maximal peak of 52,880 units/litre which then steadily decreased in number till March to record only 60 units/litre as the minimum (Table-VI). When the class Bacillariophyceae was observed for their relative percent abundance it followed more or less a similar pattern to their actual numbers. For both the cycles the months of June and November recorded 13.2% and 60.5% as maximum and in February (0.2%) and March 0.6% as minimum respectively (Fig. 6).

Bacillariophyceae consisted of two families Naviculaceae represented by three genera, Frustulia, Pinnularia and Navicula and the family Fragillariaceae by a single genus Synedra. The family Naviculaceae recorded peaks of abundance in June with 6,000 units/litre and in November with 52,880 units/litre during the first and second cycles. A minimum of 50 units/litre was recorded in April and 40 units/litre in February during both the cycles respectively. The family Fragillariaceae was totally absent during the first annual cycle and recorded their presence only in December and February of the second cycle. The maximal peak observed in June was constituted solely by the genus Navicula and so was the case for the peak of November as seen during the first and second cycles (Table-VI).

Frustulia occurred only in December, February and March during the first cycle with December recording the maximum of 800 units/litre In the second cycle, January recorded the maximal peak of abundance with 2,400 units/litre and a minimum of 1,600 units/litre in December. The genus Pinnularia occurred once in both the cycles, in August and November (Table-VI).

Myxophyceae was the next class which revealed a peak of abundance (12,640 units/litre) in December and recorded nil value in May. The following month, June then showed a smaller peak with nearly

10,000 units/litre which decreased the following month to rise again to register the highest peak in August with 14,000 units/litre during the first annual cycle. During the second cycle they appeared only in January with 7,600 units/litre and March with 1,140 units/litre (Table-VI). When their relative percent abundance was calculated in relation to the other six classes encountered in this pond, the class revealed a maximum of 55.4% in September and January with 11.9% during the first and second cycles. The relative percent abundance of this class followed a more or less similar pattern as to their actual numbers during the second cycle (Fig. 6). The class Myxophyceae consisted of four families, Oscillatoriaceae represented by two genera, Spirulina and Phormidium; Rivulariaceae by a single genus Rivularia, Chrooccoceae by two genera, Merismopedia and Coelosphaerium and finally Nostocaceae by two genera Anabaena and Nostoc. Spirulina revealed a peak of abundance in December with 10,000 units/litre and recorded their presence only in October, January, February and August while the remaining periods they were totally absent. Phormidium on the other hand occurred only in December recording 120 units/litre. Rivularia occurred in February with 1,040 units/litre and September with 6,240 units/litre and was absent for the other periods of investigation. The genera Merismopedia and Coelosphaerium constituted the major bulk of phytoplankton of this class Myxophyceae. Merismopedia showed a peak of abundance in June with 6,000 units/litre and a smaller peak in August with 4,100 units/litre. November recorded a minimum of 400 units/litre and was absent in December, January, February, May and September. Coelosphaerium recorded a maximum peak in September with 4,600 units/litre and a smaller peak prior to the maximal peak in August with 4,300 units/litre and February recorded the minimum of 136 units/litre. Anabaena occurred only in December, January and August and was absent otherwise, with August recording as the maximum with 1,900 units/litre. Finally Nostoc occurred only in December with 160 units/litre (Table-VI).

The class Xanthophyceae recorded a maximum peak of abundance in August registering 4,300 units/litre and recorded nil values in April, May and July though the lowest minimal record was in March with 360 units/litre during the first annual cycle. During the second cycle a peak of 6,800 units/litre was obtained in January and recorded nil values in December and February, and March recorded only 180 units/litre (Table-VI).

When this class was seen for their relative percent abundance, October registered 13.8% despite being numerically lower than the peak counts of August which revealed only 11.6% and so was the case with October showing 11.6% higher than the maximal peak registered for the month of January with only 10.6%. The minimum was in November (1.5%) and March (1.6%) during the first and second cycles (Fig. 6).

The class Xanthophyceae consisted of three families in this pond. The families were Xanthophyceae represented by genus Botryococcus Tribonemataceae by Tribonema and Chlorothiaciaceae by Ophiocytium. The family Xanthophyceae recorded a peak of maximum abundance in August with 4,300 units/litre and recorded a minimum of 360 units/litre in March during the first annual cycle. In the second cycle January recorded a peak with 3,200 units/litre and a minimum in March with 180 units/litre and was absent in October, November, December and February. The family Tribonemataceae was recorded only once in October with 240 units/litre during the first annual cycle. In the next cycle a peak of abundance was recorded in January with 3,600 units/litre and a minimum in October with 360 units/litre and was absent in the months of December, February and March. The family Chlorothiaciaceae was recorded in September with 1,760 units/litre during the first annual cycle and in the next cycle disappeared from the system entirely. As each family had only one genus each, they followed the similar trends of fluctuation as the family (Table-VI).

The class Dinophyceae revealed a peak of abundance in June recording 16,800 units/litre and April recording minimal count of 200 units/litre. They were absent in May and August during the first annual cycle. During the second cycle January revealed the maximum with 10,400 units/litre and October as the minimum with 560 units/litre. It was recorded nil in February and March (Table-VI).

When the relative percent abundance was seen, the first annual cycle followed more or less a trend similar to their actual numbers. The peak month revealing 37.2% abundance and April as the minimum with only 1.3%. In the second cycle, however, October showed 18.2% abundance higher to that of the maximal peak of January which recorded only 16.4%, and the minimum in November with 1.4% (Fig. 6).

The class Dinophyceae consisted of three families, Ceratiaceae represented by Ceratium, Gymnodiaceae by Gymnodinium and Glenodiaceae by Glenodinium. The family Ceratiaceae revealed peaks of abundance in June recording 7,200 units/litre and a minimum in July with 120 units/litre and was absent in November, May and August during the first annual cycle. In the next cycle, January recorded the maximum representing 5,200 units/litre and October with 560 units/litre as the minimum and was absent in December, February and March. The family Gymnodiaceae revealed a peak in December with 6,720 units/litre and a minimum in July with 840 units/litre during the first annual cycle. In the second cycle, it was recorded only in December and January recording 3,200 units/litre and 5,200 units/litre respectively. The family Glenodiaceae had a peak of abundance in June with 2,400 units/litre and a minimum in February and July recording 40 units/litre and was absent for seven months during the first annual cycle. During the second cycle, it disappeared entirely, As these families had one genus each, they followed a similar trend of fluctuation to that of the family (Table-VI).

The total phytoplankton in this system followed a winter maxima and spring, and autumn minima (Table-VI).

PHYTOPLANKTON : CIRCULAR PLASTIC POOLS

Phytoplankton encountered in all the five circular plastic pools irrespective of their fertilization were also constituted of six classes:- Chlorophyceae, Euglenophyceae, Bacillariophyceae, Xanthophyceae, Dinophyceae and Myxophyceae.

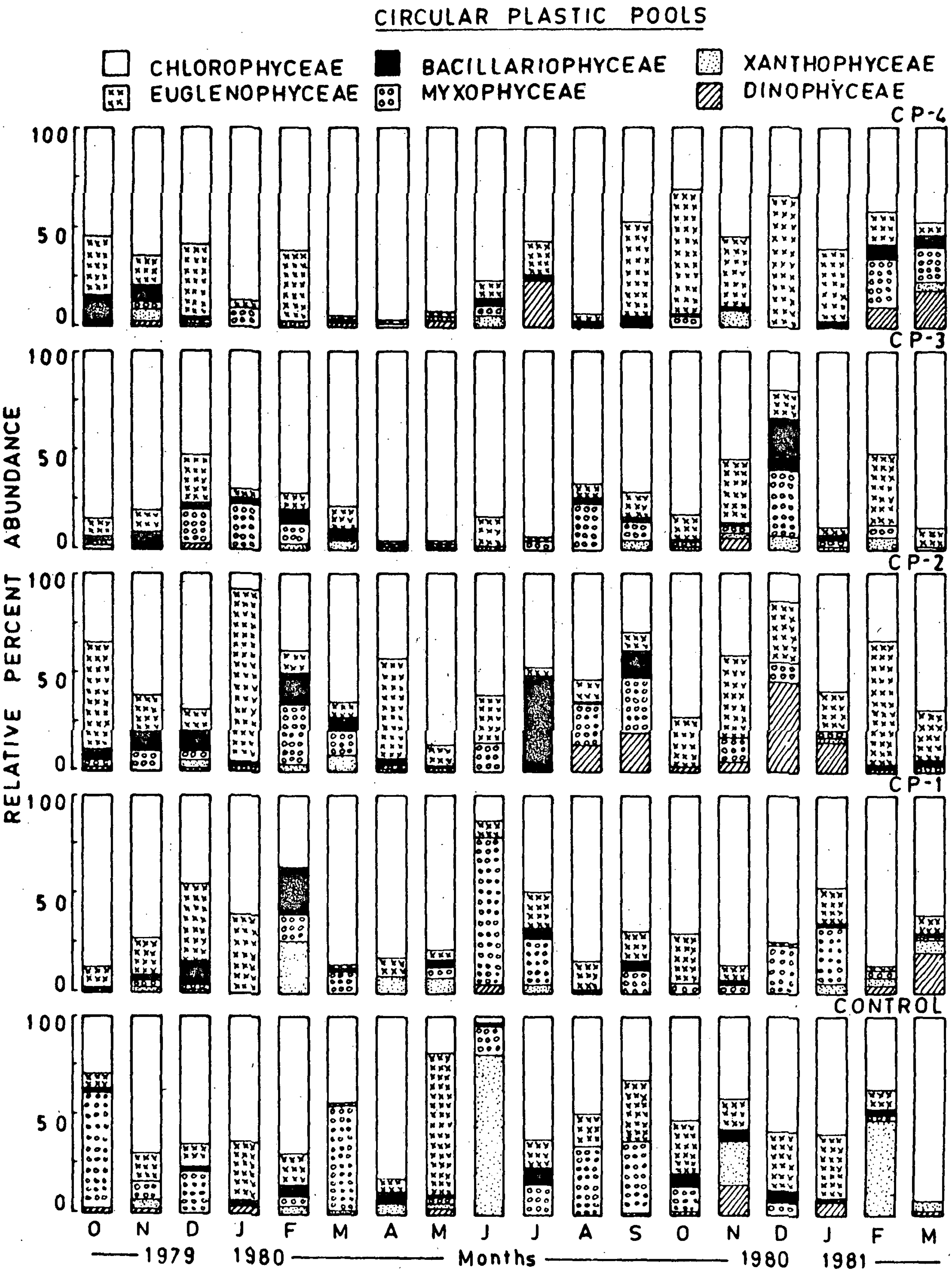
CONTROL POOL : In the control pool the class Chlorophyceae was encountered as the most dominant and was predominantly represented by two genera Chlamydomonas and Pediastrum. The class Chlorophyceae during the first annual cycle recorded a maximum peak of abundance in September registering 30,440 units/litre and a smaller peak in March with 27,761 units/litre and December recorded the minimum with 580 units/litre. During the second cycle, October registered a peak with 14,800 units/litre and a smaller peak in January with 10,100 units/litre, while the subseq ent month of February recorded a minimum of 3,240 units/litre.

When the relative percent abundance of the class was seen in relation to the other classes it showed a maximum of 69.4% in November, though individual counts obtained in September was much higher, which recorded only 32.2%. The minimum of 2.8% was recorded in June, during the first annual cycle. In the next cycle March revealed a maximum of 92.0% while the peak month of October registered only 51.0% and the minimum was recorded in February with 37.2% abundance (Fig. 7).

The class Chlorophyceae in this control pool was constituted by nine families and sixteen genera. The family Chlamydomonaceae with its single genus Chlamydomonas recorded a peak of abundance in September representing 29,600 units/litre and a minimum in December recording only 60 units/litre and was absent in April and June

Fig. 7 - Showing histograms representing the seasonality of the relative percent abundance of the major phytoplanktonic groups in the Control and Circular Plastic Pools.

CP = Circular Plastic Pools.



CIRCULAR PLASTIC POOLS
CHLOROPHYCEAE
BACILLARIOPHYCEAE
XANTHOPHYCEAE
EUGLENOPHYCEAE
MYXOPHYCEAE
DINOPHYCEAE
CP-4
CP-3
CP-2
CP-1
CONTROL
RELATIVE PERCENT ABUNDANCE
100
50
0
O N D J F M A M J J A S O N D J F M
1979 1980 Months 1980 1981

during the first annual cycle. In the next cycle January and February recorded the maximum and minimum with 5,900 units/litre and 300 units/litre respectively and was absent in November and March.

The family Scenedesmaceae was represented by two genera, Scenedesmus and Actinastrum, both of which recorded their peaks of abundance in July, recording 3,360 units/litre and 1,760 units/litre respectively in the first annual cycle. The genus Scenedesmus revealed a minimum of 100 units/litre in October and Actinastrum in December with only 40 units/litre during the first annual cycle. In the next cycle Scenedesmus recorded a maximum in October with 3,200 units/litre and Actinastrum in December with 400 units/litre. The former recorded a minimum of 710 units/litre and the latter with 50 units/litre both in March.

The family Oocystaceae recorded a peak of abundance in November with 3,320 units/litre and was absent in the months of May, June, August and September during the first annual cycle. January of the second cycle revealed a maximum density of 2,300 units/litre and was absent in February. The family was represented by four genera, Tetraedron, Ankistrodesmus, Selenastrum and Pachycladon. Tetraedron revealed maximum densities in November and January recording 3,180 units/litre and 2,300 units/litre during the first and second cycles respectively. The months of December and March recorded the minimum with 260 units/litre and 150 units/litre respectively. Pachycladon recorded two equal peaks in January and November with 200 units/litre during the first and second cycles respectively and was absent from March to October and December to March during both the cycles. Selenastrum recorded peaks of abundance in April with 1,480 units/litre and with 1,200 units/litre in October during the first and second cycles respectively. The months of December with 20 units/litre and in March with 660 units/litre revealed the minimum counts during the first and second cycles. The genus <u>Ankistrodesmus</u> was recorded only in the months of October and March during the first annual cycle . In the next cycle it was present in March only.

The family Desmidiaceae was represented by the genera <u>Closterium</u>, <u>Staurastrum</u> and <u>Cosmarium</u>. The family revealed peaks of abundance in November and October recording 2,760 units/litre and 3,000 units/litre during the first and second cycles respectively. The month of December registered the minimum with 80 units/litre and November with 500 units/litre during both the cycles.

The genus <u>Closterium</u> revealed a peak in November recording 2,100 units/litre and a minimum in December with 20 units/litre and was absent in February, March, June, July and September during the first annual cycle. In the next cycle a maximum of 1,200 units/litre was registered in October and a minimum of 200 units/litre in November and absent in December. <u>Staurastrum</u> recorded peaks of abundance in July with 1,760 units/litre and October with 1,800 units/litre during the first and second cycles respectively. A minimum of 60 units/litre and 300 units/litre was recorded in December and November during both the cycles. <u>Cosmarium</u> was recorded only in November with 180 units/litre and was absent during the rest of the investigation period of both the cycles.

The family Ulotricaceae represented by a single genus <u>Phormidium</u> was recorded only in November with 240 units/litre and 400 units/litre during the first and second cycles. It was absent during the other months of both the cycles.

The family Hydrodictyaceae was also represented by a single genus <u>Pediastrum</u>. It revealed a maximum of 2,320 units/litre in February and a minimum of only 60 units/litre in December during the first annual cycle and was absent in October and August. In the second cycle January recorded a peak with 1,100 units/litre and February and March recorded the minimum with 300 units/litre and was absent in October and November.

The family Volvocaceae represented by a single genus Pandorina was recorded only in September with 4,720 units/litre and in March with 600 units/litre.

The family Coelastraceae had a single genus Coelastrum recorded only in October with 720 units/litre and was absent during the other months of both the cycles (Table-VII).

The class Euglenophyceae recorded a peak of abundance in May representing 58,240 units/litre and in December with only 100 units/litre as the minimum during the first annual cycle. In the next cycle the months of October and February recorded the maximum and minimum with 8,400 units/litre and 960 units/litre respectively. They were absent in June and March during both the cycles (Table-VII).

The relative percent abundance of this class revealed a maximum and minimum in May with 75.9% and in March with 0.6% during the first annual cycle. In the next cycle December and February recorded the maximum and minimum with 36.8% and 11.2% respectively (Fig. 7).

The class Euglenophyceae comprised of two families, Euglenaceae and Peranemaceae. The family Euglenaceae recorded a peak in May representing 57,480 units/litre and a minimum in December representing 100 units/litre and was absent in June during the first annual cycle. In the second cycle October and February recorded the maximum and minimum registering 5,300 units/litre and 960 units/litre respectively and was absent in March. The genus Euglena recorded a maximum of 5[illegible],920 units/litre in May and a minimum with 40 units/litre in December and was absent in June during the first annual cycle.

TABLE-VII

Seasonal abundance of phytoplankton, their classes, families, respective genera and the total phytoplankton (units/litre) in the Control pool.

(A) CHLOROPHYCEAE

1. Chlamydomonaceae/Chlamydomonas
2. Scenedesmaceae
3. Scenedesmus
4. Actinastrum
5. Oocystaceae
6. Ankistrodesmus
7. Tetraedron
8. Pachycladon
9. Selenastrum
10. Desmidiaceae
11. Closterium
12. Cosmarium
13. Staurastrum
14. Ulotricaceae/Hormidium
15. Hydrodictyaceae/Pediastrum
16. Volvocaceae/Pandorina
17. Coelastraceae/Coelastrum
18.

(B) EUGLENOPHYCEAE

18. Euglenaceae
19. Euglena
20. Phacus
21. Trachelomonas
22. Peranemaceae/Urceolus

(C) BACILLARIOPHYCEAE

23. Naviculaceae
24. Navicula
25. Frustulia
26. Fragillariaceae/Synedra

(D) MYXOPHYCEAE

27. Oscillatoriaceae
28. Phormidium
29. Spirulina
30. Chroococcaceae
31. Merismopedia
32. Coelosphaerium
33. Nostocaceae/Nostoc

(E) XANTHOPHYCEAE

34. Xanthophyceae/Botryococcus
35. Tribonemataceae/Tribonema
36

(F) DINOPHYCEAE

36. Ceratiaceae/Ceratium
37. Gymnodiaceae/Gymnodinium

TABLE - VII

	1979-80												1980-81					
Sl.No.	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
(A)	5860	7840	580	1820	7800	27761	13520	13680	1600	12960	1840	30440	14800	3800	4900	10100	3240	3900
1.	800	160	60	380	920	27200	0	8840	0	2960	320	29680	6600	0	2400	5900	300	0
2.	660	1280	40	0	3600	0	10400	1720	0	5120	680	440	3200	2700	400	0	1800	760
3.	100	1280	0	0	2720	0	10400	1720	0	3360	960	440	3200	2700	0	0	1800	710
4.	560	0	40	0	880	0	0	0	0	1760	320	0	0	0	400	0	0	50
5.	2680	3320	340	960	640	320	1480	0	0	1440	0	0	2000	200	700	2300	0	1770
6.	300	0	0	0	0	320	0	0	0	0	0	0	0	0	0	0	0	960
7.	2180	3180	260	960	640	0	0	0	0	1440	0	0	300	0	700	2300	0	150
8.	100	140	60	200	0	0	0	0	0	0	0	0	0	200	0	0	0	0
9.	100	0	20	200	0	0	1480	0	0	0	0	0	1200	0	0	0	0	660
10.	1800	2760	80	100	820	0	440	1040	0	1760	640	480	3000	500	700	800	840	910
11.	400	2100	20	100	80	0	440	720	0	0	400	0	1200	200	0	800	840	910
12.	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13.	600	480	60	0	320	0	0	320	0	1760	240	400	1800	300	700	0	0	0
14.	0	240	0	0	0	0	0	0	0	0	0	0	0	400	0	0	0	0
15.	0	80	60	380	2320	241	1200	2080	1600	2080	0	1200	500	0	700	1100	300	300
16.	0	0	0	0	0	0	0	0	0	0	0	4720	0	0	0	0	0	600
17.	720	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(B)	1980	1420	100	820	1800	400	1040	58240	0	2940	560	30960	8400	9500	3500	5900	960	0
18.	1480	1180	100	340	1800	400	1040	57400	0	3040	560	30960	6800	800	3200	5300	960	0
19.	1800	280	40	220	720	160	720	56920	0	1280	560	29600	2400	0	2300	1980	320	0
20.	300	900	60	120	920	240	320	560	0	1860	0	1360	3600	800	900	3400	640	0
21.	0	0	0	0	560	0	0	0	0	0	0	0	0	0	0	0	0	0
22.	100	240	0	480	0	0	0	760	0	0	0	0	2400	700	300	600	0	0
(C)	400	0	20	100	600	0	1000	560	900	1760	0	240	1200	500	600	300	100	0
23.	400	0	20	100	600	0	560	560	900	1760	0	240	1200	500	600	300	100	0
24.	0	0	20	100	680	0	560	560	900	1760	0	240	0	300	0	0	100	0
25.	400	0	0	0	0	0	0	0	0	0	0	0	1200	200	600	300	0	0
26.	0	0	0	0	0	0	440	0	0	0	0	0	0	0	0	0	0	0
(D)	12080	1000	200	0	640	3480	0	3440	7400	3920	1360	32200	3800	0	500	0	110	0
27.	100	280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	110	0
28.	100	280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	110	0
30.	1680	720	200	0	640	0	0	880	3000	3520	1360	0	2400	0	300	0	0	0
31.	960	720	200	0	0	0	0	0	0	2240	480	0	0	0	300	0	0	0
32.	720	0	0	0	640	0	0	880	3000	1280	880	0	2400	0	0	0	0	0
33.	10300	0	0	0	0	34800	0	2560	4400	0	0	32200	1400	0	200	0	0	0
(E)	100	540	0	0	520	160	960	520	46000	0	0	480	0	2100	0	0	4300	200
34.	0	540	0	0	520	0	880	520	46000	0	0	480	0	2100	0	0	4300	200
35.	100	0	0	0	0	160	80	0	0	0	0	0	0	0	0	0	0	0
(F)	0	500	0	100	0	0	0	240	0	0	0	0	800	1400	0	700	0	110
36.	0	340	0	100	0	0	0	0	0	0	0	0	0	1400	0	700	0	110
37.	0	160	0	0	0	0	0	240	0	0	0	0	800	0	0	0	0	0
TOTAL :	20020	11300	900	2040	11360	63121	16520	78680	55500	21280	3760	94320	29000	9300	9500	17000	8110	4210

In the next cycle October and February recorded the maximum and minimum representing 2,400 units/litre and 320 units/litre respectively and was absent in November and March. The genus Phacus recorded a peak in July with 1,760 units/litre and a minimum in December with only 60 units/litre during the first annual cycle and was absent in June. In the next cycle the maximum and minimum counts were recorded in October and February representing 3,600 units/litre and 640 units/litre respectively and was absent in March. Trachelomonas was recorded only in February with 560 units/litre and was absent during both the cycles.

The family Peranemaceae with a single genus Urcoelus recorded a maximum peak of abundance in May recording 760 units/litre and a minimum in October with 100 units/litre and was absent in December, February to April, June to September during the first annual cycle. The next cycle, October and December recorded the maximum and minimum representing 2,400 units/litre and 300 units/litre respectively and was absent in February and March (Table-VII).

The next class Bacillariophyceae recorded peaks of abundance in July registering 1,760 units/litre and in October with 1,200 units/litre during the first and second cycles. The months of December with 20 units/litre and February with 100 units/litre were recorded as the minimum during the first and second cycles and absent in November, March, August and March during both the cycles (Table-VII).

The relative percent abundance of the class was recorded maximum in July with 8.3% and a minimum in May with 0.7% during the first annual cycle. In the next cycle the maximum and minimum were recorded in December and February with 6.3% and 1.2% respectively (Fig.7).

This class Bacillariophyceae was comprised of two families, Naviculaceae and Fragillariaceae. The family Naviculaceae recorded a peak in July representing 1,760 units/litre and a minimum of 20 units/litre in December and was absent in the months of November, March and August during the first annual cycle. In the next cycle a maximum peak of abundance was recorded in October with 1,200 units/litre and a minimum in December with 100 units/litre and was absent in March. The family Naviculaceae comprised of two genera of which Navicula recorded a peak in July with 1,760 units/litre and a minimum in December with 20 units/litre and was absent in October, November, March and August during the first annual cycle. In the next cycle it was recorded only in November and February. Frustulia was present only in October during the first annual cycle. In the next cycle it recorded a maximum of 1,200 units/litre in October, and November as the minimum with 200 units/litre and was absent in February and March. The family Fragillariaceae with a single genus Synedra was recorded only once in April with 440 units/litre (Table-VII).

The class Myxophyceae comprised of three families and five genera. It recorded a peak in March registering 34,800 units/litre and a minimum in December with 200 units/litre and was absent in January and April during the first annual cycle. In the next cycle October recorded the peak with 3,800 units/litre and February as the minimum with 110 units/litre and was absent in November, January and March (Table-VII).

When the class Myxophyceae was seen with respect to their relative percent abundance it recorded a maximum of 60.3% in October and 4.6% in May as the minimum during the first annual cycle. In the next cycle October registered 13.2% as the maximum and February as the minimum with only 1.3% (Fig. 7).

The family Oscillatoriaceae was represented by two genera, Phormidium and Spirulina. The genus Phormidium was recorded only in October with 100 units/litre and in November with 280 units/litre

Similarly *Spirulina* was recorded only in February with 110 units/litre. The family Chroococcaceae represented by two genera, *Coelosphaerium* and *Merismopedia* recorded peaks of abundance in July registering 3,520 units/litre and in October with 2,400 units/litre during the first and second cycles. Their minimum was recorded in the months of December representing 200 units/litre and 300 units/litre respectively. The genus *Merismopedia* revealed a peak in July recording 2,240 units/litre and a minimum in December with 200 units/litre and was absent from January to June and September during the first annual cycle. In the next cycle it was found only in December with 300 units/litre. The genus *Coelosphaerium* recorded a peak in June of 3,000 units/litre and a minimum in February with 640 units/litre and was absent from November to January, March, April and September during the first annual cycle. In the next cycle it was recorded only in October with 2,400 units/litre.

The family Nostocaceae represented by a single genus *Anabaena* recorded a peak in March registering 34,800 units/litre and a minimum in May with 2,560 units/litre and was absent for eleven months during both the cycles (Table-VII).

The class Xanthophyceae recorded peaks of abundance in June registering 46,000 units/litre and in February with 4,300 units/litre during the first and second cycles. It recorded minimum counts in October with 100 units/litre and 200 units/litre during both the first and second cycles respectively and was absent for seven months during both the cycles (Table-VII).

When the relative percent abundance of the class Xanthophyceae was observed, the months of June and February recorded the maximum with 82.8% and 49.3% respectively during the first and second cycles. The minimum was seen in March with 0.2% and again in March with 4.8% during both the cycles (Fig. 7).

The family Xanthophyceae represented by a single genus Botryococcus recorded a maximum peak of abundance in June with 46,000 units/litre and a minimum in October representing 100 units/litre and was absent in the months of December, January, July, and August during the first annual cycle. In the second cycle February recorded the maximal peak with 4,300 units/litre and the minimum in March with 200 units/litre and was absent in October, December and January. The family Tribonemataceae with a single genus Tribonema was recorded in March and April and was absent during the remaining period of both the cycles (Table-VII).

The class Dinophyceae was sporadically represented. It recorded a maximum in November with 500 units/litre and a minimum in January with 100 units/litre and in May with 240 units/litre and was absent in the other months during the first annual cycle. In the next cycle November recorded ',400 units/litre as the maximum and March the minimum with 110 units/litre and was absent in December and February (Table-VII).

When the relative percent of the class was observed it recorded a maximum percent abundance in the months of June and February recording 82.8% and 49.3% respectively during the first and second cycles. The minimum was recorded in March with 0.2% and with 4.8% in the first and second cycles (Fig. 7).

The family Ceratiaceae and its single genus Ceratium was recorded in November and January with 340 units/litre and 100 units/litre and was absent otherwise, during the first annual cycle. In the next cycle November registered 1,400 units/litre and March with 110 units/litre and was absent in October, December and January. The family Gymnodiaceae with its single genus Gymnodinium was present only in November with 160 units/litre and May with 240 units/

litre. During the second cycle October was the only month to record their presence with 800 units/litre.

When the total phytoplankton was observed for its seasonal trend of fluctuation irrespective of the genera present under them, it revealed a summer maxima and winter minima (Table-VII).

CIRCULAR PLASTIC POOL-1

The most dominant class of Phytoplankton encountered in this pool-1 was also Chlorophyceae. It had a small peak in October, then registered a gradual fall the following month and increased again to touch a maximal peak in March recording 72,360 units/litre and thereafter recorded the minimal in June representing 180 units/litre during the first annual cycle. In the next cycle the individual counts were more or less predominantly on the higher side with December recording 30,720 units/litre as maximum (Table-VIII).

When the class Chlorophyceae was analysed for their relative percent abundance, during the first annual cycle, October recorded a maximum of 87.4% while the peak month recorded only 85.3% and a minimum was observed in June representing 13.7%. During the second cycle February recorded the maximum with 87.2% while the peak month revealed only 74.8% and the minimum was in January recording 46.2% abundance (Fig. 7).

The class Chlorophyceae in this pool-1 was represented by ten families comprising of fifteen genera. The family Chlamydomonaceae represented by a single genus Chlamydomonas revealed a peak of abundance in May and February recording 13,040 units/litre and 5,600 units/litre during the first and second cycles. The minimum was recorded in June representing 100 units/litre and March with 2,520 units/litre during the first and second cycles. The family Scenedesmaceae constituted the most dominant form in terms of abundance and occurrence in relation to all the other families. Two genera were represented under this family, Scenedesmus and Actinastrum and in particular Scenedesmus constituted the major bulk. The family Scenedesmaceae recorded peaks of abundance in March representing 67,560 units/litre and a minimum in January with 480 units/litre and was

TABLE-VIII

Seasonal abundance of phytoplankton their classes, families, respective genera and the total phytoplankton (units/litre) in the Circular Plastic Pool-1.

(A) CHLOROPHYCEAE

1. Chlamydomonaceae/Chlamydomonas
2. Scenedesmaceae
3. Scenedesmus
4. Actinastrum
5. Oocystaceae
6. Ankistrodesmus
7. Tetraedron
8. Selenastrum
9. Desmidiaceae
10. Closterium
11. Cosmarium
12. Staurastrum
13. Desmidium
14. Ulotricaceae/Ulothrix
15. Volvocaceae/Pandorina
16. Hydrodictyaceae/Pediastrum
17. Micratiniaceae/Micratinium
18. Coelostraceae/Coelastrum

(B) EUGLENOPHYCEAE

19. Euglenaceae
20. Euglena
21. Phacus
22. Peranemaceae/Urceolus

(C) BACILLARIOPHYCEAE

23. Naviculaceae
24. Navicula
25. Frustulia
26. Tabellariaceae/Tabellaria

(D) MYXOPHYCEAE

27. Oscillatoriaceae
28. Phormidium
29. Oscillatoria
30. Spirulina
31. Rivulariaceae/Rivularia
32. Chroococcaceae
33. Merismopedia
34. Polycistis
35. Coelosphaerium
36. Nostocaceae
37. Nostoc
38. Anabaena

(E) XANTHOPHYCEAE

39. Xanthophyceae/Botryococcus
40. Tribonemataceae/Tribonema
41. Chlorothiciaceae/Ophiocytium

(F) DINOPHYCEAE

42. Ceratiaceae/Ceratium

TABLE - VIII

Sl.No.	1979-80												1980-81					
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
(A)	30380	25080	4400	860	5200	72360	6920	30200	180	11000	7380	9400	25200	23680	30720	12860	21520	10320
1.	660	2180	400	380	0	1640	1320	13040	100	1800	1300	1900	3600	4600	1840	5180	5600	2520
2.	23200	18020	0	480	3600	67560	1920	12360	0	2200	1680	2400	13400	8700	23700	6600	8800	2500
3.	23200	17580	0	480	3600	66600	1920	2360	0	2200	980	2200	13400	6300	23700	6600	5800	2500
4.	0	440	0	0	0	960	0	0	0	0	700	200	0	2400	0	0	0	0
5.	3020	2120	3200	0	1600	1640	0	3520	60	3000	1200	1900	4400	3680	1320	300	1840	3500
6.	1960	560	0	0	1600	520	0	1760	0	600	1200	700	2200	2200	520	0	1760	3500
7.	760	1560	3200	0	0	440	0	1760	60	0	0	900	2200	1200	240	300	0	0
8.	300	0	0	0	0	680	0	0	0	2400	0	300	0	280	560	0	80	0
9.	1660	1680	600	0	0	440	0	2450	20	1880	500	900	3800	1200	120	460	80	160
10.	1360	800	600	0	0	440	0	1640	20	80	500	400	1400	0	0	200	80	160
11.	0	0	0	0	0	0	0	0	0	0	0	200	0	0	0	0	0	0
12.	300	580	0	0	0	0	0	810	0	1800	0	300	2400	2200	120	260	0	0
13.	0	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14.	0	0	0	0	0	0	0	1280	0	0	0	0	0	0	0	40	0	0
15.	440	0	0	0	0	360	2360	2120	0	0	300	600	0	0	520	0	0	0
16.	600	1080	0	0	0	720	920	4895	0	2300	2400	1700	0	4900	3220	280	8200	1640
17.	0	0	0	0	0	0	0	440	0	0	0	0	0	0	0	0	0	0
18.	800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(B)	3600	6260	3800	560	0	1240	720	1880	90	4600	1300	2200	9000	1960	480	5100	120	1200
19.	3600	6100	3800	560	0	1240	720	1880	90	3800	1300	2000	9000	1960	480	5100	0	920
20.	2700	2520	800	340	0	880	720	1440	0	2400	1300	1100	2200	1960	160	3300	0	920
21.	600	3580	3000	220	0	360	0	440	90	1400	0	900	5800	0	320	1800	0	0
22.	300	160	0	0	0	0	0	0	0	800	0	200	0	0	0	0	120	280
(C)	560	580	1000	0	3600	360	0	1040	0	600	0	600	0	680	0	200	0	280
23.	560	580	1000	0	3600	360	0	1040	0	600	0	600	0	680	0	200	0	280
24.	560	280	1000	0	0	360	0	1040	0	0	0	200	0	600	0	200	0	280
25.	0	300	0	0	0	0	0	0	0	600	0	400	0	80	0	0	0	0
26.	0	0	0	0	3600	0	0	0	0	0	0	0	0	0	0	0	0	0
(D)	200	1280	400	0	1850	10840	0	1560	1012	5600	100	1600	1800	1080	9860	7960	1040	240
27.	0	300	400	0	0	480	0	0	0	0	0	300	1800	0	940	60	0	0
28.	0	0	400	0	0	0	0	0	0	0	0	300	0	0	0	0	0	0
29.	0	0	0	0	0	0	0	0	0	0	0	0	1800	0	0	0	0	0
30.	0	300	0	0	0	480	0	0	0	0	0	0	0	0	940	60	0	0
31.	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0
32.	200	0	0	0	1800	560	0	1560	180	2800	100	1300	0	0	1320	2600	360	0
33.	0	0	0	0	0	560	0	0	0	1600	100	800	0	0	1320	1000	360	0
34.	0	0	0	0	1800	0	0	0	0	0	0	0	0	0	0	0	0	0
35.	200	0	0	0	0	0	0	1560	180	1200	0	500	0	0	0	1600	0	0
36.	0	980	0	0	80	9800	0	0	802	2800	0	0	0	1080	7600	5300	680	240
37.	0	280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38.	0	700	0	0	50	9800	0	0	802	2800	0	0	0	1080	7600	9300	680	240
(E)	0	1400	0	0	3800	0	640	3280	0	1200	0	0	0	0	0	1700	1040	940
39.	0	0	0	0	3800	0	0	3280	0	1200	0	0	0	0	0	1700	720	940
40.	0	0	0	0	0	0	640	0	0	0	0	0	0	0	0	0	320	0
41.	0	1400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(F)	0	0	200	0	0	0	0	0	30	0	0	0	0	0	0	0	960	4000
42.	0	0	200	0	0	0	0	0	30	0	0	0	0	0	0	0	960	4000
TOTAL :	34740	34600	9800	1420	14450	84800	7880	37960	1312	23000	6780	13800	36000	27400	41060	27820	24680	16980

absent in December, June and July during the first annual cycle. The months of December and March during the second cycle recorded maximum and minimum with 23,700 units/litre and 2,500 units/litre respectively.

The genus Scenedesmus recorded a maximum in March representing 66,600 units/litre and a minimum with 480 units/litre in January during the first annual cycle. In the next cycle a peak was registered in December with 23,700 units/litre and a minimum in March with 2,500 units/litre. Actinastrum recorded a peak in March with 960 units/litre and a minimum in September with 200 units/litre. In the next cycle November was the only month to record its presence representing 2,400 units/litre.

The family Oocystaceae was represented by three genera Ankistrodesmus, Tetraedron and Selenestrum and revealed maxima and minima in May and June recording 3,520 units/litre and 60 units/litre and recorded nil values in January and April during the first annual cycle. October and January of the second cycle showed maximal and minimal counts representing 4,400 units/litre and 300 units/litre respectively. The genus Ankistrodesmus recorded peaks of abundance in October with 1,960 units/litre and in March with 3,500 units/litre during the first and second cycles. The months of March with 520 units/litre and December also with 520 units/litre recorded the minimum for both the cycles. Tetraedron recorded maximum and minimum in December with 3,200 units/litre and June with 60 units/litre during the first annual cycle. In the next cycle October registered maximum with 2,200 units/litre and a minimum in December with 240 units/litre in February and March. Selenestrum was recorded only in October, March, July and September during the first annual cycle. The month of July registered the maximum with 2,400 units/litre. In the next cycle December recorded 560 units/litre and February with 80 units/litre and was absent in October, January and March.

The family Desmidiaceae recorded a peak maxima in May with 2,450 units/litre and recorded nil values in January, February and April during the first annual cycle. They were however present throughout the second cycle with maxima and minima in October and February representing 3,800 units/litre and 80 units/litre respectively. The genera represented under this family were Closterium, Staurastrum, Cosmarium and Desmidium. Of these, Closterium and Staurastrum solely constituted the peaks of both the cycles, while Cosmarium and Desmidium occurred only once throughout the period of study. The genus Closterium revealed a maximum of 1,640 units/litre in May and a minimum of 20 units/litre in June during the first annual cycle. In the next cycle the maximum and minimum were recorded in October with 1,400 units/litre and 80 units/litre in February. Staurastrum recorded maximum in July and October registering 1,800 units/litre and 2,400 nits/litre during the first and second cycles respectively. The family Ulotrichaeceae represented by Ulothrix occurred once each for both the cycles recording 1,280 units/litre in May and 40 units/litre in January.

The family Volvocaceae was represented by Pandorina and showed a maximum in April and minimum in August representing 2,360 units/litre and 300 units/litre respectively. It occurred only once during the second cycle in December with 520 units/litre. The family Hydrodictyaceae with a single genus Pediastrum, however, occurred more abundantly and was recorded as maximum in May with 4,895 units/litre and was absent in December, January, February and June during the first annual cycle. During the next cycle February recorded maximum with 8,200 units/litre and minimum in January with only 280 units/litre. The family Micratiniaceae represented by a single genus Micratinium was present only once in May (440 units/litre) throughout the period of study. Similarly the family Coelastraceae represented by Coelastrum was present only in October (800 units/litre)(Table-VIII).

The next class Euglenophyceae showed maximum in November with a record of 6,260 units/litre and a minimum in June representing only 90 units/litre and was absent in February during the first annual cycle. October and February of the second cycle was recorded as maximum and minimum representing 9,000 units/litre and 120 units/litre respectively (Table-VIII).

When the class Euglenophyceae was seen as to their relative percent abundance in relation to the other classes encountered in this pool-1 it showed 39.4% as maximum in January while the peak month recorded only 18.1% and the minimum was recorded in March with only 1.5%, while the minimum individual counts recorded in June showed 6.8% abundance during the first annual cycle. However in the second cycle their relative percent abundance followed a trend similar to their actual numbers (Fig. 7).

The class was constituted by two families Euglenaceae and Peranemaceae. The family Euglenaceae recorded peaks of abundance in November and October representing 6,100 units/litre and 9,000 units/litre during the first and second cycles. The months of June and December recorded a minimum with 90 units/litre and 480 units/litre in both the cycles respectively. Euglenaceae was represented by two dominant genera *Euglena* and *Phacus* which showed peaks of abundances in October and November recording 2,700 units/litre and 3,580 units/litre respectively and was absent in February and June during the first annual cycle. In the next cycle *Euglena* recorded maximum in January with 3,300 units/litre while *Phacus* in October recorded 6,800 units/litre. The family Peranemaceae represented by *Urcoelus* recorded a maximum in July with 800 units/litre and a minimum in November with 160 units/litre and was absent in December to June and August during the first annual cycle. In the next cycle February and

March recorded 120 units/litre and 280 units/litre and was absent during the remaining periods (Table-VIII).

The next class Bacillariophyceae recorded maximum in February with 3,600 units/litre and minimum in March with 360 units/litre and recorded nil in January, April, June and August of the first annual cycle. November recorded 680 units/litre as maxima and January with 200 units/litre as the minima and was absent in October, December and February during the second cycle (Table-VIII).

When the relative percent abundance of this class Bacillariophyceae was seen in relation to the other classes it followed a trend more or less similar to their actuals numbers (Fig. 7).

This class was represented by two families Naviculaceae and Tabellariaceae. The former family was represented by two genera Navicula and Frustulia. Navicula was recorded in October, November, December, March, May, July and September. The month of May as the maximum record with 1,040 units/litre was during the first annual cycle. In the next cycle, November represented the maxima with 680 units/litre and January as the minimum with 200 units/litre and was absent in December and February. Frustulia was present only in the months of November, July and September and in the second cycle recorded their presence only in November. The family Tabellariaceae represented by a single genus Tabellaria occurred only once throughout the entire period of study recording 3,600 units/litre in February (Table-VIII).

The next class Myxophyceae recorded a maximum peak of abundance in March and a smaller peak in July registering 10,840 units/litre and 5,600 units/litre respectively and was absent in January and April during the first annual cycle. The months of December and

March recorded maxima and minima registering 9,860 units/litre and 240 units/litre respectively during the second cycle (Table-VIII).

When the class Myxophyceae was seen in respect to their relative percent abundance, June recorded the maximum with 77.2% and the minimum in October with only 0.6% during the first annual cycle. The next cycle revealed January as maximum with 28.6% and March with only 1.4% as the minimum (Fig. 7).

The class Myxophyceae comprised of four families; Oscillatoriaceae represented by genera Oscillatoria, Phormidium and Spirulina. It was observed that these genera were very insignificantly represented, except for the genus Oscillatoria which recorded 1,800 units/litre in October and was absent during the other periods. The next family Rivulariaceae represented by a single genus Rivularia occurred only once in June throughout the period of study. The genus Spirulina occurred during the month of November (300 units/litre) and March (480 units/litre) during the first annual cycle. In the next cycle it occurred in December with 940 units/litre and January with 60 units/litre. The family Chroococcaceae revealed peaks of abundance in July recording 2,800 units/litre and January 2,600 units/litre during the first and second cycles. They were recorded absent in November, December, January and April during the first cycle and October, November and March during the second cycle. The genera under this family were Merismopedia, Coelosphaerium and Polycistis. Of these genera, Merismopedia and Coelosphaerium constituted the major bulk of individual forms while Polycistis occurred only once in February and was totally absent during the remaining periods.

The next family Nostocaceae recorded maximum in March and in December registering 9,800 units/litre and 7,600 units/litre during the first and second cycles and recorded the minimum in February

(50 units/litre) and March with 240 units/litre and was absent for eight months during both the cycle. Two genera were represented under this family. The genus Nostoc occurred only in November and was entirely absent during the remaining periods. The genus Anabaena registered a maximum in March and minimum in February recording 9,800 units/litre and 50 units/litre and was present for five months during the first cycle. In the next cycle it recorded a peak of 7,600 units/litre in December and a minimum in March with only 240 units/litre and was absent in October (Table-VIII).

The next class Xanthophyceae recorded two peaks of abundance in February and a smaller peak in May representing respectively 3,800 units/litre and 3,280 units/litre. April recorded a minimum with only 640 units/litre and was absent in October, December, January, March, June, August and September during the first cycle. During the second cycle they were absent from October to December and reappeared in January to record a maximum of 1,700 units/litre, which thereafter gradually decreased to touch a minimum of 940 units/litre in March (Table-VIII).

When the class Xanthophyceae was seen in relation to their relative percent abundance it followed a more or less similar trend to their actual numbers (Fig. 7).

The class was represented by three families with one genus each. The family Xanthophyceae represented by a genus Botryococcus recorded the maximum in February registering 3,800 units/litre and January with 1,700 units/litre during the first and second cycles and was present only for six months during both the cycles. The family Tribonemataceae with a single genus Tribonema was recorded in April with 640 units/litre and February with 320 units/litre during the first and second cycles respectively and was absent during the other months. The family Chlorothiciaceae with a single genus *Ophiocytium* was recorded only in November registering 1,400 units/litre (Table-VIII).

The class Dinophyceae recorded peaks of abundance in December and March with 200 units/litre and 4,000 units/litre respectively during the first and second cycles. The months of June with 30 units/litre and February with 960 units/litre were the only months to record its presence. The relative percent abundance of this class followed a trend more or less similar to their actual numbers (Fig. 7).

The class Dinophyceae in this pool was represented by a single family with a single genus, *Ceratium* and recorded their maxima and minima similar to the family in both the cycles. When the total phytoplankton was observed for their seasonal trend of fluctuation it revealed a winter and spring maxima and summer minima (Table-VIII).

CIRCULAR PLASTIC POOL-2

The most dominant phytoplankton in this pool-2 encountered was also Chlorophyceae. It was observed that May and February of the first annual cycle recorded the maximal peak and minimum record representing 1,71,280 units/litre and 141 units/litre respectively. In the next cycle March and December recorded maximum and minimum with 59,520 units/litre and 680 units/litre respectively (Table-IX).

When the class Chlorophyceae was seen in relation to their relative percent abundance it revealed a maximum percent abundance in May and a minimum in January constituting 85.7% and only 8.3% during the first annual cycle. The months of October and December recorded maximal and minimal percent abundance registering 71.8% and 14.7% in the second cycle (Fig. 7). Chlorophyceae in this pool-2 was represented by seven families and thirteen genera. The family Chlamydomonaceae comprised of a single genus Chlamydomonas, revealed peaks of abundance in May and March representing 38,680 and 15,680 units/litre during the first and second cycles. The minimum counts were recorded in February with only 24 units/litre and was absent in April during the first annual cycle. In the next cycle December recorded 200 units/litre as the minimum.

The family Scenedesmaceae was represented by Scenedesmus and Actinastrum and revealed peaks in May and March representing 79,920 units/litre and 29,760 units/litre, while their minimum counts were seen in February and December recording 66 units/litre and 480 units/litre respectively during the first and second cycle. The genus Scenedesmus constituted the major bulk of individual counts while Actinastrum was infrequently represented throughout the period of study. Scenedesmus recorded peaks of abundance in May with 79,600 units/litre and in March with 29,760 units/litre during the first

TABLE-IX

Seasonal abundance of phytoplankton, their classes, families, respective genera and the total phytoplankton (units/litre) in the Circular Plastic Pool-2.

(A) CHLOROPHYCEAE

1. Chlamydomonaceae/Chlamydomonas
2. Scenedesmaceae
3. Scenedesmus
4. Actinastrum
5. Oocystaceae
6. Ankistrodesmus
7. Tetraedron
8. Selenastrum
9. Pachycladon
10. Desmidiaceae
11. Closterium
12. Cosmarium
13. Staurastrum
14. Ulotricaceae/Hormidium
15. Volvocaceae/Pandorina
16. Hydrodictyaceae/Pediastrum

(B) EUGLENOPHYCEAE

17. Euglenaceae
18. Euglena
19. Phacus
20. Peranemaceae/Urceolus

(C) BACILLARIOPHYCEAE

22. Naviculaceae
23. Navicula
24. Frustulia
25. Fragillariaceae/Synedra
26. Coscinodiscaceae/Cyclotella

(D) MYXOPHYCEAE

27. Oscillatoriaceae
28. Phormidium
29. Spirulina
30. Chroococcaceae
31. Merismopedia
32. Coelosphaerium
33. Nostocaceae
34. Nostoc
35. Anabaena

(E) XANTHOPHYCEAE

36. Xanthophyceae/Botryococcus
37. Tribonemataceae/Tribonema
38

(F) DINOPHYCEAE

38. Ceratiaceae/Ceratium
39. Gymnodiaceae/Gymnodinium
40. Peridiniaceae/Peridinium

TABLE - IX

Sl.No.	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
	1979 - 80												1980 - 81					
(A)	8160	8780	21820	1040	141	3320	15960	171280	5200	2097	20000	16000	13343	15200	680	5685	15200	59520
1.	920	680	780	160	24	640	0	38680	1800	57	4000	2400	4240	1120	200	1760	7200	15680
2.	2720	4240	15280	0	66	1900	1280	79920	0	0	7600	7200	5840	4000	480	1920	5760	29760
3.	2720	4240	13660	0	66	1900	1280	79600	0	0	7600	6400	5840	960	480	1640	5280	29760
4.	0	0	1620	0	0	0	0	320	0	0	0	800	0	3040	0	280	480	0
5.	1920	400	3220	320	0	200	560	6320	1600	1920	4400	0	143	3360	0	360	160	2240
6.	1080	400	840	160	0	0	0	1120	700	0	4400	0	0	1120	0	0	160	1280
7.	840	0	1480	0	0	200	0	1560	800	0	0	0	143	2240	0	360	0	960
8.	0	0	900	160	0	0	960	3640	0	0	0	0	0	0	0	0	0	0
9.	0	0	0	0	0	0	0	0	0	1920	0	0	0	0	0	0	0	0
10.	1480	1600	240	380	0	200	13800	3080	1880	72	0	6400	1680	4480	0	640	640	4168
11.	1480	700	240	180	0	200	9600	760	1800	72	0	2560	640	1440	0	0	320	2880
12.	0	0	0	0	0	0	0	0	0	0	0	0	0	1920	0	0	0	0
13.	0	900	0	200	0	0	4200	2320	0	0	0	3840	1040	1120	0	640	320	1280
14.	0	0	0	0	0	0	0	0	0	0	0	0	0	1120	0	0	0	0
15.	0	0	320	0	0	200	0	2320	0	48	0	0	0	0	0	0	0	0
16.	1120	1940	1980	180	51	180	320	40960	0	0	4000	0	1440	1120	0	1005	1440	7680
(B)	11720	3100	3780	11010	42	440	20400	24040	2100	201	4000	5280	4960	15200	1460	1920	29000	21440
17.	11720	3100	3940	11010	42	140	20400	22920	2100	135	4000	5280	4960	15200	1460	1920	29000	21440
18.	4200	2300	1660	2560	27	0	8200	22600	0	39	2000	0	3920	2560	320	1060	10600	12480
19.	7520	800	1080	8400	15	140	12200	320	2100	96	2000	0	1040	12640	280	0	18400	8960
20.	0	0	800	0	0	0	0	0	0	0	0	5280	0	0	860	860	0	0
21.	0	0	240	0	0	300	0	1120	0	66	0	0	0	0	0	0	0	0
(C)	1640	1360	3240	240	63	300	520	280	0	2240	200	7840	0	0	0	0	640	2240
22.	800	1360	1960	240	63	300	520	280	0	0	200	7840	0	0	0	0	640	2240
23.	800	1360	1400	240	63	0	520	0	0	0	200	3680	0	0	0	0	320	2240
24.	0	0	560	0	0	300	0	280	0	0	0	4160	0	0	0	0	320	0
25.	840	0	1280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26.	0	0	0	0	0	0	0	0	0	2240	0	0	0	0	0	0	0	0
(D)	640	1280	2074	260	111	700	560	4280	1300	0	7600	14680	0	4320	360	396	0	2560
27.	400	0	680	260	0	0	0	0	0	0	0	280	0	3360	0	0	0	0
28.	400	0	680	260	0	0	0	0	0	0	0	280	0	0	0	0	0	0
29.	0	0	0	0	0	0	0	0	0	0	0	0	0	3360	0	0	0	0
30.	0	1280	1394	0	87	300	0	0	0	0	7600	6400	0	0	0	1360	0	2560
31.	0	1280	800	0	0	300	0	0	0	0	0	0	0	0	0	80	0	2560
32.	0	0	594	0	87	0	0	0	0	0	7600	6400	0	0	0	1280	0	0
33.	240	0	0	0	24	400	560	4280	1300	0	0	8000	0	960	360	260	0	0
34.	240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35.	0	0	0	0	24	400	560	4280	1300	0	0	8000	0	960	360	260	0	0
(E)	0	0	1240	0	12	400	360	0	0	0	0	0	0	0	0	260	560	0
36.	0	0	1240	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0
37.	0	0	0	0	12	400	360	0	0	0	0	0	0	0	0	0	560	0
(F)	200	0	20	0	0	0	0	0	0	0	5600	5280	280	1920	2120	1540	0	0
38.	200	0	20	0	0	0	0	0	0	0	0	0	0	960	1680	1480	0	0
39.	0	0	0	0	0	0	0	0	0	0	5600	5280	0	960	440	160	0	0
40.	0	0	0	0	0	0	0	0	0	0	0	0	280	0	0	0	0	0
TOTAL :	22360	14320	32174	12550	369	5160	37800	199880	8600	4538	37400	54360	18583	36640	4620	9801	43400	85760

and second cycles. The months of February registered 66 units/litre and December with 480 units/litre as the minimum during both the cycles. The genus Actinastrum was present only in the months of December, May and September during the first annual cycle. In the next cycle November recorded the maximum representing 3,040 units/litre and the minimum in January with 280 units/litre and was absent in October, December and March. The family Oocystaceae represented by Ankistrodesmus, Tetraedron, Selenastrum and Pachycladon and revealed peaks of abundance in May and November representing 6,320 units/litre and 3,360 units/litre respectively during the first and second cycles. March recorded minimum with only 200 units/litre and was absent in February and September during the first annual cycle. In the next cycle October recorded a minimum of 143 units/litre and was absent in December. Ankistrodesmus recorded peaks in August and March representing 4,400 units/litre and 1,200 units/litre during the first and second cycles respectively. Tetraedron showed two peaks, in December with 1,480 units/litre and May with 1,560 units/litre during the first cycle. In November it was 2,240 units/litre in the next cycle. Selenastrum was represented only in the first annual cycle with May recording a maximum of 3,640 units/litre. Pachycladon was recorded only in July throughout the period of study. The next family Desmidiaceae represented by three genera, Closterium, Staurastrum and Cosmarium revealed maximum peaks in April with 13,800 units/litre and minimum in July with 72 units/litre and were seen absent in February and August during the first annual cycle. November of the next cycle revealed a maximum of 4,480 units/litre and was absent in December. The genera Closterium and Staurastrum showed peaks of abundance in April recording 9,600 and 4,200 units/litre respectively during the first annual cycle and similarly March of the second cycle recorded maximal peaks for both genera representing 2,880 and 1,280 units/litre. The month of November was the only month to record the occurrence of Cosmarium and so was the case with the family Ulototricaceae represented by Hormidium. The family Volvocaceae represented by Pandorina revealed a peak in May with 2,320 units/litre and minimum in July with 48 units/litre but was entirely absent during the second cycle. The last family under this class Chlorophyceae was Hydrodictyaceae and was also constituted by a single genus Pediastrum and was well represented in both the cycles. The month of May recorded the maximal peak of abundance registering 40,960 units/litre and a minimum in February with 51 units/litre and was absent in June, July and September during the first annual cycle. In the next cycle March recorded 7,680 units as maximum and January with 1,005 units/litre as minimum and was absent in December (Table-IX).

Euglenophyceae as the next class in this pool-2 recorded maxima and minima in May and February representing 24,040 units/litre and 42 units/litre in the first annual cycle. In the next cycle February and December revealed maximal and minimal counts recording 29,000 units/litre and 1,460 units/litre respectively (Table-IX).

When this class was seen for their relative percent abundance in relation to the other classes, January recorded a maximum with 87.7% and July as the minimum with 4.4% abundance in the first cycle. The next cycle, maxima and minima were observed in February with 63.8% and January with 19.6% (Fig. 7).

The class consists of two families, Euglenaceae and Peranemaceae. The family Euglenaceae recorded peaks of abundance in the months of May with 22,920 units/litre and in February with 29,000 units/litre during the first and second cycles and its minimum counts were recorded in February and December representing 42 units/litre and 1,460 units/litre respectively during the first and second cycles. The family Peranemaceae was present only during the first annual cycle with the months of May recording the maximum peak representing 1,120 units/litre and a minimum with 66 units/litre in July. Euglena had a peak in May with 22,600 units/litre and March with 12,480 units/litre in the first and second cycles and was absent in March, June and September during the first cycle. Phacus except for its absence in September was well represented with April recording 12,200 units/litre as maximum and February as minimum with only 15 units/litre during the first annual cycle. February and December in the second cycle represented the maximum and minimum with 18,400 and 280 units/litre. Trachelomonas was present only on two occasions during the first annual cycle registering 5,280 units/litre in September and in December with 800 units/litre. In the next cycle only December and January showed their presence (Table-IX).

The next class Bacillariophyceae was predominantly represented during the first annual cycle with September as the maximum recording 7,840 units/litre and minimum in February with 63 units/litre and was absent in June. During the second cycle, February and March were the only occasions to register their presence (Table-IX).

When the relative percent abundance of this class Bacillariophyceae was seen in relation to the other classes, the month of July recorded the maximum percent abundance with 49.4% and the minimum with 0.2% in May during the first annual cycle. In the next cycle March and February recorded 2.6% and 1.4% abundance (Fig. 7).

The class Bacillariophyceae was comprised of three families, Naviculaceae, Fragi-lariaceae and Coscinodiscaceae. The family Naviculaceae recorded peaks or maximum abundance in September with 7,840 units/litre and March with 2,240 units/litre during the first and second cycle. The month of February with 63 units/litre and 640 units/litre recorded the minimum during the first and second cycles respectively and was absent in June during the first annual cycle and in October to January during the second cycle. The family Fragilariaceae with a single genus Synedra was recorded only during the first annual cycle in the months of October with 840 units/litre and December with 1,280 units/litre. The family Coscinodiscaceae represented by Cyclotella was recorded only in July with 2,240 units/litre and was absent during the other months of both the cycles.

The family Naviculaceae was represented by two genera of which Navicula constituted the dominant form, with peaks of abundance in September recording 3,680 units/litre and a smaller peak in December with 1,400 units/litre. Minimum counts were in February with only 63 units/litre and was absent in March, May, June and July during the first annual cycle. In the next cycle March and February recorded 2,240 units/litre and 320 units/litre respectively. Frustulia recorded September as the maximum with 4,160 units/litre and was present only in December, March and May. February was the only occasion to record their occurrence during the second cycle (Table-IX).

The next class Myxophyceae recorded peaks of abundance in September representing 14,680 units/litre and a minimum count of 111 units/litre in February and was absent in July during the first annual cycle. During the second cycle November had a peak of 4,320 units/litre and a minimum of 360 units/litre in December and was absent in October and January (Table-IX).

The class Myxophyceae revealed peak of relative percent abundance in February recording 30.0% and a minimum of 1.5% in April during the first annual cycle. In the next cycle the maximum and minimum relative percent abundance were observed in November with 11.8% and March with only 2.9% (Fig. 7).

The class was represented by three families with six genera. Under the family Nostocaceae, Anabaena occurred in abundance both in terms of counts and in their occurrence. September recorded a peak of 8,000 units/litre and a minimum of 24 units/litre in February and was absent from October to January, July and August during the first annual cycle. November, December and January were the only months during the second cycle to register their presence in the system with November recording 960 units/litre as maximum and January 260 units/litre as the minimum counts.

The family Chroococaceae was represented by Coelosphaerium which recorded a peak of 7,600 units/litre in August and with only 87 units/litre in February and was absent during the major part of investigation. During the second cycle January was the only month in which it occurred. Merismopedia also recorded a peak in November with 1,280 units/litre and March with 2,560 units/litre during the first and second cycles and was present only in November, December, March of the first cycle and January and March in the second cycle. The family Oscillatoriaceae had two genera. Phormidium revealed a maximum in December with 680 units/litre and Spirulina in November with 3,360 units/litre during both the cycles (Table-IX).

The next class Xanthophyceae was very insignificantly represented except for the peak recorded in December with 1,240 units/litre and a minimum in February with 12 units/litre during the first annual cycle. In the next cycle January and February were the only months to record their presence (Table-IX).

The class revealed a maximum of 7.7% relative abundance in March and a minimum of 0.9% in April during the first cycle. The next cycle recorded 2.7% and 1.2% in January and February as the maximum and minimum (Fig. 7).

Two genera, Botryococcus and Tribonema were represented under this class. Botryococcus was present in December (1,240 units/litre) and in January (260 units/litre) during the first and second cycles respectively. Tribonema had a peak in April (360 units/litre) and a minimum in February (12 units/litre) during the first cycle. In the second cycle it was recorded only in February (Table-IX).

The class Dinophyceae occured very sporadically. September and December recorded 10,560 and 20 units/litre as maximum and minimum respectively during the first cycle. In the next cycle October recorded a minimum (280 units/litre) and a maximum in December (2,120 units/litre) and was absent in February and March (Table-IX). The class revealed a maximum relative percent abundance in September with 19.4% and a minimum in December with only 0.1% during the first cycle. December of the second cycle recorded maxima with 45.9% and a minima in October with 1.5% (Fig. 7). The class was represented by three families with one genus each, Ceratium, Gymnodinium and Peridinium. The genus Ceratium (Ceratiaceae) occured very sparsely and recorded a maximum in September (5,280 units/litre) and a minimum in December (20 units/litre) during the first cycle. In the next cycle a peak was recorded in December (1,680 units/litre) and a minimum in November (960 units/litre). The genus Gymnodinium (Gymnodiaceae) was recorded in August (5,600 units/litre) and September (5,280 units/litre) during the first annual cycle. In the next cycle, November recorded a peak (960 units/litre) and a minimum in January (160 units/litre). The genus Peridinium (Peridiniaceae) was recorded only in October (280 units/litre) during the entire period of study.

When the total phytoplankton was seen for its seasonal trend of fluctuation it revealed a summer maxima and spring minima (Table-IX).

CIRCULAR PLASTIC POOL-3

The class Chlorophyceae was encountered as the most dominant form in this pool. It recorded peaks of abundance in May registering 4,39,640 units/litre and in January with 60,040 units/litre during the first and second cycles. The months of August and December recorded the minimum representing 4,355 units/litre and 1,080 units/litre respectively during the first and second cycles (Table-X).

The class Chlorophyceae recorded relative percent abundance, maximum in April with 96.1% and in January with 89% during the first and second cycles. The minimum was registered in December and February representing 52.7% and 51.6% respectively (Fig. 7).

The family Chlamydomonaceae represented by a single genus Chlamydomonas recorded peaks of abundance both in the months of October with 38,800 units/litre and 30,400 units/litre during the first and second cycles. The months of August with 760 units/litre and February with 800 units/litre recorded the minimum during the first and second cycles respectively and was absent in December.

The family Desmidiaceae revealed peaks in the months of June and July of the first annual cycle with nearly 4,000 units/litre and above with the second peak reaching 5,880 units/litre in the month of March of the second cycle. They were absent in March and April of the first cycle, while a low count of 440 units/litre was seen in the second cycle. This family was represented by three genera Closterium, Cosmarium and Staurastrum. Of these, Cosmarium occurred only once throughout the study period in the month of November of the first annual cycle recording 120 units/litre. Closterium showed a trend similar to the family while Staurastrum though had a peak similar to the family for the first annual cycle revealed a peak of 1,600 units/litre in the month of February of the second cycle. Their minimum counts and their non-occurrences followed that of the family.

TABLE-X

Seasonal abundance of phytoplankton, their classes, families, respective genera and the total phytoplankton (units/litre) in the Circular Plastic Pool-3.

(A) CHLOROPHYCEAE

1. Chlamydomonaceae/_Chlamydomonas_
2. Scenedesmaceae
3. _Scenedesmus_
4. _Actinastrum_
5. Oocystaceae
6. _Ankistrodesmus_
7. _Tetraedron_
8. _Selenastrum_
9. _Kirchneriella_
10. Desmidiaceae
11. _Closterium_
12. _Cosmarium_
13. _Staurastrum_
14. Dictyosphaeriaceae/_Dictyosphaerium_
15. Ulotricaceae
16. _Ulothrix_
17. _Hormidium_
18. Volvocaceae
19. _Volvox_
20. _Pandorina_
21. Hydrodictyaceae/_Pediastrum_
22. Microsporaceae/_Microspora_

(B) EUGLENOPHYCEAE

23. Euglenaceae
24. _Euglena_
25. _Phacus_
26. Peranemaceae/_Urceolus_

(C) BACILLARIOPHYCEAE

27. Naviculaceae
28. _Navicula_
29. _Frustulia_
30. Nitzschiaceae/_Nitzschia_
31. Tabellariaceae/_Tabellaria_

(D) MYXOPHYCEAE

32. Oscillatoriaceae/_Phormidium_
33. Chroococcaceae
34. _Merismopedia_
35. _Polycistis_
36. _Coelosphaerium_
37. Nostocaceae
38. _Anabaena_
39. _Nostoc_

(E) XANTHOPHYCEAE

40. Xanthophyceae/_Botryococcus_
41. Tribonemataceae/_Tribonema_

(F) DINOPHYCEAE

42. Ceratiaceae/_Ceratium_
43. Gymnodiaceae/_Gymnodinium_

TABLE - X

	1979-80												1980-81					
Sl.No.	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
(A)	93400	19780	17880	32000	16880	21700	436830	439640	66400	93400	4355	23620	40670	9700	1080	60840	6400	59860
1.	38800	5940	8920	6000	1600	7000	14430	17560	19200	3000	760	1380	30400	1320	0	4840	800	12320
2.	1680	8960	4240	19600	3200	8000	398400	141520	9600	22000	1040	10600	4360	1040	440	49200	0	20280
3.	1680	8960	4240	14800	1600	1640	398400	142520	9680	22800	760	10240	4360	1040	440	4680	0	20280
4.	0	0	0	4800	1600	6360	0	0	0	0	280	360	0	0	0	320	0	0
5.	5720	1920	1360	0	2800	2700	9600	4160	4800	0	320	1400	2210	1840	0	720	1600	4040
6.	960	960	0	0	1200	300	0	2640	4800	0	0	280	1840	0	0	0	1600	280
7.	1600	960	880	0	0	400	0	1520	0	0	0	0	70	1840	0	720	0	2960
8.	3160	0	480	0	1600	0	9600	0	0	0	320	1120	300	0	0	0	0	0
9.	0	0	0	0	0	2800	0	0	0	0	0	0	0	0	0	0	0	800
10.	2760	1560	1200	800	1200	0	0	1600	4400	4000	520	2880	3140	1480	440	960	2400	5880
11.	1600	280	320	0	400	0	0	0	0	4000	0	1280	2100	1260	440	0	800	5760
12.	0	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13.	1160	1160	800	800	800	0	0	1600	4400	0	520	1600	1040	220	0	960	1600	120
14.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1000	0
15.	1160	880	0	0	0	0	0	0	880	2000	0	0	0	3380	0	0	0	0
16.	1160	0	0	0	0	0	0	0	800	2000	0	0	0	3380	0	0	0	0
17.	0	880	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.	0	320	960	1600	800	800	0	85000	2800	5600	240	360	0	0	0	0	0	0
19.	0	0	0	0	800	0	0	0	0	0	0	0	0	0	0	0	0	0
20.	0	320	960	1600	0	800	0	85000	2800	9600	240	360	0	0	0	0	0	0
21.	3200	600	1040	4000	6400	2400	18400	189880	24800	16000	1475	7800	960	640	200	3320	1600	13340
22.	0	0	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(B)	6000	2240	8000	2300	2000	3240	12960	7160	12000	1400	680	3400	6320	5700	880	2480	4400	6680
23.	6000	1680	7840	2200	2000	2840	12960	1640	12000	1400	600	3400	6320	5020	880	2480	4400	6320
24.	1920	1000	7600	1200	2800	2080	10400	880	9200	1400	600	720	1340	140	880	2080	4400	6320
25.	4080	680	240	1000	0	760	2560	760	2800	0	0	2600	4900	4880	0	400	0	0
26.	0	560	160	0	0	400	0	9520	0	0	0	0	0	680	0	0	0	360
(C)	800	2440	1120	1400	1600	0	1600	0	0	0	240	760	560	260	1520	1240	0	600
27.	800	2440	480	1400	1600	0	1600	0	0	0	240	760	0	260	1520	1240	0	600
28.	800	1160	0	1400	1600	0	1600	0	0	0	240	760	0	260	480	1240	0	600
29.	0	1280	480	0	0	0	0	0	0	0	0	0	0	0	1040	0	0	0
30.	0	0	0	0	0	0	0	0	0	0	0	0	560	0	0	0	0	0
31.	0	0	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(D)	1720	0	6160	10600	2400	1960	3200	1160	1200	2000	2040	3800	1040	820	1610	2760	800	0
32.	0	0	0	0	800	480	0	0	0	2000	0	0	0	100	0	120	0	0
33.	1280	0	0	10600	1200	1480	0	0	0	0	2040	3440	1040	720	0	2360	0	0
34.	0	0	0	4200	0	0	0	0	0	0	2840	3440	0	720	0	1560	0	0
35.	0	0	0	0	1200	0	0	0	0	0	0	0	0	0	0	0	0	0
36.	1200	0	0	6400	0	1480	0	0	0	0	0	0	1040	0	0	800	0	0
37.	440	0	6160	0	400	0	3200	1160	1200	0	0	360	0	0	1610	280	800	0
38.	440	0	5520	0	400	0	3200	1160	1200	0	0	360	0	0	1610	280	800	0
39.	0	0	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(E)	600	0	0	0	400	800	0	11200	0	0	0	1900	480	360	360	920	800	0
40.	0	0	0	0	0	800	0	11200	0	0	0	0	0	0	0	920	0	0
41.	600	0	0	0	400	0	0	0	0	0	0	1900	480	360	360	0	800	0
(F)	240	0	640	0	0	0	0	0	0	0	0	0	0	780	0	0	0	0
42.	240	0	480	0	0	0	0	0	0	0	0	0	0	720	0	0	0	0
43.	0	0	160	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0
TOTAL :	62760	24460	33720	46200	22480	27700	454590	459160	76000	96800	8095	33480	49070	17620	5450	67440	12400	63140

The family Scenedesmaceae represented by two genera *Scenedesmus* and *Actinastrum* recorded peaks of abundance in April representing 3,98,400 units/litre and March with 20,280 units/litre during the first and second cycles respectively. The months of August with 1,040 units/litre and December with 440 units/litre represented the minimum during the first and second cycle and was absent in February (Table-X).

The genus *Scenedesmus* recorded a peak in April with 3,98,400 units/litre and a minimum in August with 760 units/litre during the first annual cycle. In the next cycle March recorded a maximum of 20,280 units/litre and a minimum in December with 440 units/litre and was absent in February. *Actinastrum* recorded a maximum and minimum in March and August representing 6,360 units/litre and 280 units/litre respectively during the first annual cycle. They were absent from October to December and April to July. In the next cycle January recorded a count of 320 units/litre and was absent from October to December and February and March.

The family Oocystaceae revealed a peak of abundance in October recording 5,720 units/litre and a minimum in August representing 320 units/litre during the first annual cycle respectively and was absent in January and July. In the next cycle a peak was registered in March with 4,040 units/litre and a minimum in January with 720 units/litre and was absent in December.

The genus *Ankistrodesmus* recorded peaks of abundance in June and October registering 4,800 units/litre and 1,840 units/litre respectively during the first and second cycles. It revealed a minimum of 300 units/litre in March and was absent in December, January, April, July and August during the first cycle. In the next cycle a minimum of 280 units/litre was registered in March and was absent in November to January. *Tetraedron* recorded October as the maximum with

1,600 units/litre and was absent in January, February, April, June to September during the first annual cycle. In the next cycle a maximum of 2,960 units/litre were registered in March and was absent in December and February. Selenastrum recorded a maximum in April with 5,600 units/litre and was absent in November, January, March, May to July during the first annual cycle. In the second cycle it was recorded only in October with 300 units/litre. The genus Kirchneriella was recorded in March with 2,000 units/litre and was absent from October to February, April to September during the first annual cycle. In the next cycle it was recorded only in March registering 800 units/litre.

The family Dictyosphaeriaceae with a single genus Dictyosphaerium was absent during both the cycles with the exception of January which recorded a count of 1,000 units/litre.

The family Ulotricaceae represented by two genera Ulothrix and Hormidium revealed a maximum in July registering 2,000 units/litre and a minimum of 800 units/litre in June and was absent in October, December to May, August and September during the first annual cycle. In the next cycle it was present only in November representing 3,380 units/litre. The genus Ulothrix followed a trend of abundance to that of the family, while the genus Hormidium was recorded once in November with 880 units/litre and was entirely absent during the remaining months of both the cycles. The family Hydrodictyaceae represented by a single genus Pediastrum recorded a maximum peak of abundance in May representing 1,89,800 units/litre and a minimum in November with only 600 units/litre during the first annual cycle. In the next cycle a maximum peak was registered in March recording 13,340 units/litre and a minimum in December with only 200 units/litre. The family Microsporaceae with a single genus Microspora was present only in the month of December with 480 units/litre (Table-X).

The class Euglenophyceae constituted the second largest group. It recorded maximum and minimum densities in April and August representing 12,960 units/litre and 600 units/litre respectively during the first annual cycle. In the next cycle the maximum was recorded in March with 6,680 units/litre and the minimum in December with 880 units/litre (Table-X).

When the relative percent of the class was seen it recorded a maximum of 23.7% in December and a minimum of 1.6% in May during the first annual cycle. In the next cycle the maximum and minimum was recorded in February with 35.5% and January with 3.7% abundance (Fig. 7).

The family Euglenaceae recorded peaks of abundance in the months of April with 12,960 units/litre and in March with 6,320 units/litre during the first and second cycle. The months of August and December represented the minimum counts with 600 units/litre and 880 units/litre respectively during the first and second cycle. The family Peranemaceae represented by a single genus Urcoelus recorded maximum in May with 55,20 units/litre during the first annual cycle and was absent for eight months during the first annual cycle. In the next cycle it was recorded only in December (680 units/litre) and March (360 units/litre).

The genus Euglena constituted the dominant form and recorded peaks of abundance in April with 10,400 units/litre and in March with 6,320 units/litre and their minimum in August with 600 units/litre and November with 140 units/litre, during the first and second cycles respectively. Phacus registered two nearly equal peaks in June with 2,800 units/litre and in September with 2,680 units/litre and was absent for six months during both the cycles (Table-X).

The next class Bacillariophyceae recorded a maximal density in November registering 2,440 units/litre and a minimum in August with 240 units/litre and was absent in March, May, June and July during the first annual cycle. In the next cycle December recorded a maximum with 1,520 units/litre and a minimum in November with 260 units/litre and was absent in February (Table-X).

The class Bacillariophyceae revealed a maximum relative abundance representing 9.9% and 27.9% in November and December and their minimum was recorded in April with 0.3% and in October with 1.1% during the first and second cycles respectively (Fig. 7).

The class Bacillariophyceae comprised of three families, Naviculaceae represented by two genera Navicula and Frustulia, the family Nitzschiaceae by a single genus Nitzchia and Tabellariaceae also by a single genus Tabellaria. Of these families Naviculaceae constituted the most dominant form under this class and recorded peaks of abundance in November and December representing 2,440 units/litre and 1,520 units/litre during the first and second cycles. The months of August with 240 units/litre and November with 260 units/litre was recorded as the minimum and was absent in the months of March, May to July, October and February during the first and second cycles respectively. The families Nitzschiaceae and Tabellariaceae were recorded only once each, the former during October with 560 units/litre and the latter in December with 640 units/litre during both the cycles.

Navicula recorded two peaks of abundance in February and April with 1,600 units/litre and a minimum in August with 240 units/litre and was absent in December, March, May, June and July during the first annual cycle. In the next cycle January recorded a maximum with 1,240 units/litre and a minimum in November with 260 units/litre and was absent in October and February. Frustulia was recorded only in

November and December registering 1,280 units/litre and 480 units/litre during the first cycle. In the next cycle December was the only occasion to register their presence (Table-X).

The class Myxophyceae recorded a peak of abundance in January with 10,600 units/litre and a minimum in May with 1,160 units/litre during the first annual cycle. In the next cycle a maximum was recorded in January with 2,760 units/litre and a minimum in February registering 820 units/litre and was absent in March (Table-X).

The maximum relative percent abundance of this class was seen in August with 35.5% and in December with 29.5% during the first and second cycles. Their minimum was recorded in May with 0.2% and in October with 2.1% (Fig. 7).

Three families were represented under the class Myxophyceae. They were Oscillatoriaceae, Chroococcaceae and Nostocaceae. The family Oscillatoriaceae occurred only five times with a peak in July with 2,000 units/litre. Nostocaceae recorded a peak in December registering 6,160 units/litre and a minimum in September with 360 units/litre during the first annual cycle. In the second cycle December and January represented the maximum and minimum with 6,160 units/litre and 230 units/litre respectively and was absent for eight months during both the cycles. Anabaena revealed a peak of abundance in December with 5,520 units/litre and a minimum in September recording 360 units/litre during the first annual cycle. In the next cycle, December recorded the peak with 1,610 units/litre and January as the minimum with 280 units/litre and was absent for eight months during both the cycles. The genus Nostoc was recorded only in December with 640 units/litre

The family Chroococcaceae recorded peaks of abundance in January with 10,600 units/litre and 2,360 units/litre respectively during the first and second cycles. It recorded minimum in February with 1,200 units/litre and 720 units/litre in November during both the cycles. *Merismopedia* recorded a peak in January registering 4,200 units/litre and a minimum in August with 2,840 units/litre and was absent from October to December and February to July during the first annual cycle. In the next cycle the genus was recorded only in November with 720 units/litre and January with 1,560 units/litre. *Polycistis* was recorded only in February with 1,200 units/litre during the entire period of study. *Coelosphaerium* recorded a peak in January registering a count of 6,400 units/litre and a minimum in October with 1,280 units/litre during the first annual cycle. In the second cycle it was recorded only in October with 1,040 units/litre and January with 800 units/litre (Table-X).

The class Xanthophyceae recorded maximum abundance in May and January representing 11,200 units/litre and 920 units/litre during the first annual cycle. The months of February with 400 units/litre and November, December with 360 units/litre each recorded the minimum for both the cycles and was absent from November to January, April, June to August and March during both the cycles (Table-X).

The class Xanthophyceae revealed a maximum percent abundance with 5.7% and 6.6% in September and December and their minimum was recorded in October with only 0.9% and in January with 1.4% during the first and second cycles (Fig. 7). The class Xanthophyceae was comprised of two families Xanthophyceae and Tribonemataceae. The family Xanthophyceae represented by a single genus *Botryococcus* revealed a peak of abundance in May registering 11,200 units/litre and a minimum in March with 800 units/litre and was recorded absent during the other months of the first annual cycle. In the next cycle it was recorded only once in January with 920 units/litre. The family

Tribonemataceae was also represented by a single genus Tribonema and was recorded only in the months of September with 1,900 units/litre, and also in October and February with 600 units/litre and 400 units/litre respectively and was absent during the other months of the first cycle. In the next cycle February registered 800 units/litre as maximum and was absent in January and March (Table-X).

The class Dinophyceae in this pool was not well represented and was recorded only in the months of October, December and November recording 240 units/litre, 640 units/litre and 780 units/litre respectively during both the cycles.

The relative percent abundance of the class revealed October with 0.4% and December with 1.8% during the first annual cycle. In the next cycle November recorded 4.4% (Fig.).

The class was comprised of two families Ceratiaceae and Gymnodiaceae. The family Ceratiaceae was represented by a single genus Ceratium and was recorded only in October, December and November recording 720 units/litre as maximum counts. Similarly Gymnodinium was recorded only in the months of December with 160 units/litre and November with 60 units/litre.

When the total phytoplankton was seen for its seasonal trend of fluctuation it showed a late autumn and spring maxima and a summer minima during the first annual cycle. In the next cycle the increased trend was observed during the winter months (Table-X).

CIRCULAR PLASTIC POOL-4

The phytoplankton population in this pool-4 was also mainly constituted by the class Chlorophyceae. They were the most abundant forms throughout the period of study. It flourished profusely in January and March to touch a maximal density in April recording 24,83,200 units/litre and persisted till June though in decreasing order and recorded a minimum in July registering 1,080 units/litre during the first annual cycle. In the next cycle the maximal density was observed in January recording 32,840 units/litre and a minimum in March representing 17,680 units/litre (Table-XI).

The class Chlorophyceae recorded almost equal maximum relative percent abundance in March with 99.8% and in April with 99.7% and a minimum in September with 46.8% during the first annual cycle. In the next cycle, the maximum and minimum were recorded in January and October representing 60.7% and 32.1% respectively (Fig. 7).

The family Chlamydomonaceae represented by a single genus Chlamydomonas recorded maximum in April with 3,00,240 units/litre and minimum in July with only 180 units/litre during the first annual cycle. In the second cycle January and November recorded maximum and minimum density recording 13,400 units/litre and 2,046 units/litre respectively. The family Scenedesmaceae represented by two genera <u>Scenedesmus</u> and <u>Actinastrum</u>, revealed peaks of abundance in April with 21,00,560 units/litre and November with 15,960 units/litre during the first and second cycles respectively. Minimum counts during the first annual cycle was observed in July recording 200 units/litre and in the next cycle in January with 1,000 units/litre and was absent in December (Table-XI).

<u>Scenedesmus</u> constituted the dominant population recording maxima in April with 20,99,040 units/litre and in November recording

TABLE-XI

Seasonal abundance of phytoplankton, their classes, families, respective genera and the total phytoplankton (units/litre) in the Circular Plastic Pool-4.

(A) CHLOROPHYCEAE

1. Chlamydomonaceae/Chlamydomonas
2. Scenedesmaceae
3. Scenedesmus
4. Actinastrum
5. Oocystaceae
6. Ankistrodesmus
7. Tetraedron
8. Selenastrum
9. Desmidiaceae
10. Closterium
11. Staurastrum
12. Dictyosphaeriaceae/Dictyosphaerium
13. Ulotricaceae
14. Ulothrix
15. Hormidium
16. Zygnemataceae/Spirogyra
17. Volvocaceae/Pandorina
18. Hydrodictyaceae/Pediastrum

(B) EUGLENOPHYCEAE

19. Euglenaceae
20. Euglena
21. Phacus
22. Peranemaceae/Urceolus

(C) BACILLARIOPHYCEAE

23. Naviculaceae
24. Navicula
25. Frustulia
26. Fragillariaceae/Synedra

(D) MYXOPHYCEAE

27. Oscillatoriaceae/Spirulina
28. Chroococcaceae
29. Merismopedia
30. Coelosphaerium
31. Nostocaceae/Anabaena

(E) XANTHOPHYCEAE

32. Xanthophyceae/Botryococcus
33. Tribonemataceae/Tribonema

(F) DINOPHYCEAE

34. Ceratiaceae/Ceratium
35. Gymnodiaceae/Gymnodinium

TABLE - XI

Sl.No.	1979-80												1980-81					
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
(A)	12680	9920	37040	256640	8760	876080	2403200	128300	45880	1080	133811	23200	26900	28660	22400	32840	18080	17680
1.	4320	800	21540	4480	1800	102080	308240	20500	7680	180	61620	4800	6180	2040	6000	13400	6880	9600
2.	1320	1440	12600	173600	5840	769040	2100560	75980	82200	200	68665	8800	11100	15960	0	1000	9920	9680
3.	1320	1440	11920	171360	5240	67200	2099840	75980	17800	200	68665	5800	10300	15960	0	1000	9920	9680
4.	0	0	680	2240	600	2640	720	0	4400	0	0	3000	880	0	0	0	0	0
5.	5400	3200	1500	8160	0	480	4080	8160	9800	160	274	800	3300	0	8000	7480	960	400
6.	1400	0	300	3680	0	0	720	4000	3560	0	0	0	700	0	0	7320	0	0
7.	4000	3200	1200	2240	0	0	1280	3560	1040	160	80	0	2300	0	8000	160	960	480
8.	0	0	0	2240	0	480	2080	16000	400	0	194	800	300	0	0	0	0	0
9.	1040	2960	1160	5780	400	840	1680	720	400	100	80	5400	3300	1120	7200	4080	0	800
10.	640	80	800	2240	400	440	760	0	0	0	0	2400	1200	1120	6800	1480	0	0
11.	400	2880	360	3520	0	400	920	720	400	100	80	3000	2600	0	400	2600	0	800
12.	0	0	0	0	720	0	0	0	2680	0	960	0	0	0	0	0	0	880
13.	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	320	240
14.	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	320	0
15.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	240
16.	0	160	0	0	0	240	0	0	0	0	0	0	0	0	0	0	0	0
17.	320	880	0	20480	0	160	1440	14220	400	380	480	0	600	0	0	0	0	0
18.	280	480	240	44160	0	2520	75200	8720	7600	60	1731	3400	1500	1540	1200	6880	0	0
(B)	7320	2640	23600	7840	5200	880	2320	1840	5200	300	4511	24000	51600	13680	44000	20780	8160	2320
19.	6800	2400	20220	4800	5200	880	2320	1840	5200	120	3371	24000	50800	12520	44000	20780	8160	2320
20.	5560	640	19420	4800	4880	320	1360	1560	3200	60	2877	8800	18500	9880	8400	10720	5280	1040
21.	12640	1760	800	0	400	560	960	280	2800	60	494	15200	32300	2640	35600	10060	2880	1280
22.	520	240	3380	3040	0	0	0	0	0	180	1140	0	800	1160	0	0	0	0
(C)	3560	1400	1720	0	0	0	0	2080	1600	0	0	2400	1280	280	0	440	2880	1920
23.	2040	720	1720	0	0	0	0	2080	1600	0	0	2400	1000	280	0	440	2880	1920
24.	2040	720	1720	0	0	0	0	2080	0	0	0	2400	1000	280	0	440	640	1360
25.	0	0	0	0	0	0	0	0	1600	0	0	0	0	0	0	0	2240	560
26.	1520	680	0	0	0	0	0	0	0	0	0	0	280	0	0	0	0	0
(D)	0	960	820	31360	480	0	1680	3520	2800	60	0	0	1800	0	0	0	10720	7040
27.	0	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	480	0
28.	0	0	820	0	0	0	1680	0	2800	0	0	0	1800	0	0	0	9280	4240
29.	0	0	0	0	0	0	960	0	2800	0	0	0	600	0	0	0	0	1440
30.	0	0	820	0	0	0	720	0	0	0	0	0	1200	0	0	0	9280	2800
31.	0	80	0	31360	480	0	0	3520	0	60	0	0	0	0	0	0	960	2800
(E)	0	800	0	0	0	1160	0	0	2840	0	1140	0	0	2960	0	0	0	1680
32.	0	400	0	0	0	1160	0	0	2840	0	1140	0	0	2960	0	0	0	1040
33.	0	400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	640
(F)	0	300	280	0	0	120	0	2320	0	400	0	0	0	0	0	0	4320	6480
34.	0	300	280	0	0	120	0	0	0	0	0	0	0	0	0	0	4320	6480
35.	0	0	0	0	0	0	0	2320	0	400	0	0	0	0	0	0	0	0
TOTAL :	23560	19620	63460	295840	14360	878240	2487200	138060	58320	1840	139462	49600	81588	37580	66400	54060	44160	37120

15,960 units/litre as the peaks in the first and second cycles respectively. Actinastrum recorded a maxima and minima in June with 4,000 units/litre and in February with 600 units/litre and was absent in October, November, May, July and August during the first cycle and the next cycle recorded once only in the month of October with 800 units/litre.

The family Oocystaceae represented by three genera Ankistrodesmus, Tetraedron and Selenastrum recorded two maximum peaks in January and May with 8,160 units/litre and minimum in July with only 160 units/litre during the first annual cycle. In the next cycle November recorded total absence while December recorded the maximum, registering 8,000 units/litre constituted by a single genus Tetraedron and the minimum in March with 480 units/litre. The genus Ankistrodesmus recorded peaks of abundance in May registering 4,000 units/litre and in January with 7,320 units/litre during the first and second cycles respectively. The months of December and October recorded the minimum, representing 300 units/litre and 700 units/litre respectively and was present only for eight months during both the cycles. Tetraedron recorded a peak in October registering 4,000 units/litre and a minimum in August with 80 units/litre during the first annual cycle. In the next cycle December recorded the maximum count with 8,000 units/litre and January as the minimum with only 160 units/litre. Selenastrum recorded a peak in January representing 2,240 units/litre and a minimum in August with only 194 units/litre during the first annual cycle. In the second cycle it was recorded only in the month of October with 300 units/litre.

The family Desmidiaceae was represented by two genera, Closterium and Staurastrum. The family recorded maximal densities in January with 5,760 units/litre and in December with 7,200 units/litre during the first and second cycles, while August and March recorded minimum representing 80 units/litre and 800 units/litre. Staurastrum constituted the major bulk of individuals under this family with its peak in January with 3,520 units/litre and nil in February during the first annual cycle. October and January of the second cycle recorded equal peaks with 2,600 units/litre and were absent in November and February. Closterium also recorded a peak in the first cycle in January with 2,240 units/litre and December with 6,800 units/litre in the next cycle and was recorded absent in May to August, February and March during both the cycles.

The family Dictyosphaeriaceae represented by a single genus Dictyosphaerium was recorded only in the months of February, June, August and March during both the cycles. The genus however recorded a high count in June representing 2,680 units/litre.

The family Ulotricaceae represented by two genera Ulothrix and Hormidium were found only in February and March during the whole period of study and so was the case with Spirogyra under the family Zygnemataceae present only in March recording 240 units/litre. Volvocaceae represented by a single genus Pandorina was predominantly represented during the first annual cycle. It had maximal density in January with 20,480 units/litre and a minimum in March with 160 units/litre and was absent in December, February and September during the first annual cycle. In the second cycle it was recorded only in October with 600 units/litre. The last family under this class was Hydrodictyaceae represented by Pediastrum and revealed maximal densities in April with 75,200 units/litre and January with 6,880 units/litre during the first and second cycles. Their minimum was recorded in July with 60 units/litre during the first annual cycle and in the next cycle December with 1,200 units/litre (Table-XI).

The lass Euglenophyceae in this pool constituted the second largest population. It recorded maximal densities in December and October representing 23,600 units/litre and 51,600 units/litre during the first and second cycles respectively. The months of July with 300 units/litre and March with 2,320 units/litre represented the minimum counts during the first and second cycles (Table-XI).

The class Euglenophyceae revealed maximum relative percent abundance in September with 48.4% and the minimum in March and April recording 0.1% each during the first annual cycle. In the next cycle December recorded the maximum with 66.3% and March as the minimum with only 6.3% (Fig. 7).

The class Euglenophyceae was represented by two families Euglenaceae and Peranemaceae. The family Euglenaceae comprised of two genera Euglena and Phacus and revealed a maximum density in September recording 24,000 units/litre and a smaller peak in December with 20,220 units/litre and recorded a minimum in July with only 120 units/litre during the first annual cycle. In the next cycle October and December registered peaks of abundances recording 50,800 units/litre and 44,000 units/litre and the minimum in March with only 2,320 units/litre. The family Peranemaceae had one genus Urcoelus and recorded a peak of abundance in December with 3,380 units/litre and a minimum in July with 180 units/litre and was absent from February to June and September during the first annual cycle. In the second cycle the months of October and November were the only months to record their presence with 800 units/litre and 1,160 units/litre respectively (Table-XI).

The genus Euglena was well represented throughout the period of investigation with peaks of abundance recorded in the months of December and October registering 19,420 units/litre and 18,500 units/litre during the first and second cycles. The months of July and

February recorded 60 units/litre and 5,280 units/litre as the minimum during the first and second cycles respectively. Phacus recorded peaks of maximum abundance in September with 15,200 units/litre and in December with 35,600 units/litre during the first and second cycles respectively. A minimum of 60 units/litre was recorded in July and their absence in January during the first annual cycle. In the next cycle a minimum of 1,280 units/litre was registered in March (Table-XI).

The class Bacillariophyceae was not well represented throughout the period of study in this pool. Its maximum densities was recorded in October with 3,560 units/litre and in February with 2,880 units/litre during the first and second cycles. They were absent from January to April, July and August during the first cycle and in December during the second cycle (Table-XI).

When the class Bacillariophyceae was seen for its relative percent abundance with the other classes a maximum of 15.2% and mininum of 1.5% was recorded in October and May respectively during the first annual cycle. In the second cycle a maximum of 6.5% and a minimum of 0.7% was recorded in February and November respectively (Fig.7).

The class Bacillariophyceae comprised of two families, Naviculaceae represented by two genera Navicula and Frustulia and the family Fragilariaceae with a single genus Synedra. The family Naviculaceae recorded peaks of abundance in September with 2,400 units/litre and in February with 2,880 units/litre during the first and second cycle. The months of November with 1,400 units/litre and 280 units/litre represented the minimum for both the cycles. They were absent from January to April, July, August and December during both the periods of study (Table-XI).

The genus Navicula recorded a peak in September with 2,400 units/litre and a minimum in November with 720 units/litre during the first annual cycle and was absent in the months of January to April, June to August. In the next cycle the month of March recorded the maximum with 1,360 units/litre and the minimum in November with 280 units/litre and was absent in December. Frustulia was recorded only in June with 1,600 units/litre during the first annual cycle. In the second cycle February and March only recorded their occurrence represented by 2,240 units/litre and 560 units/litre respectively.

The family Fragilariaceae represented by a single genus Synedra was recorded in October (1,520 units/litre), November (680 units/litre) and October (280 units/litre) and was absent during the remaining months of both the cycles (Table-XI).

The class Myxophyceae revealed maximum densities in January and February registering 31,360 units/litre and 10,720 units/litre respectively during the first and second cycles. Their minimum densities were recorded in July with 60 units/litre and 1,800 units/litre in October during the first and second cycle and was absent for seven months during both the cycles (Table-XI).

The class Myxophyceae recorded a maximum and minimum relative percent abundance in January with 10.6% and 0.1% in April during the first annual cycle. In the next cycle the maximum was recorded in November with 7.8% and the minimum in March with 4.5% (Fig. 7).

Myxophyceae was comprised of three families Oscillatoriaceae, Chroococcaceae and Nostocaceae. The family Oscillatoriaceae was represented by a single genus Spirulina which was recorded only in November and February representing 480 units/litre each. The family Chroococcaceae was represented by two genera Coelosphaerium and Merismopedia. It showed a maximum density in June registering 2,800 units/litre and the minimum in December with 820 units/litre and was absent for eight months during the first annual cycle. In the next cycle a maximum was registered in February with 9,280 units/litre and a minimum in October with 1,800 units/litre and was absent from November to January (Table-XI).

The genus Coelosphaerium was registered only on two occassions recording 820 units/litre and 720 units/litre in December and April during the first annual cycle. In the next cycle a peak with 9,280 units/litre was recorded in February and a minimum in October with 1,200 units/litre and was absent from November to January. The genus Merismopedia was also recorded only on two occasions during the first annual cycle in the month of April with 960 units/litre and May with 2,800 units/litre. In the next cycle October registered 600 units/litre and March with 1,440 units/litre and was absent from November to February (Table-XI).

The class Dinophyceae revealed a peak in May recording 2,320 units/litre and the minimum in March with only 120 units/litre during the first annual cycle. They were absent for seven months. During the second cycle, March recorded 6,480 units/litre and February with 4,32 4,320 units/litre and was absent from October to January (Table-XI).

When the relative percent abundance of this class was seen, July recorded the maximum with 21.7% and the minimum was in March with only 0.1% during the first annual cycle. In the next cycle March recorded 17.5% as the maximum and February 9.8% as the minimum (Fig.7).

The class was represented by two families with one genus each. The family Ceratiaceae represented by Ceratium occurred thrice and recorded a maximum in November registering 300 units/litre and a minimum in March with 120 units/litre during the first annual cycle. In the next cycle it occurred twice with 6,480 units/litre in March and a minimum in February registering 4,320 units/litre. The family

Gymnodiaceae represented by a single genus *Gymnodinium* was registered only in May and July recording 2,320 units/litre and 400 units/litre during the entire investigation (Table-XI).

When the total phytoplankton was seen for its seasonal trend of fluctuation irrespective of the genera present under them, it revealed a spring maxima and more or less a summer minima during the first annual cycle. The next cycle showed an increase during the winter months (Table-XI).

The zooplankton recorded in the present investigation was represented by four major groups:- Cladocera, Copepoda, Rotifera and Protozoa. Cladocera was represented by Ceriodaphnia, Moina, Bosmina, Simocephalus and Diaphanosoma. Copepoda by Cyclops and Diaptomus; Rotifera by Asplanchna, Filina, Anuraeopsis, Polyarthra, Keratella, Lecane, Notholca, Trichocerca, Pleosoma, Hexarthra, Brachionus, Chromogaster, Colurella and Cephalodella; Protozoa by Trichodina, Coleps, Difflugia, Arcella and Diaphorodon. Though these were the ones present in the experimental ponds yet all genera were not present together and only some occurred and dominated at the different ponds during the present study.

CONTROL POND : The control pond registered four genera under the group Cladocera. The genus Ceriodaphnia recorded a maximum peak in April representing 3,200 units/litre and recorded a minimum of 20 units/litre in September during the first annual cycle. In the next cycle October recorded 16 units/litre and were absent for the remaining periods. The genus Moina recorded a peak in November with 333 units/litre and a minimum in January with 10 units/litre during the first annual cycle. In the second cycle March represented 52 units/litre as the maximum and nil in November and February. The genera Bosmina and Simocephalus recorded 20 and 190 units/litre in December and November respectively and were absent throughout the entire period of study (Table-XII).

The group Copepoda was represented by two genera Cyclops and Diaptomus. Cyclops showed a bimodal peak with maximal abundance, one in winter and the other in summer at least for the first annual cycle, with second peak moved earlier to Spring during the second cycle. Diaptomus also showed a winter and summer maximal abundance for the

TABLE-XII

Seasonal abundance of zooplankton, their major groups, genera and the total zooplankton (units/litre) in the Control Pond.

(A) CLADOCERA

1. *Ceriodaphnia*
2. *Moina*
3. *Bosmina*
4. *Simocephalus*

(B) COPEPODA

5. *Cyclops*
6. *Diaptomus*

(C) ROTIFERA

7. *Asplanchna*
8. *Filina*
9. *Anuraeopsis*
10. *Polyarthra*
11. *Keratella*
12. *Lecane*
13. *Notholca*
14. *Trichocerca*
15. *Ploesoma*
16. *Brachionus*
17. *Hexarthra*

(D) PROTOZOA

18. *Trichodina*
19. *Coleps*
20. *Difflugia*
21. *Diaphoradon*

TABLE - XII

Sl.No.	1979-80 OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	1980-81 OCT	NOV	DEC	JAN	FEB	MAR
(A)	11	678	40	10	0	95	3200	320	0	29	143	234	26	0	27	26	0	52
1.	0	155	0	0	0	926	3200	320	0	0	0	20	16	0	0	0	0	0
2.	11	333	20	10	0	26	0	0	0	29	143	214	10	0	27	26	0	52
3.	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.	0	190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(B)	719	1665	3580	1578	240	386	2840	2268	1640	172	327	1080	546	170	320	224	960	915
5.	474	633	1700	722	160	277	1460	1190	1020	93	209	668	338	93	153	136	420	529
6.	245	1032	1880	856	80	109	1380	1070	620	79	119	411	208	77	166	88	540	386
(C)	1693	4470	3380	2080	520	1240	3620	3600	680	1100	2010	950	980	240	3847	1000	1640	1440
7.	0	0	40	0	0	0	1180	360	480	0	0	0	0	0	0	0	0	0
8.	40	1050	100	0	0	0	0	0	0	560	70	0	300	0	47	160	0	0
9.	0	480	180	900	0	0	0	1540	0	140	1010	160	0	0	0	160	480	360
10.	133	500	40	360	0	0	0	0	200	0	0	0	0	0	1200	0	320	0
11.	93	1010	860	700	240	0	440	260	0	0	0	0	0	180	1800	0	520	0
12.	0	0	40	0	0	0	0	0	0	0	30	0	0	60	800	120	0	160
13.	40	0	80	0	0	0	0	260	0	0	0	30	0	0	0	0	320	0
14.	1067	620	60	120	120	0	0	140	0	240	440	280	680	0	0	80	0	160
15.	0	0	0	0	0	0	480	560	0	0	0	0	0	0	0	0	0	0
16.	320	810	1980	0	160	1240	1520	0	0	160	460	480	0	0	0	480	0	760
17.	0	0	0	0	0	0	0	480	0	0	0	0	0	0	0	0	0	0
(D)	1734	880	100	0	500	1360	800	240	0	0	0	0	1160	260	1200	380	880	280
18.	67	280	100	0	0	0	0	0	0	0	0	0	0	0	1200	0	200	0
19.	0	600	0	0	0	0	800	0	0	0	0	0	0	260	0	0	0	0
20.	1667	0	0	0	500	1360	0	0	0	0	0	0	1160	0	0	380	680	280
21.	0	0	0	0	0	0	0	240	0	0	0	0	0	0	0	0	0	0
TOTAL	4157	7693	7100	3668	1260	3938	10460	6420	2320	1301	2480	2264	2712	670	5394	1630	3480	2687

first annual cycle and with the second peak in early spring of the second cycle.

Cyclops showed a maximum abundance in December and March representing 1,700 units/litre and 529 units/litre in the first and second cycles respectively and the minimum was recorded in July with 93 units/litre and November (93 units/litre) for the first and second cycles. The genus Diaptomus revealed a peak in December recording 1,880 units/litre and a minimum in July with 79 units/litre during the first annual cycle. In the next cycle a peak was registered in March representing 386 units/litre and a minimum in November recording 77 units/litre (Table-XII).

Eleven genera of Rotifera were recorded in this pond. Asplanchna showed a spring maxima and winter minima during the first annual cycle, but the next cycle recorded their complete absence. Filina, Polyarthra, Keratella and Trichocerca recorded peaks with maximal abundances in winter with summer minima. Brachionus revealed a bimodal peak of maximal abundance in winter and spring during the first and second cycles. Anuraeopsis showed a late spring maxima and winter minima (Table-XII).

Asplanchna had its maximum numbers of abundance in the month of April (1,180 units/litre) and December with 40 units/litre as minimum during the first annual cycle and was recorded nil throughout the second cycle. Filina recorded peaks of abundance in November (1,050 units/litre) and February (480 units/litre) during the first and second cycles. The genera Polyarthra and Keratella recorded maximal peaks of abundance in the months of November (500 units/litre and 1,010 units/litre) and December (1,200 units/litre and 1,800 units/litre) during the first and second cycles respectively. Trichocerc recorded maximal peaks of abundance in the months of

October (1,067 units/litre and 680 units/litre) for the first and second annual cycles respectively. The minimum was recorded in December with 60 units/litre and January with 80 units/litre during the first and second cycles. Brachionus recorded peaks of abundance in December (1,980 units/litre) and April (1,520 units/litre) for the first annual cycle and in March (760 units/litre) during the second cycle. Anuraeopsis showed maximal peaks of abundance in May (1,540 units/litre) and in February (480 units/litre) during the first and second cycles. Lecane was insignificantly represented during the first cycle, however, recorded a peak of abundance in the second cycle in December (800 units/litre). Notholca was recorded in October, December, May and September with the maximal peak in May (260 units/litre) during the first annual cycle and in the next cycle it was recorded only in February (320 units/litre). The genera Pleosoma and Hexarthra were recorded only in April and May (480, 560 units/litre) and (480 units/litre) respectively (Table-XII).

The group Protozoa was represented by four genera, Trichodina, Coleps, Difflugia and Diaphorodon. The genus Trichodina revealed a winter maximal peak of abundance and nil values during the summer. Difflugia showed a peak of maximum abundance in winter and early spring during the first and second cycles. Coleps revealed a spring and winter peak and the genus Diaphorodon was recorded only in early summer of May (240 units/litre).

Trichodina showed its maximum numbers of abundance in the months of November (280 units/litre) and December (1,200 units/litre) in the first and second cycles. Difflugia recorded its maximum abundance in October (1,167 units/litre) and March (1,360 units/litre) during the first annual cycle. In the second cycle it showed their peaks of abundance in October (1,160 units/litre) and March (280 units/litre) (Table-XII).

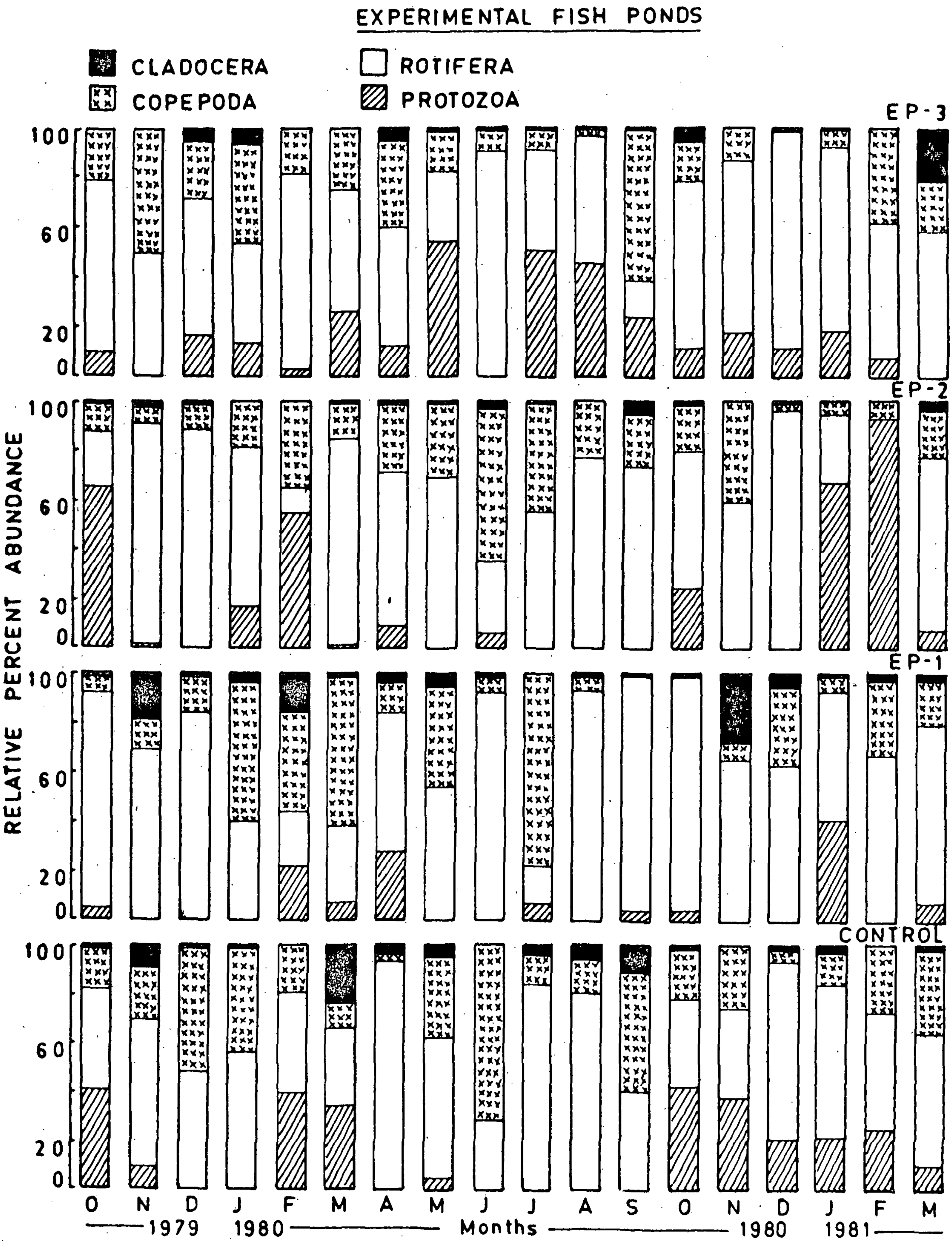
When the groups of zooplankton were seen for their seasonal fluctuations irrespective of the genera present under them, Cladocera showed a fluctuation abundance as spring and summer maxima and winter minima. Copepoda revealed a winter and spring maxima and summer minima. The group Rotifera showed a spring maxima and autumn minima, while Protozoa revealed a spring and autumn maxima and summer minima (Table-XII).

When the relative percent abundance of these groups were seen, Cladocera registered maximum in March with 24.3% and a minimum in January with only 0.3% during the first cycle. In the next cycle March and December recorded the maximum and minimum with 1.9% and 0.6% respectively. Copepoda registered maximum percent abundance in June and March recording 70.7% and 34.2% respectively during the first and second cycles. The minimum was seen in April with 3.6% and December with 5.9% during the first and second cycles. Rotifera recorded 91.5% in April and 71.3% in December as maximum during both the cycles and minimum in June with 29.3% and November with 35.8% during the first and second cycles respectively. The group Protozoa recorded 41.7% and 42.8% as maximum in October during both the cycles and the minimum in December with 1.4% and March with 10.4% during the first and second cycles respectively (Fig. 8).

When the zooplankton and its seasonal abundance was seen they showed a bimodal peak of abundance one in winter and the other in spring during the first and second cycles and a minima in summer (Table-XII).

Fig. 8 - Showing histograms representing the seasonality of the relative percent abundance of the major zooplanktonic groups in the Control and Experimental fish Ponds.

EP = Experimental Fish Ponds.



EXPERIMENTAL FISH PONDS
CLADOCERA
COPEPODA
ROTIFERA
PROTOZOA
EP-3
EP-2
EP-1
CONTROL
RELATIVE PERCENT ABUNDANCE
100
60
20
0
O N D J F M A M J J A S O N D J F M
1979 1980 Months 1980 1981

EXPERIMENTAL FISH POND-1

The four groups of zooplankton recorded in this pond-1 were Cladocera, Copepoda, Rotifera and Protozoa. The group Cladocera was represented by four genera Ceriodaphnia, Moina, Bosmina and Diaphanosoma. Ceriodaphnia showed a bimodal peak with maximal abundance in winter and summer months and minima in spring and autumn. Moina revealed a summer minima and winter maxima. The genera Bosmina and Diaphanosoma were recorded only once during the winter months.

Ceriodaphnia recorded a maximum peak of abundance in May, registering 1,260 units/litre and a smaller peak in November with 520 units/litre with a minimum in April of only 47 units/litre during the first annual cycle. In the second cycle, November recorded the maximum and March as the minimum with 114 units/litre and 28 units/litre respectively and was absent in October. The genus Moina recorded a peak in November with 280 units/litre and 94 units/litre during the first and second cycles respectively. The months of December and January recorded 20 units/litre and 26 units/litre respectively as the minimum during the same period. Bosmina and Diaphanosoma occurred only in November with 1,120 units/litre and the latter with 60 units/litre during both the cycles (Table-XIII).

The group Copepoda was represented by two genera, Cyclops and Diaptomus. The genus Cyclops revealed a summer maxima and winter minima. Diaptomus similarly showed a winter minima and summer maxima. Cyclops recorded peaks of abundance in July and February recording 14,453 units/litre and 340 units/litre respectively during the first and second cycles. The months of September with 17 units/litre and October with 85 units/litre recorded the minimum counts during the first and second cycles. Diaptomus recorded peaks of abundance in July registering 14,084 units/litre and in March with 309 units/litre

TABLE-XIII

Seasonal abundance of zooplankton, their major groups, genera and the total zooplankton (units/litre) in the Experimental Fish Pond-1.

(A) CLADOCERA

1. *Ceriodaphnia*
2. *Moina*
3. *Bosmina*
4. *Diaphanosoma*

(B) COPEPODA

5. *Cyclops*
6. *Diaptomus*

(C) ROTIFERA

7. *Asplanchna*
8. *Filina*
9. *Anuraeopsis*
10. *Chromogaster*
11. *Polyarthra*
12. *Keratella*
13. *Lecane*
14. *Notholca*
15. *Trichocerca*
16. *Brachionus*

(D) PROTOZOA

17. *Trichodina*
18. *Difflugia*
19. *Arcella*
20. *Diaphorodon*

TABLE - XIII

Sl.No.	1979-80 OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	1980-81 OCT	NOV	DEC	JAN	FEB	MAR
(A)	27	860	20	91	454	160	141	1260	134	0	199	0	0	1328	91	26	58	92
1.	0	520	0	0	420	160	47	1260	0	0	0	0	0	114	39	0	0	28
2.	27	280	20	91	34	0	94	0	134	0	199	0	0	94	52	26	58	64
3.	0	0	0	0	0	0	0	0	0	0	0	0	0	1120	0	0	0	0
4.	0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(B)	215	520	186	1300	1177	6690	367	11000	501	28537	717	32	206	407	507	300	571	506
5.	86	330	73	728	789	5480	186	6110	284	14453	426	17	85	245	215	235	341	211
6.	129	190	113	572	388	1210	181	4890	217	14084	291	15	121	162	292	201	230	295
7.																		
(C)	3240	3120	960	960	524	3740	2000	14880	7640	5740	12640	4684	9680	3160	960	2080	1240	1980
7.	40	0	0	0	0	0	440	0	0	0	0	0	440	0	0	0	0	0
8.	900	0	0	0	0	0	240	0	1400	0	0	0	0	80	0	0	0	300
9.	400	0	0	960	300	0	240	6880	3380	660	5440	480	660	520	0	1200	520	0
10.	0	0	0	0	0	0	0	1460	0	0	0	0	0	0	0	0	0	0
11.	160	0	240	0	0	700	0	0	900	640	0	1880	1340	320	320	0	0	0
12.	516	0	0	0	0	140	600	2040	0	0	0	1080	2780	720	0	0	280	760
13.	280	0	0	0	0	440	80	600	720	0	0	0	840	180	0	0	0	440
14.	0	0	160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.	900	1440	0	0	0	0	40	0	0	2160	2400	520	2460	760	0	320	0	200
16.	0	1680	560	0	224	2460	360	3900	1240	2280	4800	720	1160	580	640	560	440	280
(D)	240	0	0	0	700	760	960	0	0	2180	0	166	240	0	0	1680	0	200
17.	0	0	0	0	0	760	0	0	0	0	0	160	240	0	0	0	0	0
18.	0	0	0	0	180	0	520	0	0	520	0	0	0	0	0	1520	0	0
19.	240	0	0	0	0	0	0	0	0	1660	0	0	0	0	0	0	0	40
20.	0	0	0	0	520	0	440	0	0	0	0	0	0	0	0	160	0	160
TOTAL	3722	4500	1166	2351	2855	11350	3468	27140	8275	36457	13556	4876	10126	4895	1558	4086	1869	2778

during the first and second cycles. It recorded a minimum in September with 15 units/litre during the first annual cycle and October with 121 units/litre as the minimum during the second cycle (Table-XIII).

Ten genera of the group Rotifera were represented in this pond. Asplanchna was recorded only during the autumn and summer months. Filina revealed a summer maxima and winter minima. The genera Anuraeopsis and Chromogaster recorded summer maxima and winter minima. Polyarthra revealed an autumn maxima and spring minima. The genera Keratella, Lecane and Trichocerca revealed a fluctuation trend of autumn maxima and winter minima. Brachionus recorded a summer maxima and winter minima, while the genus Notholca was recorded only once in December with 160 units/litre.

Asplanchna was recorded only in October and April representing 40 units/litre and 440 units/litre and in October with 440 units/litre during the first and second cycles and was absent during the other months of both the cycles. Filina was recorded in October, April and June during the first annual cycle, with the month of June recording a maximum representing 1,400 units/litre during the first annual cycle. In the next cycle the months of November with 80 units/litre and March with 300 units/litre were recorded. Anuraeopsis recorded a peak of abundance in May with 6,880 units/litre and a minimum in April with 240 units/litre during the first annual cycle and was absent in the months of November, December and March. In the second cycle January recorded the maximum and November and February recorded the minimum with 1,200 units/litre and 520 units/litre respectively. It was absent in December. Chromogaster was recorded in May with 1,460 units/litre and was absent during the other months of both the cycles. Polyarthra recorded a peak of abundance in September registering 1,880 units/litr and a minimum in December with 240 units/litre and registered their occurrence four times during the first annual cycle. A peak was recorded in October with 1,340 units/litre and 320 units/litre in November and December during the second cycle and was absent from January to March.

Keratella revealed a peak in May recording 2,040 units/litre and the minimum in March recording only 140 units/litre and was absent from November to February and June to August during the first annual cycle. In the next cycle October recorded the maximum representing 2,780 units/litre and a minimum in February recording 280 units/litre. Lecane revealed peaks in June registering 720 units/litre and in October with 840 units/litre during the first and second cycles and recorded minimum in September with only 4 units/litre and November with 180 units/litre during the first and second cycles respectively. Trichocerca recorded peaks of abundance in August recording 2,400 units/litre and Brachionus in the same month with 4,800 units/litre during the first annual cycle. The month of April revealed the minimum for Trichocerca recording only 40 units/litre and for Brachionus in February with 224 units/litre during the first annual cycle. These two genera recorded peaks of abundance in October representing 2,460 units/litre and 1,160 units/litre during the second annual cycle (Table-XIII).

The group Protozoa was represented by four genera, Trichodina, Difflugia, Arcella and Diaphorodon. Trichodina was recorded only in spring and autumn months and was absent during winter and summer. Difflugia revealed summer and winter maxima. Arcella was recorded only in Autumn, Summer and Spring and Diaphorodon revealed spring occurrence and complete disappearance during the other seasons.

Trichodina was recorded in March with 760 units/litre and in September with 160 units/litre and was absent during the other months of the first annual cycle. In he next cycle October registered with 240 units/litre. Diffluqia showed higher individual counts in April and July recording 520 units/litre each during the first annual cycle but occurred only once in January with 1,520 units/litre during the second cycle. Arcella was recorded in October with 240 units/litre and in July representing 1,660 units/litre and was absent during the other months of the first annual cycle. In the next cycle only the month of March recorded 140 units/litre. Diaphorodon recorded a maximum count of 520 units/litre in February and in April with 440 units/litre during the first cycle and in the next cycle January and March revealed their presence recording 160 units/litre each (Table-XIII).

When the groups of zooplankton were seen for their seasonal fluctuations irrespective of the genera present under them, Cladocera revealed summer and winter maxima and autumn minima. Copepoda revealed a trend of summer maxima and winter minima. The group Rotifera showed a bimodal peak of fluctuation with spring and autumn maxima and winter minima and Protozoa recorded a summer maxima and winter minima during the first annual cycle and in the second cycle the peak shifted to early spring (Table-XIII).

When the relative percent abundance of the groups were seen, the seasonal trend of fluctuations followed more or less a similar pattern to their actual numbers. The group Copepoda revealed a maximum of 78.4% in July and 32.5% in December during the first and second cycles. The months of September with 0.7% and October with 2.0% represented the minimum percent abundance. Rotifera recorded a maximum in September with 96.1% and a minimum in July with only 15.7% during the first annual cycle. In the next cycle October and January recorded the maximum representing 95.6% and 50.9% respectively. The group Protozoa registered a maximum in April recording 27.6% and a minimum in September with only 3.2% during the first annual cycle. In the next cycle January with 41.2% and October with 7.2% recorded the minimum percent abundance (Fig. 8).

When the total zooplankton and its seasonal abundance was seen for both the cycles, it revealed a bimodal peak of abundances with spring and summer maxima and winter minima (Table-XIII).

EXPERIMENTAL FISH POND-2

The four groups of zooplankton recorded in the pond-2 were Cladocera, Copepoda, Rotifera and Protozoa.

The Cladocera though present in most of the study periods constituted only a meagre zooplankton population. In this pond only two genera were represented, Ceriodaphnia and Moina. The former genus recorded a peak of abundance in April and the latter in June recording 340 units/litre and 459 units/litre respectively during the first annual cycle. In the second cycle March and October registered the maximum abundance with 78 units/litre and 53 units/litre respectively. Ceriodaphnia revealed spring maxima and summer minima, whereas Moina recorded a summer maxima and winter minima during the entire period of study (Table-XIV).

The group Copepoda was represented by two genera, Cyclops and Diaptomus. Cyclops showed maximal abundance in summer and minimum in winter. It recorded maximum abundance in June (6,792 units/litre) and recorded minimum in July (187 units/litre) during the first annual cycle. Diaptomus recorded a peak of abundance in June (6,277 units/litre) and minimum in July (113 units/litre). In the second cycle Cyclops recorded maximum in March (500 units/litre) and Diaptomus in November (338 units/litre) and their minimum in December recording 140 units/litre and 86 units/litre respectively (Table-XIV).

The group Rotifera constituted the most important zooplankton population in this pond and was comprised of eleven genera viz., Asplanchna, Lecane, Anuraeopsis, Polyarthra, Keratella, Trichocerca, Pleosoma, Chromogaster, Filina, Colurella and Brachionus. Asplanchna was recorded only in January (400 units/litre) and December with (800 units/litre) during the entire period of study. Lecane revealed a peak of abundance in spring and was absent in winter and summer months

TABLE-XIV

Seasonal abundance of zooplankton, their major groups, genera and the total zooplankton (units/litre) in the Experimental Fish Pond-2.

(A) CLADOCERA

1. *Ceriodaphnia*
2. *Moina*

(B) COPEPODA

3. *Cyclops*
4. *Diaptomus*

(C) ROTIFERA

5. *Asplanchna*
6. *Lecane*
7. *Anuraeopsis*
8. *Polyarthra*
9. *Keratella*
10. *Trichocerca*
11. *Ploesoma*
12. *Chromogaster*
13. *Filina*
14. *Brachionus*
15. *Colurella*

(D) PROTOZOA

16. *Trichodina*
17. *Arcella*
18. *Difflugia*
19. *Diaphorodon*

TABLE - XIV

	1979-80												1980-81					
Sl.No.	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
(A)	24	139	79	0	0	228	340	76	486	13	37	107	64	0	46	0	0	124
1.	0	56	26	0	0	0	340	0	27	0	0	20	11	0	20	0	0	78
2.	24	83	53	0	0	228	0	76	459	13	37	87	53	0	26	0	0	46
(B)	798	535	566	1506	2800	5320	4460	3226	13069	300	518	433	643	650	226	448	214	767
3.	439	285	350	783	1360	1719	3150	2144	6722	187	405	216	366	312	140	197	127	500
4.	359	250	216	723	1440	3601	1310	1082	6277	113	113	217	277	338	86	251	87	267
(C)	1360	9180	4120	5200	800	28386	10580	7139	6131	360	1680	1440	1880	960	7800	2561	0	2840
5.	0	0	0	400	0	0	0	0	0	0	0	0	0	0	800	0	0	160
6.	0	0	0	0	0	1368	0	0	0	0	0	0	560	320	0	0	0	0
7.	100	2200	120	0	0	0	2060	0	0	0	0	720	400	0	0	0	0	0
8.	0	1700	0	0	0	1368	220	0	0	0	0	0	0	0	2600	600	0	0
9.	0	540	2200	2560	0	20178	0	0	1800	0	0	0	0	0	0	0	0	720
10.	1260	1800	800	640	0	2736	0	0	0	0	0	0	0	320	1200	800	0	360
11.	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.	0	0	0	0	0	0	1680	0	0	0	0	0	0	0	0	0	0	0
13.	0	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160
14.	0	2400	1000	1600	800	2736	6620	7139	4331	360	1680	720	920	320	2600	1160	0	1440
15.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	600	0	0	0
(D)	3940	40	0	1400	4520	274	1520	0	930	0	0	0	860	0	0	5720	2640	320
16.	3940	0	0	1400	0	0	0	0	600	0	0	0	260	0	0	1960	0	0
17.	0	0	0	0	0	0	0	0	330	0	0	0	0	0	0	0	0	0
18.	0	40	0	0	4520	0	0	0	0	0	0	0	600	0	0	3760	0	0
19.	0	0	0	0	0	274	1520	0	0	0	0	0	0	0	0	0	2640	320
TOTAL	6122	9894	4765	8106	8120	34208	16900	10441	20616	673	2235	1980	3447	1610	8072	8728	2854	4051

during the first annual cycle. In the next cycle October and November recorded 560 units/litre and 320 units/litre and were absent for the remaining periods. The genera Anuraeopsis, Polyarthra, Keratella, Trichocerca, Chromogaster and Brachionus revealed spring and winter maxima and summer minima.

The most dominant genera recorded were Brachionus, Trichocerca, Keratella, Anuraeopsis and Polyarthra, while the other genera were scantily represented. Asplanchna, Lecane, Pleosoma, Chromogaster, Filina and Colurella were only once or twice recorded during both the cycles. Brachionus recorded nil values in October and gradually increased and persisted throughout the first annual cycle with May registering the maximum peak of abundance (7,139 units/litre) which thereafter decreased to record a minimum in July (360 units/litre). In the next cycle December revealed maximum (2,600 units/litre) and a minimum in November (320 units/litre) and was absent in February. Trichocerca registered a small peak in November (1,800 units/litre) which thereafter decreased to record nil in February. In March it revealed the maximum peak of abundance representing 2,736 units/litre and was absent for the remaining months of the first annual cycle. December of the second cycle registered a maximum of 1,200 units/litre and recorded nil in October and February. Keratella recorded maximum in March (20,178 units/litre) and a minimum in November with 540 units/litre and occurred only on three occasions during the first annual cycle. In the next cycle, it was only present in March (720 units/litre). Anuraeopsis recorded two peaks of abundance in November (2,200 units/litre) and April with 2,060 units/litre during the first cycle and was recorded only in October with 400 units/litre during the second cycle. Polyarthra revealed peaks of abundance in November (1,700 units/litre) and March (1,368 units/litre) and were absent during the summer and autumn months during the first annual cycle. In the next cycle it was present only in December (2,600 units/litre) and January (600 units/litre) (Table-XIV).

Finally, the group Protozoa which was irregularly present was represented by four genera. *Trichodina* recorded peaks of abundance in the winter months and minimum in spring and autumn. *Arcella* was recorded only in June during the entire period of study. *Difflugia* revealed maximum abundance in spring and winter months and absence in the summer months. *Diaphorodon* recorded spring abundance and was absent during the other seasons. It occurred in March and April recording (274 units/litre) and (1,520 units/litre) and remained absent during the other months of the first annual cycle. However, it reappeared again in February (2,640 units/litre) and March (320 units/litre) during the first annual cycle. In the next cycle, the only months of October and January recorded their presence registering 600 units/litre and 3,760 unit /litre respectively. *Trichodina* registered a peak of abundance in October (3,940 units/litre) and in January (1,960 units/litre) during the first and second cycles respectively and was recorded present only on three occasions during both the cycles (Table-XIV).

When the major groups of zooplankton and their trends of seasonal fluctuations were observed, Cladocera and Copepoda recorded a summer maxima and winter minima. Rotifera however showed a spring and winter maxima and summer and autumn minima and Protozoa revealed a trend of early spring maxima and summer minima (Table-XIV).

When the percentage abundance of these groups were seen, the group Cladocera revealed a maxima with 5.5% in September despite its lean population over the peak month which showed only 2.4% in June. However, March of the second cycle recorded 3.1% abundance as maximum in conformity with the peak population recorded. Copepoda revealed maxima in June with 63.4% and minima in December with only 11.9% during the first annual cycle. The months of December and November recorded the minima and maxima with 2.8% and 40.4% abundance. Rotifera recorded a maximum of 92.7% in November, while the peak month of March was only 82.9%. In the second cycle however the relative percent abundance followed a trend more or less similar to their actual numbers. Protozoa revealed a maximum of 64.4% in October though in terms of population abundance it was relatively smaller to the peak month of February which recorded only 55.7%. Similarly during the second cycle, February recorded 92.5% and January only 65.5% (Fig. 8).

When the total zooplankton and its trend of fluctuation was observed it revealed a winter and spring maxima and summer minima (Table-XIV).

EXPERIMENTAL FISH POND-3

This pond was also seen to comprise of four major groups of zooplankton. The group Cladocera was represented by three genera; *Ceriodaphnia* which recorded winter and spring peaks during the first annual cycle and was absent during autumn and winter months during the second cycle. *Moina* revealed peaks of abundance in spring and autumn with winter minima. *Diaphanosoma* was only recorded in April (14 units/litre) during the first annual cycle. *Ceriodaphnia* was most abundant in the months of May (270 units/litre) and in December (340 units/litre) and recorded a minimum of 7 units/litre during the first annual cycle. In the next cycle it was recorded only in March representing 73 units/litre. *Moina* recorded peaks of abundance in the months of April (150 units/litre) and in October (100 units/litre) during the first and second cycles. The months of July and March recorded minimum counts with 7 units/litre and 28 units/litre respectively during the first and second cycles (Table-XV).

The group Copepoda was represented by two genera, *Cyclops* and *Diaptomus*. Both these genera had more or less a similar trend of abundance recording maximum in the months of May (1,030 units/litre) and (999 units/litre) respectively during the first annual cycle. The minimum count of *Cyclops* was registered in March with 86 units/litre and *Diaptomus* in July with 125 units/litre during the same period. Similarly, February recorded the maximum peak of abundance recording 1,720 units/litre and 1,320 units/litre respectively. The minimum count of *Cyclops* was recorded in March with 13 units/litre and *Diaptomus* also in March with 94 units/litre during the same period. The two genera revealed a seasonal trend of fluctuation with spring maxima and summer minima (Table-XV).

The group Rotifera constituted the most dominant zooplankton

TABLE-XV

Seasonal abundance of zooplankton, their major groups, genera, and the total zooplankton (units/litre) in the Experimental Fish Pond-3.

(A) CLADOCERA

1. *Ceriodaphnia*
2. *Moina*
3. *Diaphanosoma*

(B) COPEPODA

4. *Cyclops*
5. *Diaptomus*

(C) ROTIFERA

6. *Filina*
7. *Asplanchna*
8. *Lecane*
9. *Anuraeopsis*
10. *Polyarthra*
11. *Keratella*
12. *Trichocerca*
13. *Colurella*
14. *Brachionus*
15. *Notholca*

(D) PROTOZOA

16. *Trichodina*
17. *Difflugia*
18. *Diaphorodon*

TABLE - XV

Sl.No.	1979-80 OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	1980-81 OCT	NOV	DEC	JAN	FEB	MAR
(A)	0	20	340	240	14	30	185	270	117	27	68	13	100	39	0	91	0	101
1.	0	0	340	240	0	0	21	270	39	20	7	0	0	0	0	0	0	73
2.	0	20	0	0	14	30	150	0	78	7	61	13	100	39	0	91	0	28
3.	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0
(B)	1520	1545	1340	1440	289	397	1420	2030	689	294	212	860	300	798	208	767	3040	107
4.	760	779	670	760	109	87	950	1030	338	169	77	261	74	376	124	397	1720	13
5.	760	766	670	680	180	310	470	999	351	125	135	599	226	362	84	870	1320	94
(C)	5240	1600	3420	1460	1320	760	1910	3580	8800	1260	8400	200	1120	4420	11600	6000	4400	280
6.	0	0	0	0	0	0	1600	140	0	0	0	0	0	0	0	0	0	0
7.	0	0	0	200	0	0	0	0	0	0	0	0	240	640	0	0	1320	0
8.	0	0	240	0	200	0	0	0	0	120	100	0	0	0	0	0	880	0
9.	820	280	0	0	40	0	0	300	0	0	0	0	0	160	0	0	0	40
10.	2520	240	480	0	120	0	0	480	0	0	0	0	0	0	0	2400	0	0
11.	0	0	700	840	600	400	120	740	0	360	0	0	560	640	5200	3600	880	0
12.	660	600	820	0	200	240	50	740	3200	760	2600	0	0	0	4800	0	840	120
13.	800	0	0	0	0	0	110	0	0	0	0	0	0	0	0	0	0	0
14.	440	480	1180	420	160	120	30	1180	5600	20	2700	200	320	2980	1600	0	480	60
15.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60
(D)	700	0	920	480	40	413	450	6980	0	1600	5100	320	160	1280	1600	1600	520	0
16.	0	0	360	480	40	413	0	340	0	0	0	320	160	1280	1600	0	520	0
17.	0	0	0	0	0	0	450	340	0	1600	5100	0	0	0	0	0	0	0
18.	700	0	560	0	0	0	0	6300	0	0	0	0	0	0	0	1600	0	0
TOTAL	7460	3165	6020	3620	1663	1600	3965	12860	4605	3181	10780	1393	1680	6537	13408	8458	7960	488

in this pond and consisted of twelve genera. Keratella recorded a winter maxima and summer minima. Brachionus showed a trend of seasonal fluctuation with summer and winter maxima and spring minima. The genus Trichocerca showed a summer and winter maxima and autumn and spring minima. The genera Filina, Pleosoma, Colurella, Cephalodella and Notholca were represented very insignificantly and recorded mostly during the spring seasons. Anuraeopsis though scantily represented showed maximum abundance in late spring and winter season during the first annual cycle. Polyarthra revealed a winter maxima and summer minima. Lecane revealed a trend of increase during the winter months and summer months and Asplanchna was sparsely represented in both the cycles with the exception of February of the second cycle.

The genera Filina and Colurella were recorded only in the month of April representing 1,600 units/litre and 110 units/litre respectively. Asplanchna was present only in January with 200 units/litre during the first annual cycle. In the second cycle it recorded a peak in February registering 1,320 units/litre and a minimum in October with only 240 units/litre. Lecane revealed a peak of abundance in December and February recording 240 units/litre and 800 units/litre during the first and second cycles respectively. Anuraeopsis was registered only in the months of October, November, February and May recording 320 units/litre in October as the maximum during the first annual cycle. In the next cycle also November and March recorded 160 units/litre and 40 units/litre respectively. Polyarthra revealed a peak in October with 2,520 units/litre and a minimum in February with 120 units/litre and was recorded only on three occasions during the first annual cycle. The month of January during the second cycle recorded 2,400 units/litre and was absent during the remaining periods. Keratella showed peaks of maximum abundance in the months of January with 840 units/litre and December with 5,200 units/litre during the first and second cycles. The months of April with 120 units/litre and October with 560 units/litre recorded the minimum during the first and second cycles. *Trichocerca* recorded a peak in June with 3,200 units/litre and a minimum in April with 50 units/litre and was absent in January and September during the first annual cycle. In the next cycle, the month of December registered 4,800 units/litre as maximum and was present only in February and March recording 840 units/litre and 120 units/litre respectively. The genera *Pleosoma* and *Cephalodella* were recorded only in October registering 660 units/litre and 440 units/litre respectively. *Brachionus* was well represented over the entire period and recorded peaks of abundance in June with 5,600 units/litre and November with 2,980 units/litre during the first and second cycles. The months of July and March registered the minimum counts with 20 units/litre and 60 units/litre during the first and second cycle respectively. The genus *Notholca* was totally absent in both the cycles with the only exception of the month of May which recorded 140 units/litre (Table-XV).

The group Protozoa was represented by three genera *Trichodina*, *Difflugia* and *Diaphorodon*, all well represented during both the cycles in terms of their occurrence. Of these three genera, *Trichodina* and *Difflugia* constituted the dominant forms. *Trichodina* revealed a spring and autumn maxima and summer minima, while *Difflugia* was predominantly a summer occurring form with nil values recorded in the other seasons. *Diaphorodon* more or less revealed a summer and winter maxima.

The genus *Trichodina* recorded peaks of abundance in January and December representing 480 units/litre and 1,600 units/litre during the first and second cycles and the months of February and October recorded the minimum with 40 units/litre and 160 units/litre during the first and second cycles respectively and was recorded only on four occasion during the first cycle. Diffluqia was recorded only in April, May, July and August during the first annual cycle. The maximum peak of abundance was recorded in August registering 5,100 units/litre. Diaphorodon was recorded only in the months of October, December, May and January during both the cycles. The maximum was recorded in May representing a count of 6,300 units/litre and in January with 1,600 units/litre during the first and second cycles respectively (Table-XV).

When the group Zooplankton was seen for their seasonal fluctuations, Cladocera and Copepoda revealed a winter maxima and summer minima. The group Rotifera showed a bimodal peak of abundance with summer and winter maxima and spring minima and Protozoa showed more or less a summer maxima and winter minima (Table-XV).

When the relative percent abundance of the groups were observed Cladocera followed a trend more or less similar to their actual numbers representing 6.6% and 20.7% as maximum in January and March during the first and second cycles and their minimum recorded in November with 0.6% of both the cycles. Copepoda recorded a maximum of 61.8% in September and 38.2% in February during the first and second cycles. The minimum was recorded in August with 1.9% December with 1.6% during the first and second cycles. Rotifera showed maximum in June and December recording 91.6% and 86.5% during the first and second cycles. Their minimum was recorded in September with 14.4% and February with 55.3% during both the cycles. The group Protozoa recorded 54.3% as the maximum in May and 2.4% in February as the minimum during the first annual cycle. In the next cycle January and February recorded the maximum and minimum representing 18.9% and 6.5% respectively (Fig. 08).

When the total zooplankton and its seasonal abundance was observed it revealed winter and summer maxima and spring minima (Table-XV).

The Zooplankton recorded in the circular plastic pools were represented by four major groups-- Cladocera, Copepoda, Rotifera and Protozoa. Cladocera was represented by Ceriodaphnia, Moina, Bosmina and Diaphanosoma. Copepoda was represented by two genera, Cyclops and Diaptomus. Rotifera constituted the largest number of genera, Asplanchna, Filina, Anuraeopsis, Polyarthra, Keratella, Notholca, Pleosoma, Chromogaster, Ascomorpha, Brachionus, Cephalodella, Colurella and Lecane. Protozoa by Coleps, Diffluqia, Trichodina, Arcella and Diaphorodon. Though these were the ones recorded in the present investigation not all genera were present together and only some occurred and dominated at the different pools.

CONTROL POOL

The control pool comprised of two genera, Ceriodaphnia and Moina under the group Cladocera, which revealed a summer maxima and spring minima. Ceriodaphnia recorded a peak of abundance in July registering 320 units/litre and in March with 52 units/litre during the first and second cycles and was recorded absent from October to June, August and September during the first annual cycle and in the next cycle in the months of December to February. The genus Moina was recorded only in November, July and August representing 157 units/litre, 800 units/litre and 480 units/litre respectively during the first annual cycle. In the next cycle the months of October and November registered equal counts of 13 units/litre and a minimum of 4 units/litre in January and was absent in December, February and March (Table-XVI).

The group Copepoda was represented by two genera Cyclops and Diaptomus. The group constituted the second largest counts of organ-

<u>TABLE - XVI</u>

Sl.No.	1979-80 OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	1980-81 OCT	NOV	DEC	JAN	FEB	MAR
(A)	0	157	0	0	0	0	0	0	0	1120	480	0	34	40	0	4	0	52
1.	0	0	0	0	0	0	0	0	0	320	0	0	21	27	0	0	0	52
2.	0	157	0	0	0	0	0	0	0	800	480	0	13	13	0	4	0	0
(B)	940	337	0	191	0	0	0	0	0	2880	800	0	326	225	65	191	0	156
3.	320	167	0	100	0	0	0	0	0	2240	280	0	179	94	37	82	0	52
4.	620	170	0	91	0	0	0	0	0	640	520	0	147	131	28	109	0	104
(C)	1060	680	60	220	2200	0	2880	4120	24000	1600	800	3120	2200	2900	1600	3100	800	920
5.	0	0	0	0	0	0	0	240	0	0	0	0	0	0	0	700	0	0
6.	0	0	60	0	0	0	0	1000	0	0	0	680	0	0	700	200	0	0
7.	0	80	0	0	320	0	0	120	0	0	0	0	0	800	0	100	0	0
8.	0	160	0	0	0	0	0	0	0	0	0	0	0	600	600	0	200	400
9.	320	80	0	120	0	0	0	1160	0	0	480	1280	600	600	0	900	0	0
10.	0	0	0	0	0	0	280	0	0	0	0	0	0	0	0	0	0	0
11.	0	0	0	100	680	0	0	0	0	0	320	440	0	0	0	0	0	0
12.	740	180	0	0	1200	620	2600	1320	24000	1600	0	0	1600	600	300	1200	620	520
13.	0	0	0	0	0	0	0	160	0	0	0	720	0	0	0	0	0	0
14.	0	180	0	0	0	0	0	120	0	0	0	0	0	300	0	0	0	0
(D)	0	0	0	0	0	400	0	1160	0	0	0	680	1800	0	0	300	200	400
15.	0	0	0	0	0	400	0	0	0	0	0	680	1800	0	0	300	200	400
16.	0	0	0	0	0	0	0	480	0	0	0	0	0	0	0	0	0	0
17.	0	0	0	0	0	0	0	240	0	0	0	0	0	0	0	0	0	0
18.	0	0	0	0	0	0	0	440	0	0	0	0	0	0	0	0	0	0
TOTAL	2000	1174	60	411	2200	1020	2880	5280	24000	5600	2080	3800	4360	3165	1665	3595	1000	1528

TABLE-XVI

Seasonal abundance of zooplankton, their major groups, genera and total zooplankton (units/litre) in the Control Pool.

(A) CLADOCERA

1. *Ceriodaphnia*
2. *Moina*

(B) COPEPODA

3. *Cyclops*
4. *Diaptomus*

(C) ROTIFERA

5. *Lecane*
6. *Anuraeopsis*
7. *Polyarthra*
8. *Keratella*
9. *Trichocerca*
10. *Chromogaster*
11. *Filina*
12. *Brachionus*
13. *Ascomorpha*
14. *Notholca*

(D) PROTOZOA

15. *Coleps*
16. *Trichodina*
17. *Arcella*
18. *Difflugia*

isms. Both genera recorded peaks of abundance in July with 2,420 units/litre and 640 units/litre and also their minimum in January recording 100 units/litre and 91 units/litre during the first annual cycle respectively. Cyclops recorded a peak during the second cycle in October with 179 units/litre and a minimum in December with 37 units/litre and was absent in the month of February, while the genus Diaptomus recorded a peak in October and a minimum in December recording 147 units/litre and 28 units/litre during the second cycle and was absent in February (Table-XVI).

The group Rotifera was recorded as the most dominant zooplankton in this control pool. Lecane showed a summer maxima and winter minima. Anuraeopsis revealed peaks of abundance in late spring and autumn with winter minima. Polyarthra recorded a winter maxima and summer minima. Keratella showed a winter abundance and their total absence in spring and summer months. Trichocerca recorded a summer and winter maxima and spring minima. Chromogaster, Filina, Ascomorpha were predominantly recorded during the spring and summer months. Brachionus revealed a summer maxima and winter minima during the first annual cycle and the minima in winter during the second cycle.

Among these genera, Brachionus was encountered as the most dominant zooplankton and recorded a peak of abundance in June with 24,000 units/litre and a minimum in November with 180 units/litre during the first annual cycle and was absent in December, January, August and September. In the second cycle October recorded a maximum with 1,600 units/litre and a smaller peak in January with 1,200 units/litre and a minimum in December representing 300 units/litre. Trichocerca recorded a minimum in November with 80 units/litre and thereafter disappeared, to reappear only again in May and followed a similar trend till it registered a peak in September representing 1,280 units/litre during the first annual cycle. The month of January recorded the maximum with 900 units/litre and was absent in December, February and March during the second cycle. Anuraeopsis revealed a peak in May with 1,000 units/litre and a minimum in December, recording only 60 units/litre during the first annual cycle. During the second cycle it occurred only in December and January recording 700 units/litre and 200 units/litre respectively. Ascomorpha was recorded only in May with 160 units/litre and September with 720 units/litre and was absent during the other months of both the cycles. Notholca was recorded in November and May during the first annual cycle representing 180 units/litre and 120 units/litre and during the second cycle only in November with 300 units/litre. Filina recorded a peak in February and a minimum in January recording 680 units/litre and 100 units/litre. It was also found only in August and September during the first annual cycle and was totally absent in the second cycle. Polyarthra was recorded only in the months of November, February, May during the first cycle and was totally absent during the second cycle. The month of February recorded the peak with 320 units/litre and November with only 80 units/litre. The genus Chromogaster was present only in April with 280 units/litre and was absent during the other months of both the cycles (Table-XVI).

The group Protozoa was represented in this control pool during both the cycles in the months of March, May, September, October, January, February and March. Protozoa comprised of five genera, Coleps, Trichodina, Arcella and Difflugia. Of these genera Coleps constituted the major bulk of organisms and was recorded in September with 680 units/litre and March with 200 units/litre during the first annual cycle and was absent from October to February and April to August. In the next cycle it registered a peak with 1,800 units/litre in October and a minimum in February with 200 units/litre and was absent in

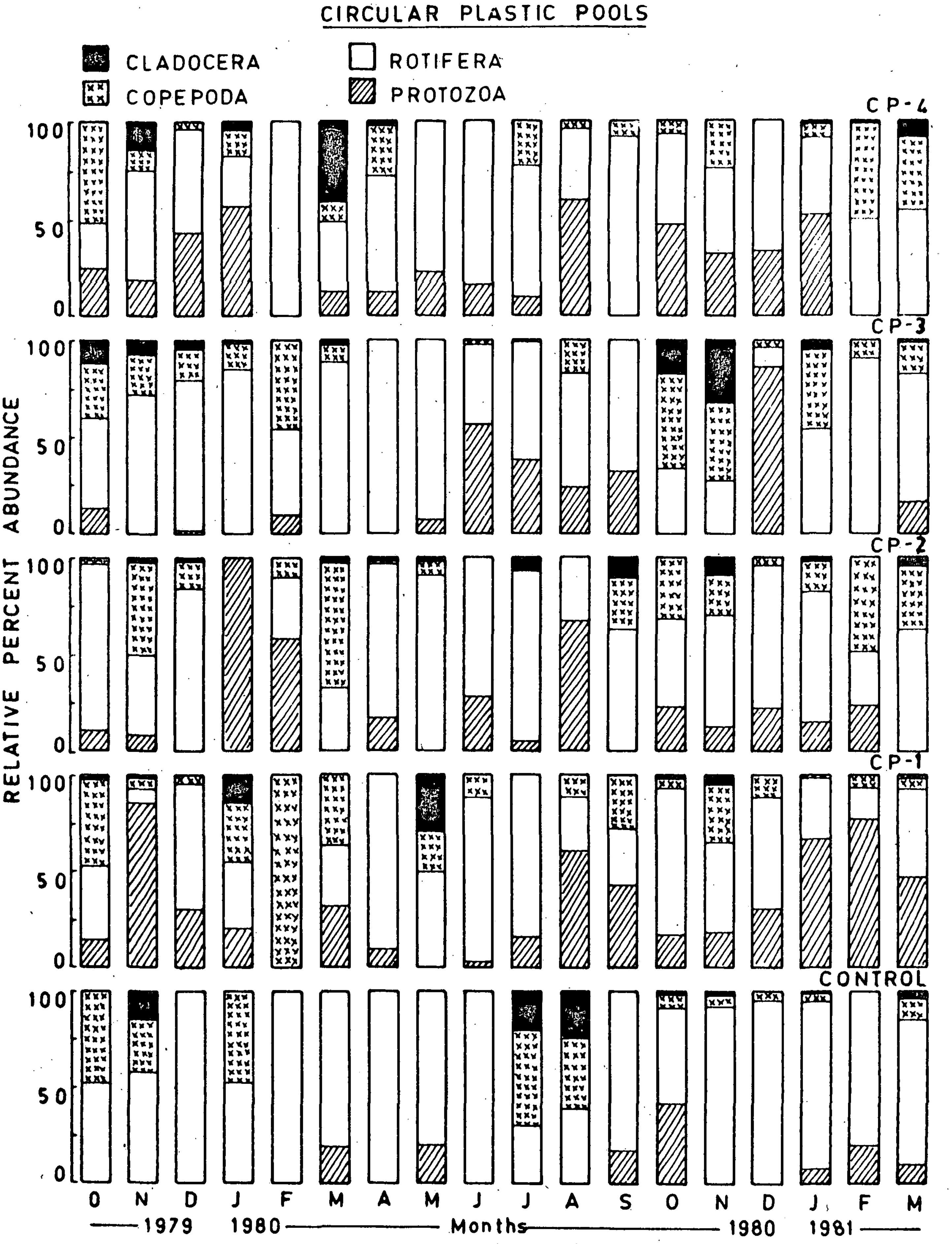
November and December. Trichodina, Arcella and Difflugia were recorded only in May representing 480 units/litre, 240 units/litre and 440 units/litre respectively and were totally absent during the other months of both the cycles (Table-XVI).

When the four groups of zooplankton in this control pool were seen for their seasonal trend of fluctuations irrespective of the different genera recorded under them, Cladocera and Copepoda revealed a summer maxima and winter minima and their total absence during the spring months. The group Rotifera revealed a bimodal peak of abundance with summer and autumn maxima and spring minima. Protozoa showed tendency to increase during autumn and spring seasons (Table-XVI).

When the relative percent abundance of the groups were observed, Cladocera recorded a maximum in August with 23.0% though the peak month showed only 20.0% during the first annual cycle. In the second cycle the percent abundance figures followed a trend more or less similar to the actual numbers. Copepoda recorded a maximum of 51.4% in July and 10.2% in March during the first and second cycles. However, the minimum was recorded with 28.8% in November though constituted larger numbers of counts than that of January which revealed 46.4% during the first annual cycle. In the next cycle December recorded the minimum with 3.9% abundance. The group Rotifera constituted 100% abundance in the months of December, February, April and June and a minimum in July recording only 28.6% during the first annual cycle. In the next cycle December and October recorded the maximum and minimum with 96.1% and 50.6% respectively. The group Protozoa revealed its percent abundance more or less similar to their actual numbers with the months of May and October recording as maximum with 21.9% and 41.3% during the first and second cycles respectively (Fig. 9). When the total zooplankton and its seasonal abundance was seen it revealed a summer maxima and winter minima (Table-XVI).

Fig. 9 - Showing histograms representing the seasonality of the relative percent abundance of the major zooplanktonic groups in the Control and the Circular Plastic Pools.

CP = Circular Plastic Pools.



CIRCULAR PLASTIC POOLS
CLADOCERA
COPEPODA
ROTIFERA
PROTOZOA
CP-4
CP-3
CP-2
CP-1
CONTROL
RELATIVE PERCENT ABUNDANCE
100
50
0
O N D J F M A M J J A S O N D J F M
1979 1980 Months 1980 1981

CIRCULAR PLASTIC POOL-1

The zooplankton in this pool-1 also comprised of four major groups: Cladocera, Copepoda, Rotifera and Protozoa. The group Cladocera in this pool was very insignificant and revealed a more or less summer maxima and winter minima. It was absent during the autumn and spring seasons. Cladocera was represented by three genera: Ceriodaphnia, Moina and Simocephalus. Ceriodaphnia was recorded in the months of October with 4 units/litre, January with 240 units/litre, November with 20 units/litre and March with 26 units/litre and was absent during the remaining months of both the cycles. Moina recorded a peak of abundance in May representing 4,260 units/litre and a minimum of 6 units/litre in November during the first annual cycle. In the second cycle a peak of only 59 units/litre and a minimum of 13 units/litre was recorded in November and October respectively. The genus Simocephalus was recorded only once throughout the entire period of investigation recording 1,880 units/litre in the month of May during the first annual cycle (Table-XVII).

The group Copepoda was well represented with the only exception of April and May that recorded their absence. The group revealed peaks of abundance in spring and winter and was minimum in the summer months. Copepoda was represented by two genera Cyclops and Diaptomus and both revealed peaks of abundance in May recording 2,095 units/litre and 2,495 units/litre and minimum in December with 16 units/litre and 9 units/litre respectively during the first annual cycle. Cyclops had a peak of abundance in November with 339 units/litre and a minimum in January with 22 units/litre during the second cycle and similarly in the same cycle Diaptomus recorded a peak and a minimum in October and January recording 209 units/litre and 19 units/litre respectively (Table-XVII).

TABLE-XVII

Seasonal abundance of zooplankton, their major groups, genera and total zooplankton (units/litre) in the Circular Plastic Pool-1.

(A) CLADOCERA
1. _Ceriodaphnia_
2. _Moina_
3. _Simocephalus_

(B) COPEPODA
4. _Cyclops_
5. _Diaptomus_
6. _Diaphanosoma_

(C) ROTIFERA
7. _Asplanchna_
8. _Lecane_
9. _Anuraeopsis_
10. _Polyarthra_
11. _Keratella_
12. _Trichocerca_
13. _Hexarthra_
14. _Notholca_
15. _Filina_
16. _Brachionus_
17. _Cephalodella_

(D) PROTOZOA
18. _Coleps_
19. _Trichodina_
20. _Arcella_
21. _Difflugia_

TABLE - XVII

Sl.No.	1979-80 OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	1980-81 OCT	NOV	DEC	JAN	FEB	MAR
(A)	13	10	0	240	0	0	0	6140	0	0	0	0	13	79	0	0	0	78
1.	0	4	0	240	0	0	0	0	0	0	0	0	0	20	0	0	0	26
2.	30	6	0	0	0	0	0	4260	0	0	0	0	13	59	0	0	0	52
3.	0	0	0	0	0	0	0	1880	0	0	0	0	0	0	0	0	0	0
(B)	349	131	25	520	48	830	0	4590	130	0	139	298	482	547	358	41	514	326
4.	154	85	16	350	24	240	0	2095	55	0	73	162	273	339	195	22	254	192
5.	195	22	9	170	24	590	0	2495	15	0	66	136	209	208	163	19	260	134
6.	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(C)	300	120	400	600	0	680	3560	10840	1000	2000	300	800	7600	800	1240	1520	1400	2900
7.	0	0	0	0	0	0	640	480	70	0	0	0	0	0	0	0	120	0
8.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	520
9.	0	0	0	160	0	0	0	2000	600	0	0	300	0	0	0	0	0	480
10.	0	0	0	0	0	120	0	600	0	0	0	0	0	0	440	0	160	0
11.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	480	940
12.	300	120	400	0	0	240	0	3120	70	600	300	0	1600	800	360	320	0	0
13.	0	0	0	0	0	0	0	240	0	0	0	0	0	0	0	0	0	0
14.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	0	0	0
15.	0	0	0	0	0	0	1000	3640	150	600	0	0	2200	0	0	240	280	0
16.	0	0	0	440	0	320	1120	760	110	800	0	0	3800	0	320	800	360	960
17.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	0	0
(D)	100	1620	200	360	0	720	440	0	30	400	700	400	2000	320	1320	3300	6120	3200
18.	0	1400	0	0	0	0	0	0	0	0	700	400	1400	200	0	0	120	160
19.	0	120	0	0	0	0	440	0	0	0	0	0	0	120	0	0	320	0
20.	100	100	200	140	0	0	0	0	30	400	0	0	600	0	0	0	0	0
21.	0	0	0	220	0	720	0	0	0	0	0	0	0	0	1320	3300	5680	3040
TOTAL	762	1881	625	1720	48	2230	4000	21570	1160	2400	1139	998	10095	1746	2918	4861	8034	6504

The group Rotifera comprised of the largest number of genera and constituted the largest number of individual forms which persisted and flourished during the entire period of study. Rotifera was represented by Asplanchna which showed their abundance during the spring seasons and absence in summer and winter months. Lecane was recorded only once during the entire period of both the cycles with the exception of March recording 520 units/litre. The genera Anuraeopsis, Trichocerca, Hexarthra and Filina recorded peaks of abundance during the summer and winter months and recorded very lean population during the other seasons. Brachionus revealed a summer maxima and winter minima. Keratella, Notholca and Cephalodella were recorded only during the second cycle in the winter months.

The genus Asplanchna revealed a peak in April with 640 units/litre and a minimum in June with 70 units/litre during the first annual cycle and also occurred in May with 480 units/litre. In the next cycle it was recorded only in February with 120 units/litre. The genera Anuraeopsis with 2,000 units/litre, Polyarthra with 600 units/litre, Brachionus with 3,120 units/litre, Hexarthra with 240 units/litre, Filina with 3,640 units/litre and Trichocerca with 3,120 units/litre recorded as maximum peaks of abundance in the same month of May during the first annual cycle. During the next cycle they recorded their peaks at different intervals. Trichocerca recorded a maximum in October with 1,600 units/litre and a minimum in January registering 320 units/litre. Similarly, the genus Filina recorded maximum and minimum counts in October and January representing 2,200 units/litre and 240 units/litre respectively during the second cycle and Brachionus revealed a maximum and minimum in October and December representing 3,800 units/litre and 320 units/litre during the same period (Table-XVII).

The last group of zooplankton in this pool was Protozoa and was quite significantly represented by four genera, Coleps, Trichodina, Arcella and Difflugia. Coleps recorded abundance during the autumn months and was absent in summer. Arcella restricted their occurrence during the winter months but with a peak recorded in summer during the first annual cycle. In the second cycle they were recorded once in October and was absent the other months. Trichodina was also erratically represented during both the cycles. Difflugia was recorded only in January and March during the first annual cycle. In the next cycle it revealed a winter abundance.

Coleps recorded equal peaks of abundance in the months of November and October representing 1,400 units/litre each during the first and second cycles and revealed a minimum in September with 400 units/litre and February with 120 units/litre during the first and second cycles respectively and was absent in October, February to July, December and January during both the cycles. Trichodina recorded peaks of abundance in April with 440 units/litre and 320 units/litre in February during the first and second cycles. The minimum was both in November with 120 units/litre each during the first and second cycles. Arcella recorded July as the maximum and June as the minimum registering 440 units/litre and 30 units/litre during the first annual cycle and in the next cycle October recorded 600 units/litre and was absent during the remaining periods. The genus Difflugia was present during the first annual cycle, only in the months of January with 220 units/litre and March with 720 units/litre. In the second cycle, February registered the maximum recording 5,680 units/litre and December revealed a minimum count with 1,320 units/litre and was absent in October and November (Table-XVII).

The four groups of zooplankton irrespective of the genera recorded under them revealed an almost similar trend of seasonal fluctuation. Cladocera, Copepoda and Rotifera showed a more or less summer maxima and winter minima. Protozoa revealed a summer minima and winter maxima and also recorded peaks of abundance during autumn (Table-XVII).

When the different groups relative percent abundance was seen, Cladocera was observed to follow a trend more or less similar to their actual numbers. The months of May and November recorded 28.5% and 4.5% during the first and second cycles. The group Copepoda registered a 100% abundance in February though the peak month of May recorded only 21.3% during the first annual cycle. In the second cycle the relative percent abundance followed a trend similar to their actual numbers. The maximum and minimum recorded were 31.3% and 0.8% in November and January respectively. The group Rotifera revealed a maximum in April with 89.0% and minimum in November with 6.4% of the first cycle. The second cycle showed a maxima and minima during October and February recording 75.3% and 17.4% respectively. Protozoa recorded a maximum percent abundance in November representing 86.1% and a minimum in June with 2.6% during the first annual cycle. In the second cycle the month of February recorded the maximum with 76.2% and a minimum in November recording 18.4% (Fig. 9).

When the total zooplankton and its seasonal fluctuation was seen it revealed a bimodal peak of abundance in summer and autumn with a winter minima. However, the trend of fluctuation was seen with a peak formation in the early spring during the second cycle (Table-XVII).

CIRCULAR PLASTIC POOL-2

The groups of zooplankton recorded in this pool was also similar to that of pool-1 and was represented by Cladocera, Copepoda, Rotifera and Protozoa. The group Cladocera was very poorly represented in their abundance and occurrence and comprised of two genera Ceriodaphnia which was recorded during the months of October, November, December and May showing as the maximum of 40 units/litre and recorded a minimum of 7 units/litre in November. It was also present in the months of October and December during the first annual cycle. The only months of January and March of the second cycle recorded 14 units/litre and 336 units/litre respectively. Moina recorded a peak of abundance in September registering 299 units/litre and a minimum in April with only 4 units/litre during the first annual cycle. In the next cycle October registered the maximum with 774 units/litre and January as the minimum with 78 units/litre and was recorded only six times during both the cycles (Table-XVIII).

The group Copepoda was represented by two genera Cyclops and Diaptomus. Cyclops revealed a winter maxima and summer minima. Diaptomus recorded bimodal peaks of abundance in winter and autumn with summer minima during the first annual cycle. In the next cycle, however, the peak of abundance shifted to early spring. The genus Cyclops constituted the dominant form and revealed peaks of abundance in November with 1,326 units/litre and in March with 2,088 units/litre and minimum in February recording 13 units/litre and in December with 59 units/litre during the first and second cycles respectively. Diaptomus similarly recorded peaks of abundance in November and March representing 1,142 units/litre and 1,416 units/litre during the first and second cycles. The months of February and December recorded 5 units/litre and 66 units/litre as minimum during the first and second cycles (Table-XVIII).

TABLE-XVIII

Seasonal abundance of zooplankton, their major groups, genera and total zooplankton (units/litre) in the Circular Plastic Pool-2.

(A) CLADOCERA

1. *Ceriodaphnia*
2. *Moina*

(B) COPEPODA

3. *Cyclops*
4. *Diaptomus*

(C) ROTIFERA

5. *Asplanchna*
6. *Lecane*
7. *Anuraeopsis*
8. *Polyarthra*
9. *Keratella*
10. *Trichocerca*
11. *Notholca*
12. *Filina*
13. *Brachionus*
14. *Cephalodella*
15. *Colurella*

(D) PROTOZOA

16. *Coleps*
17. *Trichodina*
18. *Arcella*
19. *Difflugia*
20. *Diaphorodon*

TABLE - XVIII

Sl.No.	1979-80 OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	1980-81 OCT	NOV	DEC	JAN	FEB	MAR
(A)	10	17	30	0	0	20	4	87	0	18	0	299	0	774	0	92	0	336
1.	10	7	30	0	0	0	0	40	0	0	0	0	0	0	0	14	0	336
2.	0	10	0	0	0	20	4	47	0	18	0	299	0	774	0	78	0	0
(B)	125	2468	460	0	18	664	46	403	0	0	0	862	897	1760	125	660	1066	3504
3.	60	1326	255	0	13	623	24	198	0	0	0	484	440	814	59	395	689	2088
4.	65	1142	205	0	5	41	22	205	0	0	0	378	455	946	66	265	377	1416
(C)	4520	2010	2530	0	57	340	4800	5180	4545	255	4000	2080	1200	4800	2040	4260	560	6400
5.	0	0	0	0	0	0	0	1280	1300	0	4000	0	0	0	0	0	0	0
6.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	0	0
7.	4280	0	1320	0	0	0	4800	0	0	0	0	0	0	1120	200	0	0	0
8.	0	0	210	0	0	100	0	1320	0	0	0	1440	0	1920	280	0	240	0
9.	0	0	800	0	0	0	0	00	0	0	0	0	0	0	200	0	0	0
10.	0	680	0	0	21	240	0	400	1600	54	0	0	0	0	0	1720	0	2560
11.	0	350	0	0	12	0	0	0	0	0	0	0	560	0	0	0	0	0
12.	0	0	0	0	0	0	0	2000	1300	174	0	0	0	0	440	420	0	0
13.	240	980	200	0	24	0	0	180	45	27	0	640	0	1760	640	960	820	3840
14.	0	0	0	0	0	0	0	0	0	0	0	0	640	0	380	0	0	0
15.	0	0	0	0	0	0	0	0	300	0	0	0	0	0	0	0	0	0
(D)	640	460	0	560	111	0	1295	0	1800	18	8400	0	720	1120	640	760	560	0
16.	640	0	0	560	111	0	1295	0	1800	0	7200	0	720	0	0	760	560	0
17.	0	0	0	0	0	0	0	0	0	0	0	0	0	1120	200	0	0	0
18.	0	0	0	0	0	0	0	0	0	18	1200	0	0	0	0	0	0	0
19.	0	460	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	440	0	0	0
TOTAL	5295	4955	3020	560	186	1024	6145	5670	6345	291	12400	3241	2817	8454	2805	4772	2186	10240

The group Rotifera constituted the most dominant zooplankters in this pool and was represented by eleven genera. The genera Asplanchna, Polyarthra, Notholca, Cephalodella and Brachionus recorded their peaks of abundance during the autumn months and minima during the spring seasons. Lecane and Colurella were recorded only in January with 160 units/litre and June with 300 units/litre respectively during the entire period of study. Anuraeopsis revealed a winter and spring maxima and summer minima. Keratella recorded winter occurrence and absence during the other seasons. Trichocerca showed a summer and early spring maxima and autumn minima. Filina showed a summer maxima and winter and autumn minima during the first annual cycle, while in the next cycle recorded peaks of abundance during winter.

The genus Asplanchna was present in the months of May, June and August and was absent during the remaining period. It recorded a peak of 4,000 units/litre in August. Similarly Lecane was recorded only in January with 160 units/litre. Anuraeopsis recorded peaks of abundance in April and November representing 4,800 units/litre and 1,120 units/litre during the first and second cycles and recorded minimum in the months of December registering 1,320 units/litre and 200 units/litre during the first and second cycles and besides these months they were recorded twice during both the cycles. Polyarthra recorded peaks of abundance in September with 1,440 units/litre and in November with 1,920 units/litre and minimum in March with 100 units/litre and January with 240 units/litre during the first and second cycles respectively and besides these months they occurred only thrice during the first and second cycles. Keratella was present only in the months of December with 800 units/litre and 200 units/litre during the first and second cycles respectively. Trichocerca revealed a peak of abundance in June recording 1,600 units/litre and a minimum in February with only 21 units/litre during the first annual cycle and was absent for six months. During the second cycle March recorded 2,560 units/litre and January 1,720 units/litre and was absent from October to December and February. Notholca was recorded only in the months of November with 350 units/litre and February with only 12 units/litre during the first annual cycle. In the next cycle October recorded 560 units/litre and was entirely absent during the remaining periods. Filina recorded peaks of abundance in May with 2,000 units/litre and in December with 440 units/litre during the first and second cycles and in addition to these months they were recorded thrice during both the cycles. Brachionus recorded a peak in November registering 980 units/litre and a minimum in February with only 24 units/litre during the first annual cycle and was absent in the months of January, March, April, August and September. In the next cycle, March registered a maximum recording 3,840 units/litre and a minimum in February with 320 units/litre. Cephalodella was represented only in October and in December with 640 units/litre and 280 units/litre and was absent during the other months of both the first and second cycles (Table-XVIII).

The group Protozoa was represented by five genera; Coleps, Trichodina, Arcella, Difflugia and Diaphorodon. Of these genera, Coleps constituted the dominant form and revealed peak of abundance in June recording 1,800 units/litre and a minimum in February with 111 units/litre and was represented only four times during the first annual cycle. In the second cycle, January registered a peak with 760 units/litre and February with 560 units/litre and was absent in October, January and March. Trichodina was entirely absent during the first annual cycle and was recorded only in November registering 1,120 units/litre and December with 200 units/litre in the second cycle. Arcella was present only in the months of July and August recording

18 units/litre and 1,200 units/litre during the first annual cycle and was absent during the entire second cycle. Diffluqia and Diaphorodon were registered in November with 460 units/litre and in December with 440 units/litre during the first and second cycles respectively and was absent during the other months of both the cycles (Table-XVIII).

When the group Cladocera was seen for its relative percent abundance among the other three groups, the months of September and November recorded an equal magnitude of abundance with 9.2% and the months of April and December recorded the minimum with 0.1% and 1.9% during the first and second cycles respectively. Copepoda recorded maximum in March with 64.8% and February with 48.8% and minimum in October with 2.2% and December with 4.5% respectively during the first and second cycles. The group Rotifera constituted the highest relative percent abundance recording 91.4% and 72.7% in May and December and with 30.6% and 25.6% as minimum in the months of February during the first and second cycles respectively. Protozoa constituted a 100% abundance in January and a minimum in July with 6.2% during the first annual cycle. In the second cycle February registered the maximum with 25.6% and a minimum in November with 13.2% (Fig. 9).

When the total zooplankton was seen for their seasonal fluctuations it revealed a summer maxima and spring minima (Table-XVIII).

CIRCULAR PLASTIC POOL-3

The major groups of zooplankton registered in this pool were also Cladocera, Copepoda, Rotifera and Protozoa. Of these groups Rotifera constituted the dominant form both in term of individual counts and occurrence. The group Cladocera was represented by three genera, Ceriodaphnia, Moina and Simocephalus. The genus Ceriodaphnia was recorded only in November representing a count of only 117 units/litre and was absent during the remaining periods of both the cycles. The genus Moina revealed peaks of abundance during the early winter months with November recording a maximum of 229 units/litre and a minimum in March with only 28 units/litre during the first annual cycle and was absent in the months of February and April to September. In the next cycle October recorded the peak with 1,080 units/litre and March as the minimum with only 39 units/litre and was absent in October, December and February. Simocephalus was recorded only once with a count of 2,000 units/litre in November and was totally absent during the other months of both the cycles (Table-XIX).

The group Copepoda was represented by only two genera Cyclops and Diaptomus both of them revealed an autumn maxima and summer minima. Cyclops recorded peaks of abundance in February with 1,200 units/litre and October with 1,482 units/litre and minimum in July (55 units/litre) and January with 274 units/litre during the first and second cycles respectively. Diaptomus recorded a peak in October with 798 units/litre and a minimum in March recording 77 units/litre during the first annual cycle. In the next cycle October recorded a maximum with 1,482 units/litre and a minimum in December registering 200 units/litre (Table-XIX).

The group Rotifera constituted the most dominant zooplankton and was represented throughout the period of study. Rotifera was

TABLE-XIX

Seasonal abundance of zooplankton, their major groups, genera and the total zooplankton (units/litre) in the Circular Plastic Pool-3.

(A) CLADOCERA

1. Ceriodaphnia
2. Moina
3. Simocephalus

(B) COPEPODA

4. Cyclops
5. Diaptomus

(C) ROTIFERA

6. Anuraeopsis
7. Polyarthra
8. Keratella
9. Trichocerca
10. Notholca
11. Filina
12. Brachionus
13. Colurella
14. Asplanchna

(D) PROTOZOA

15. Coleps
16. Trichodina
17. Arcella
18. Difflugia

TABLE - XIX

Sl.No.	1979-80 OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	1980-81 OCT	NOV	DEC	JAN	FEB	MAR
(A)	680	346	166	33	0	28	0	0	0	0	0	0	1080	3040	0	72	0	39
1.	0	117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.	680	229	166	33	0	28	0	0	0	0	0	0	1080	1040	0	72	0	39
3.	0	0	0	0	0	0	0	0	0	0	0	0	0	2000	0	0	0	0
(B)	1600	962	636	626	1600	181	0	0	364	111	640	0	2964	3640	474	885	671	856
4.	802	523	340	313	1200	104	0	0	149	55	320	0	1482	1260	274	456	359	415
5.	798	439	296	313	400	77	0	0	265	51	320	0	1482	1300	200	429	312	441
(C)	2520	3480	2920	3400	1600	2000	15360	8800	5360	9200	2440	14700	2040	3000	1690	1160	7600	3520
6.	600	0	360	0	0	0	1600	0	0	0	0	2860	440	0	0	0	0	0
7.	0	0	480	0	0	200	0	680	0	0	0	0	0	520	160	0	800	0
8.	0	560	200	0	0	0	0	520	0	0	0	240	0	680	0	0	0	1760
9.	400	0	0	0	400	0	4800	1360	320	1800	960	840	0	80	490	0	2400	160
10.	0	1160	320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11.	0	0	320	3200	0	440	3360	4720	0	0	1160	9440	440	280	0	0	0	0
12.	720	1760	1240	200	1200	1360	5600	1520	4800	1800	320	240	1160	1440	1040	1160	4400	1600
13.	0	0	0	0	0	0	0	0	240	3800	0	720	0	0	0	0	0	0
14.	720	0	0	0	0	0	0	0	0	1800	0	360	0	0	0	0	0	0
(D)	800	0	40	0	400	0	0	640	7600	5800	960	7320	0	0	14640	0	0	880
15.	0	0	0	0	0	0	0	0	7600	5800	0	6480	0	0	0	0	0	880
16.	0	0	0	0	0	0	0	640	0	0	0	840	0	0	0	0	0	0
17	600	0	40	0	400	0	0	0	0	0	960	0	0	0	0	0	0	0
18.	200	0	0	0	0	0	0	0	0	0	0	0	0	0	14640	0	0	0
TOTAL	5600	4788	3762	4059	3600	2209	15360	9440	13324	1511	4040	22020	6084	9680	16804	2117	8271	5295

comprised of nine genera, _Anuraeopsis_ recorded an autumn and spring peak with winter and summer minima during the first annual cycle. In the next cycle it was recorded only in October. _Polyarthra_ was confined to the winter and spring occurrence and showed summer minima. _Keratella_ revealed a peak in winter and was absent during spring and summer during the first annual cycle. In the next cycle a peak was seen in March and was absent in the winter months. _Trichocerca_ revealed summer maxima and spring and autumn minima. _Notholca_ was recorded only on two occasions during the first annual cycle in winter and was absent throughout the remaining periods of both the cycles. _Filina_ revealed spring and autumn peaks and winter minima. _Brachionus_ recorded a bimodal peak in summer and winter and autumn minima during the first annual cycle. In the next cycle it recorded a winter maxima. _Colurella_ and _Asplanchna_ were present only in the summer months.

The genus _Anuraeopsis_ revealed a peak in September registering 2,860 units/litre and a minimum in December with 360 units/litre during the first annual cycle. In the next cycle October recorded 440 units/litre and was absent during the remaining months. _Polyarthra_ showed peaks of abundance in May and February representing 680 units/litre and 200 units/litre respectively during the first and second cycles. The months of March and December recorded minimum counts with 200 units/litre and 160 units/litre respectively during the first and second cycles. _Keratella_ recorded a peak in November with 560 units/litre and a minimum in December with 200 units/litre during the first cycle. In the next cycle March represented the maximum with 1,760 units/litre and minimum in November with 260 units/litre. _Trichocerca_ revealed a peak in April with 4,800 units/litre and a minimum in June with 320 units/litre during the first annual cycle and was absent from November to January. In the next cycle February registered the maximum with 2,400 units/litre and a minimum in November with 80 units/litre and was absent in October and January. Notholca was registered only in the months of November and December recording 1,160 units/litre and 320 units/litre and was absent in the other months of both the cycles. Filina showed a peak in September with 9,440 units/litre and a minimum in December with 320 units/litre during the first annual cycle and was absent in the months of October, November, February, June and July. In the second cycle a maximum and minimum was recorded in October with 440 units/litre and November with 280 units/litre and was absent from December to March. Brachionus recorded a maximum peak in April registering 5,600 units/litre and also a smaller peak in June with 4,800 units/litre and a minimum in January recording 200 units/litre during the first annual cycle. In the next cycle the months of February and December recorded the maximum and minimum with 4,400 units/litre and 1,040 units/litre respectively. Colurella revealed a peak in July with 3,800 units/litre and a minimum in June recording 240 units/litre and was absent from October to May and August during the first annual cycle. In the next cycle it was totally absent. Asplanchna was also recorded only during the first annual cycle in the months of October, July and September representing 720 units/litre, 1800 units/litre and 366 units/litre respectively (Table-XIX).

The group Protozoa was represented by four genera Coleps which constituted the dominant form and Trichodina, Arcella and Diffluqia. Coleps was represented only during the late summer of the first annual cycle and in the next cycle in early spring. Trichodina was restricted only to the summer months, while Arcella in winter and a peak in summer and Diffluqia revealed an occurrence only during the autumn months.

Coleps recorded peaks of abundance in June with 7,600 units/litre and in September with 6,480 units/litre and a minimum in July recording 5,800 units/litre and was absent from October to May and

August during the first annual cycle. In the next cycle it was recorded only in March with 880 units/litre. <u>Trichodina</u> was registered only in the months of May with 640 units/litre and September with 840 units/litre and was absent during the remaining months of both the cycles. <u>Arcella</u> revealed a peak with 960 units/litre in August and a minimum with 40 units/litre in December during the first annual cycle and was absent throughout the second cycle. <u>Difflugia</u> was registered only in the months of October and December recording 200 units/litre and 14,640 units/litre during the first and second cycles respectively (Table-XIX).

When the groups of zooplankton were seen for their seasonal trend of fluctuation irrespective of the genera recorded under them, Cladocera showed a winter and late autumn maxima and summer minima. Copepoda revealed an autumn maxima and summer minima. Rotifera revealed peaks of abundance in spring and summer, and winter minima. The group Protozoa revealed a summer maxima and spring minima (Table-XIX).

When the groups relative percent abundance were seen, Cladocera recorded a maximum in October with 12.1% and a minimum in January with 0.8% during the first annual cycle. The months of November and March recorded the maximum and minimum with 31.4% and 0.7% respectively during the second cycle. Copepoda showed maximum percent abundance in the months of February with 44.5% and October with 48.7% during the first and second cycle and minimum in July with 0.7% and December with with 2.8% respectively. Rotifera was solely represented in the month of April and constituted 100% abundance and with a minimum in June of only 40.3% during the first annual cycle. In the next cycle they recorded 87.1% in December and March with 16.6% as maximum and minimum respectively. Protozoa recorded maximum in June and December with 57.0% and 87.1% and the minimum in December and March with 1.1% and 16.6% during the first and second cycles respectively (Fig. 9).

When the total zooplankton and its seasonal trend of fluctuation was seen it revealed a summer and winter maxima and spring minima (Table-XIX).

CIRCULAR PLASTIC POOL-4

Four major groups of zooplankton were also represented in this pool-4. They were Cladocera, Copepoda, Rotifera and Protozoa.

The group Cladocera was represented by two genera Ceriodaphnia and Moina, but was very insignificantly represented and occurred only in the months of November, January, March and April during the first cycle and recorded maximum density in March and minimum in April. During the second cycle they were present only in the months of January to March. Ceriodaphnia was recorded only in November with 519 units/litre and in January with 113 units/litre and a maximum density in March recording 1,920 units/litre and was recorded absent throughout the periods of the second cycle. The genus Moina revealed a peak in January registering 1,143 units/litre and a minimum in March with only 80 units/litre and was absent in October, December, January and April to September during the first annual cycle. In the second cycle the month of March registered the maximum with 648 units/litre and a minimum of 59 units/litre in January and was absent from October to December (Table-XX).

The group Copepoda was represented by two genera Cyclops and Diaptomus and revealed their abundance in April and minimum in February and was absent in the months of February, May and June during the first annual cycle. In the next cycle March and October recorded the maximum and minimum abundance and was absent in December. The genus Cyclops revealed a winter maxima and spring minima and in the autumn a tendency to increase. It recorded a peak of abundance in January registering 1,782 units/litre and a minimum in July with 40 units/litre during the first annual cycle. In the next cycle a maximum and minimum was registered in the months of March with 1,579 units/litre and October with 91 units/litre and was absent in February, May, June and December during both the cycles.

TABLE-XX

Seasonal abundance of zooplankton, their major groups, genera and the total zooplankton (units/litre) in the Circular Plastic Pool-4.

(A) CLADOCERA
1. *Ceriodaphnia*
2. *Moina*

(B) COPEPODA
3. *Cyclops*
4. *Diaptomus*

(C) ROTIFERA
5. *Asplanchna*
6. *Lecane*
7. *Anuraeopsis*
8. *Polyarthra*
9. *Keratella*
10. *Trichocerca*
11. *Notholca*
12. *Filina*
13. *Brachionus*
14. *Colurella*
15. *Ascomorpha*

(D) PROTOZOA
16. *Coleps*
17. *Trichodina*
18. *Arcella*
19. *Difflugia*

TABLE - XX

Sl.No.	1979-80 OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	1980-81 OCT	NOV	DEC	JAN	FEB	MAR
(A)	0	728	0	1256	0	2000	156	0	0	0	0	0	0	0	0	59	108	648
1.	0	519	0	113	0	1920	0	0	0	0	0	0	0	0	0	0	0	0
2.	0	209	0	1143	0	80	156	0	0	0	0	0	0	0	0	59	108	648
(B)	1200	577	94	3511	0	490	2760	0	0	80	186	193	143	923	0	397	3132	3348
3.	580	311	57	1782	0	490	147	0	0	40	83	100	91	376	0	218	1458	1579
4.	620	266	37	1729	0	0	2613	0	0	40	143	93	52	547	0	179	1674	1769
(C)	560	3039	1600	800	6080	1720	6240	3200	14400	240	1398	2400	1000	1680	800	2280	3040	4880
5.	0	239	0	0	0	520	0	0	0	0	0	0	0	0	0	0	2080	0
6.	0	0	0	0	440	0	0	400	400	0	400	0	200	0	0	640	0	480
7.	560	440	0	3040	0	0	0	480	1000	0	423	0	600	0	0	0	0	0
8.	0	320	0	2080	600	0	1600	320	0	0	200	0	0	0	0	80	0	240
9.	0	1080	240	0	1600	0	1040	0	0	0	0	0	0	680	0	0	920	320
10.	0	280	480	0	0	0	1760	560	400	40	194	0	0	1000	0	360	0	0
11.	0	280	0	0	0	280	0	0	0	0	0	0	0	0	0	0	0	0
12.	0	80	0	0	0	0	0	1240	12600	140	114	0	0	0	0	0	0	1520
13.	0	320	880	2880	3440	680	1840	200	0	60	67	2400	200	0	800	1200	1120	2320
14.	0	0	0	0	0	240	0	0	0	0	0	0	0	0	0	0	0	0
15.	0	0	0	0	0	0	3440	0	0	0	0	0	0	0	0	0	0	0
(D)	600	1040	1280	18720	0	600	960	1920	2800	40	2320	0	1200	1200	400	3000	0	0
16.	600	0	800	0	0	0	0	0	0	0	2320	0	1200	1200	400	3000	0	0
17.	0	80	480	0	0	320	0	1600	2800	0	0	0	0	0	0	0	0	0
18.	0	0	0	3040	0	280	960	320	0	40	0	0	0	0	0	0	0	0
19.	0	240	0	15680	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2360	5384	2974	31487	6080	4810	10116	5120	17200	360	3904	2593	2343	3803	1200	5736	6280	8876

Diaptomus recorded a peak in April registering 2,613 units/litre and a minimum in July with 40 units/litre during the first annual cycle. In the next cycle March and October revealed the maximum and minimum density representing 1,769 units/litre and 52 units/litre respectively (Table-XX).

The group Rotifera was encountered as the most dominant zooplankter in their occurrence. The group was represented by eleven genera. *Asplanchna* was recorded only in the months of November, March and February during both the cycles, registering 239 units/litre 520 units/litre and 2,080 units/litre respectively. *Lecane* was recorded in February with 440 units/litre, June and August with 400 units/litre each during the first annual cycle. In the next cycle January recorded the maximum with 640 units/litre and a minimum in October with 200 units/litre and was absent in November, December and February. *Anuraeopsis* recorded a peak in June with 1,000 units/litre and a minimum in August with 423 units/litre and besides this they were registered only four times during the first annual cycle. In the next cycle it was recorded only in October registering 600 units/litre. *Polyarthra* revealed peaks of abundance in January and March registering 2,080 units/litre and 240 units/litre during the first and second cycles respectively. A minimum of 200 units/litre in August and 80 units/litre in January was recorded during the first and second cycles. *Keratella* revealed peaks of maximum densities in the months of February with 1,600 units/litre and with 1,920 units/litre during the first and second cycles respectively. A minimum of 240 units/litre and 320 units/litre was recorded in December and March respectively during both the cycles. *Trichocerca* showed maximum density in April registering 1,760 units/litre and a minimum in July recording only 40 units/litre during the first annual cycle. In the next cycle November registered 1,000 units/litre as the maximum and January as the minimum with 360 units/litre. The genus Trichocerca was also recorded present in the months of November, December, May, June and August during the first cycle. Notholca was recorded in November and March with equal peaks representing 280 units/litre and was absent during the other periods of both the cycles. Filina recorded maximum peaks of abundance in June representing 12,600 units/litre and in March with 1,520 units/litre. It recorded minimum in November with 80 units/litre during the first annual cycle and was absent from October to February during the second cycle. Brachionus recorded peaks of abundance in February and September registering 3,440 units/litre and 2,400 units/litre and a minimum in July with only 60 units/litre during the first annual cycle. In the next cycle March registered the peak with 2,320 units/litre and October as the minimum with 200 units/litre and was absent in October, June and November during both the cycles. The genera Colurella and Ascomorpha were recorded once during the first annual cycle in March with 240 units/litre and May with 3,440 units/litre respectively and was totally absent during the other months of both the cycles (Table-XX).

The group Protozoa was represented by the genera Coleps, Trichodina, Arcella and Difflugia. The group recorded maximal densities in January and minimum in July during the first annual cycle. In the second cycle January recorded 3,000 units/litre as the peak and December with 400 units/litre as the minimum.

The genera Arcella and Difflugia recorded their maximal peaks of abundance in January registering 3,040 units/litre and 15,680 units/litre during the first annual cycle and recorded their minimum counts in July with 40 units/litre and November with 240 units/litre during the first and second cycles respectively. In addition to the maximum and minimum recorded months, the genus Arcella was present only in March, April and May and was absent during the other months of both the cycles, while Difflugia besides the months of November and January was absent throughout the other months of both the cycles. The genus *Coleps* recorded peaks of abundance in August registering 2,320 units/litre and in January with 3,000 units/litre during the first and second cycles. The months of October with 600 units/litre and December with 400 units/litre recorded the minimum counts of these forms during the first and second cycles. They also occurred in the months of December (800 units/litre), October (1,200 units/litre) and November (1,200 units/litre) during both the cycles. *Trichodina* was found present only during the first annual cycle with the month of June and November representing the maximum and minimum registering 2,800 units/litre and 80 units/litre and was totally absent during the second cycle (Table-XX).

When the relative percent abundance of the different groups were seen, Cladocera showed a maximum of 41.6% in March and a minimum of 1.5% in April during the first annual cycle. In the next cycle, March and January recorded the maximum and minimum representing 7.4% and 1.0% respectively. The group Copepoda revealed a maximum abundance in October with 50.8% and in December with only 3.1% as minimum during the first annual cycle. The months of March with 37.7% and October with 6.1% represented the maximum and minimum during the second cycle. Rotifera registered a maximum relative percent abundance in February recording 100% and a minimum in October with only 23.7% during the first annual cycle. In the next cycle maximum percent abundance was seen in December with 66.7% and a minimum of 42.7% in October. The group Protozoa constituted a maximum of 59.4% in August and only 9.5% in April during the first annual cycle. In the next cycle the maximum and minimum relative percent abundance was registered in January with 52.4% and November with 31.5% (Fig. 09).

When the total zooplankton was seen irrespective of the groups and genera present under them it revealed a summer and winter maxima and spring and autumn minima (Table-XX).

DISCUSSION

After the consideration of the basic physical and chemical nature of the fish ponds and pools it was felt to observe the living things namely the biota in these ecosystems. This helps in understanding the spatial and temporal relationships through which groups of individual forms of either the same or different species are formed and their linkages into ecological patterns and associations. It is well documented that several environmental factors either by themselves or in combinations interact to regulate this spatial and temporal growth of biota, yet it was needed at this stage to understand their basic dynamics of the biota itself and their interactions.

With the above in view the biota in the present investigation of the fish ponds and pools were broadly categorised into two major groups, the phytoplankton and zooplankton. The dynamics of both of these two groups have been confined to the results obtained from their occurrences from the euphotic zones in the different systems under study.

When the phytoplankton associations were observed in the different systems it was seen that Chlorophyceae was the dominant group present in all the fertilized ponds and pools and Euglenophyceae came next in importance. However, in the control systems both in the ponds and pools Euglenophyceae was the dominant group with Chlorophyceae coming next in importance. Between these two groups itself there is a clear evidence of a successional pattern being altered because of fertilization measures and it seems that irrespective of the fertilization such a change is quite obvious even in those systems where only supplementary feed as administered.

The third dominant group of phytoplankton was Myxophyceae and this occupied the same position for all the ponds and pools. There seemed to be no change in its dominant role even with fertilization though of course there was definitely an increase in their numbers on fertilization, yet with the simultaneous increase of the two dominant groups Chlorophyceae and Euglenophyceae they came third in importance. Among the Circular Plastic Pools, Bacillariophyceae occupied the fourth position and was so found irrespective of fertilization measures and also in the control. However, though this occupied the fourth position as abundant forms in Experimental Fish Ponds 1 and 3, yet they formed the last in the control and only second to the Experimental Fish Pond-1. The last two groups Xanthophyceae and Dinophyceae alternated over the seasons, dominating each other and since their numbers were very low they did not seem to play a very significant role in affecting the dynamics of the system. Their low abundances were found both in the Experimental Fish Ponds and Pools.

One observation arising out of such an analysis of the major groups of phytoplankton is that though there is a shift from the Euglenoids to the abundant form of green algae (Chlorophyceae), from natural systems to fertilized ones, yet the blue-green (Myxophyceae) which are an indicator of eutrophic situations seem to be relegated to the third position inspite of fertilization measures, probably reflecting the equilibrium attained in such acidic waters where a well maintained buffer operates, not allowing the excess of alkalinity to form the usual bloom and crash of blue-green algae. This indicated that the present fertilization management is quite adequate for the control of such noxious blue-green algae to develop to only an extent required and not to levels as obtained elsewhere in fish ponds and in particular the plains of India. Bacillariophyceae or diatoms add to the above contention in that the situations are not highly eutrophic and there exists a negative relationship between Dinophyceae or desmids. It has been suggested as early as 1946 by Allen that the phenomenon of mutual exclusion occurs between diatoms and dinoflagellates.

When these major groups are broken down into their respective genera that they comprise of, it was clearly observed that among Chlorophyceae the genera, Chlamydomonas and Scenedesmus invariably occupied the first two positions in all the systems undertaken for the present study. Moreover there was a drastic increase in their numbers in the fertilized ponds and pools, and in fact these two genera alone decided the dominance of the group. One observes here that though the general blue-green algae was kept quite under control, yet among the green algae, the two genera Chlamydomonas and Scenedesmus were abundant and are known as indicators of eutrophication. Therefore, in these ponds and pools, fertilization does increase the eutrophic status of the systems not necessarily by the usual eutrophic group, but even at generic levels of usually a Oligotrophic group. This sort of a phenomena is not very new in acidic waters which are perturbed since the minor shifts at generic level could be attributed to the increase in amplitude of the turnover rates, which over the seasons,be explained by the diversity of phytoplankton populations with a decrease of total biomass (Javornicky and Komarkova, 1978). Moreover it is known that green algae and diatoms are more efficient producers than blue-greens and dinoflagellates (Findenegg, 1965; and Pyrina, 1966). It is therefore a beneficial aspect that even eutrophic genera grow abundantly in fish ponds than the blue-greens which effect primary production levels deciding the production of higher trophic levels which in the present case is fish.

The other observations from the present investigation was the maximum numbers of genera present under Chlorophyceae than in any other group. Moreover there was a clear inverse relationship to the seasonality of these dominant genera under Chlorophyceae like Chlamydomonas, Scenedesmus and Ankistrodesmus with that of the genus Navicula of Bacillariophyceae. Though the numbers of abundance were far less in the latter yet it seemed that there was a clear cut oscillating rhythmicity in the successional pattern of these different genera to create a primary production level possibly at equilibrium throughout the annual cycle. This was true irrespective of fertilization, except that in intense fertilized ponds and pools or in those where inorganic and organic fertilizers and supplementary feedings were administered showed that the field rhythms seemed to possess an inherent rhythmicity more or less similar between systems except, probably with the differences of magnitude (Enright, 1970 and Gliwicz, 1975).

Such increases in amplitude of turnover rates during the seasons and between the systems could also be a cause of the altered diversity of phytoplankton population and the uniform population of blue-greens must probably possess low value of turnover rates. Further, that diverse population of phytoplankton probably being more intensely consumed by predators and so sustained in active phase of growth could possibly be a factor to be reckoned with.

In a simple analysis of the above, the assemblages of many species/genera could concievably operate as a single unit with a unique rhythmicity. It is known that coexistence of potential competitors at these levels of statistical evidences that competition is usually avoided (Hutchinson, 1961). Further kinetics dominance of co-dominant species as in the present study especially Chlorophyceae, Euglenophyceae and Myxophyceae as higher hierarchical groups, and while Chlamydomonas, Scenedesmus, Euglena and Coelosphaerium at generic levels has been suggested as one mechanism for avoiding or minimising competition in an environment where nutrient source is continuous as in the fertilized ponds and pools where there was a regular administration of fertilizers (Williams, 1971; Eppley et.al., 1971). Although changes in species composition and total biomass accompanying such eutrophication processes can be striking to the most casual eye, the ultimate environmental factors limiting the changes often remain unclear and disputed, as do the biological interactions attending changes in species dominance during the same period.

With this knowledge of the phytoplankton and biota in the fish ponds and pools, the immediate higher trophic level, the zooplankton a d their dynamics in relation to both the previous levels and the next higher trophic levels is to be understood. This is all the more necessary since they do not only graze on the phytoplankton but also have their own level of production as food for the higher animals.

In the present investigation four major groups of zooplankton were identified and they were Rotifera, Copepoda, Protozoa and Cladocera. It was observed that the group Rotifera in both the ponds and pools irrespective of fertilization was the most dominant zooplankton group encountered. They were followed by Copepoda in all the Experimental Fish Ponds and though they did also show in the Circular Plastic Pools, Control, 2 and 3, yet they were replaced by Protozoa in pools 1 and 4. Cladocera and Protozoa were quite less in numbers in comparison to the other groups in the Experimental Fish Ponds and were present in that order both in the control and pond 1. However, they exchanged their positions in ponds 1 and 3. In the Circular Plastic Pools, Cladocera was encountered as the least, while Protozoa occupied the third position in all the Circular Plastic Pools except in pools 1 and 4 as mentioned earlier which was replaced by Copepoda.

In the present systems undertaken a clear observation of a numerical superiority of the group Rotifera over other major groups of zooplankton was seen, which is by itself an indicator for the eutrophic status of the systems as this corroborates the view of Nordquist (1921) where Rotifers were always seen to dominate in rich organic freshwater systems. Copepoda as the next major group in all the Experimental Fish Ponds and Circular Plastic Pools is also an indicator of eutrophication though primarily it is the species which decides the occupancy of such systems, which in the present investigation was found to be dominated by the genus Cyclops and Diaptomus. The group Protozoa especially in Experimental Fish Ponds 2 and 3 is understanable as both supplementary feeding and cowdung or oganic manure could have contributed to their enhancement in numbers. Similarly in Circular Plastic Pools 1 and 4, this group Protozoa was very high in numbers, probably attributed to similar management practice. This presence of the group Protozoa in large numbers especially in ponds and pools where supplementary feeding was given alone or in combination of fertilizers could probably have served as a very good substrate for their growth.

On further analysis it was seen that most of the Rotifer genera were abundant in the winter months along with Protozoa, the latter which started increasing from the autumn months. Cladocera and Copepoda were usually present as summer occurring forms. This sort of a rhythmicity in their behaviour and the successional seasonality of abundances seemed to follow a pattern parallel to the group of phytoplankton over the season with each group occupying a special feeding ecological niche as it were. This phenomena of the regulation which affects the fecundity of the zooplankton due primarily to food intake may not be instantaneous and it is probably here that the underlying phenomena of zooplankton dynamics are hidden.

As phytoplankton and zooplankton are dependent on each other, zooplankton grazing on the former enhances the process of fracturing the frustule which might add to the autochthonous input (Ferrante and Parker, 1977). However the generation rates of this having more or less the same time scale the zooplankton suppresses the algae to low levels if not itself being grazed by small fish (Steel, 1975). Further the aggregation of zooplankton and especially their adults in the narrow zone in light intensities at the surface waters may be involved and contribute to a large extent to such population regulation.

Biological factors such as predation (Hrbacek and Hrbackova-Esslova, 1960; Brooks and Dodson, 1965), starvation (Warren, 1900; Von Dehm, 1930) and inter or intraspecific competition (Frank, 1952; Parker, 1960) have been suggested as important factors in regulating the birth and death processes which on balance account for the observed density of these organisms. In addition it has been well documented that Cladocera have a maximal feeding rate only at certain optimal pH (Ivanova, 1969 and Walter, 1969).

Though many factors contribute to an understanding of the population dynamics of zooplankton, yet in fish ponds which are managed, the allochthonous component is of great concern. In particular organic manuring effects the development of zooplankton and has been emphasized not only in pond farms (Lewkowicz et. al., 1975) but also attempts have been made to utilize such allochthonous materials in mass developing of zooplankton as fish food (Barthelmes, 1969). In addition a chain of reactions are set when ready organic substances is introduced into the waters which is utilised by all trophic levels with a stimulating influence on the development of phytoplankton which get released after mineralization (Schaperclaus, 1961; Ljachnowic, 1962; and Huet, 1970) utilized by zooplankton and subsequently by fish.

This phenomenon especially in managed ecosystems is assumed that any organism would not become dependent on a rare element for its existence. It is, therefore, frequently seen that organisms not only take up a given element but utilize it to its maximum in some fashion. However, it is possible and even plausible that the given element may be taken up and used to control or limit the uptake of another element by substitution processes. All these probably reflects the differences in the seasonal dynamics of these groups that have been studied. However further information on natural variations on dynamics and species composition is needed before changes in zooplankton or phytoplankton accompanying fertilization experiments may be accurately interpreted.

REFERENCES

Abeliovich, A. & M. Shilo 1972 Photoxidative death in blue-green algae. J. Bacteriol., 111:682-689

Alfred, J.R.B., S. Kaur & M.P. Thapa 1978 The role of nutrients and their effects on the biota in freshwater lentic systems. Int. Confr. of Water Poll. Res. Bangkok, Water. Poll. Res., 1:133-139.

Allen, W.E. 1946 "Redwater" in La Jolla Bay in 1945. Trans. Amer. Micro. Soc., 65(2):149-153.

Anderson, H.H. 1889 Notes on Indian Rotifers. J. Asiatic Soc. Bengal, 58:345-358.

Apstein, C. 1896 Das SuBwasserplankton, Lipsius & Tischer, Kiel and Leipzig, pp. 206.

Bamforth, S.S. 1958 Ecological studies on the planktonic protozoa of a small artificial pond. Limnol. Oceanogr., 3:398-412.

Barthelmes, D. 1969 Moglichkeiten einer industriemassigen Naturnahrungs-produktion in Kombination mit der industrielmassigen karp fenproduktion. Z. Fisch Hilfswiss, 117-125.

Begg, G.W. 1976 The relationship between the diurnal movements of some of the zooplankton and the sardine Li nothrissa miod n in Lake Kariba, Rhodesia Limnol. Oceanogr., 21:529-539.

Birge, E.A. & C. Juday 1922 The Inland Lakes of Wisconsin. The plankton. I. Its Quantity and Chemical Composition. Wisconsin Geol. Nat. Hist. Surv., Bull. 64, Sci. ser., No. 13, pp 1-222.

Boers, J.J. & J.C.H. Carter 1978 Instar development rates of Diaptomus minutus (Copepoda: Calanoida) in a small lake in Quebec. Can. J. Zool., 56:1710-1714.

Boyd, C.E. 1981 Comparison of five fertilization programmes for fish ponds. Trans. Am. Fish. Soc., 110: 541-545.

__________, Yont Musig & Luther Tucker 1981 Effects of three phosphorus fertilizers on phosphorus concentrations and phytoplankton production. Aquaculture, 22:175-180.

Ball, R.C. & H.A. Tanner 1951 The biological effects of fertilizers on a warm water lake. Mich. State Coll. Agr. Expt. Sta., Sect. Zool. Tech. Bull. 223, 32 p.

Brooks, J.L. 1947 Turbulence as an environmental determinant of relative growth in Daphnia. Proc. Nat. Acad. Sci., 33:141-148.

Brooks, J.L. & S.I. Dodson 1965 Predation, body size and composition of plankton. Science 150:28-35.

Brown, T.J. & J.R. Sibert 1977 Food of some benthic harpacticoid copepods. J. Fish. Res. Board Can., 34:1028-1031.

Burgis, M.J. 1973 Observations of the Cladocera of Lake George, Uganda. Journal of Zoology, London, 170:339-49.

Burns, N.M. 1976 Temperature, oxygen and nutrient distribution patterns in Lake Erie, 1970. J. Fish. Res. Board. Can., 33:485-511.

Butler, E.I., E.D.S. Corner & S.M. Marshall 1970 On the nutrition and metabolism of Zooplankton. 7. Seasonal survey of nitrogen and phosphorus excretion by Calanus in the Clyde Sea area. J. Mar. Biol. Assoc. U.K., 50:525-560.

Canter, H.M. & J.W. Lund 1951 Studies on Plankton parasites II. Ann. Bot. 15.

Castenholz, R.W. 1969 "Thermophilic blue-green algae and the thermal environment". Bacteriol. Rev. 33:476-504.

Claude, E. Boyd & John, W. Sowles 1978 Nitrogen fertilization of ponds. Trans. Am. Fish. Soc, 107(5):737-741.

Coker, R.F. & H.H. Addleatone 1938 Influence of Temperature on cyclomorphosis of Daphnia longispina. Jour. Elisha Mitchell Sci. Soc., 54:45-75.

Cooney, J.D. & C.W. Gehrs 1980 The relationship between egg size and naupliar size in calanoid copepod Diaptomus claviceps. Schacht. Limnol. Oceanogr., 25:549-552.

Corjunova, S.V. 1968 Blue-green algae as producers of toxic substances. Izuest. Akad. Nauk. SSR, Ser. Biol., 5:683-690.

Daday, E. 1898 Microscopische Sußwasserthiere aus Ceylon. Termeszetr. Fuz. (Budapest) 21:1-23.

Donald, J. Hall, William E. Cooper & Earl E. Werner 1970 An experimental approach to the production dynamics and structure of freshwater animal communities. Limnol. Oceanogr. 15:839-928.

Dice, L.R. 1914 The factors determining the Vertical Movements of Daphnia. Jour. Animal Behaviour, 4:229-265.

Droop, M.R. 1974 Heterotrophy of Carbon. In. W.D.P. Stewart, ed. Algal Physiology and Biochemistry. Berkeley, Univ. of California Press, pp. 530-559.

Edmondson, W.T. 1944 Ecological studies of sessile Rotatoria. Part I. Factors affecting distribution. Ecol. Monogr., 14:31-66.

Edmondson, W.T. 1945 Ecological studies of sessile Rotatoria. Part II. Dynamics of populations and social structures. Ecol. Monogr., 15:141-172.

____________ 1946 Factors in the dynamics of rotifer populations. Ecol. Monogr., 16:357-372.

____________ 1957 Trophic relations of the zooplankton. Trans. Amer. Micros. Soc. 76.

____________ 1959 Freshwater Biology (2nd Edn.). John Wiley and Sons. Inc. New York, 1248 pp.

Enright, J.T. 1970 Ecological aspects of endogenous rhythmicity. In: R.F. Jonston, Ed., Annual Review of Ecology and systematics, 1970. Annual Reviews, Palo Alto, California.

Eppley, R.W., J.N. Rogers, J.J. McCarthy & A. Sournia 1971 Light/dark periodicity in nitrogen assimilation of the marine phytoplankters Skeletonema costatum and Coccolithus huxleyi in N-limited chemostat cultures. J. Phycol. 7:150-154.

Fallon, R.D. & T.D. Brock 1980 Planktonic blue-green algae: Production, sedimentation and decomposition in Lake Mendota, Wisconsin. Limnol. Oceanogr., 25:72-88.

Fernando, C.H. 1980 The species and size composition of Tropical freshwater zooplankton with special reference to the Oriental Region (South East Asia). Int. Revue. ges. Hydrobiol. 65(3):411-426.

Ferrante, J.G. 1976 The characterization of phosphorus excretion products of a natural population of limnetic zooplankton. Hydrobiologia, 50:11-15.

____________ & J.I. Parker 1977 Transport of diatom frustules by copepod fecal pellets to the sediments of Lake Michigan. J. Fish. Res. Bd. Can., 34:545-551.

Findenegg, I. 1965 Relationship between standing crop and primary productivity. In: C.R. Goldman (ed.), Primary Productivity in Aquatic Environments. Mem. Ist. ital. Idrobiol. 18 Suppl., 273-289.

Fitzgerald, G.P. 1971 The biotic relationships within water blooms. pp. 26-32, University of Nebraska Press, Lincoln, p. 876. In: Rosowski, J.R. and B.C. Parker (eds.). Selected Papers in Phycology.

Fogg, G.E. 1956 Comparative physiology and biochemistry of blue-green algae. Bact. Rev., 29:148-

____________ 1965 Algal Cultures and Phytoplankton Ecology. Madison, University of Wisconsin Press, 126pp.

____________ 1971 Extracellular products of algae in freshwater. Archiv fur Hydrobiologue, Beihefte, Ergebnisse den Limnologie, 5:1-25.

Fogg, G.E., D.P. Stewart, P. Fay & A.E. Walsby 1973 The Blue-green Algae. New York, Academic Press, 459 pp.

Fott, B. 1971 Algenkunde. 2 Auflage. Gustav Fischer.

Franke, P.W. 1952 A laboratory study of intraspecific and interspecific composition in Daphnia pulicaria (Forbes) and Simocephalus vetulus O.F.Muller. Physiol. Zool. 25:178-204.

Ganapati, S.V., P.I. Chacko & R. Srinivasan 1953 Hydrobiological conditions of the Gangadhareswarar temple tank, Madras. J. Asiatic Soc. Sci., 19(2):149-159.

Gerloff, G.C., G.P. Fitzgerald & F. Skoog 1950 The mineral nutrition of Coccochloris peniocystis. Am. J. Bot., 37:835-840.

________________, ________________ & ________________ 1952 The mineral nutrition of Microcystis aeruginosa. Am. J. Bot., 39:26-32.

________________ & F. Skoog 1957a Nitrogen as a limiting factor for the growth of Microcystis aeruginosa in Southern Wisconsin lakes. Ecology, 38(4):556-561.

________________ & ________________ 1957b Availability of iron and manganese in southern Wisconsin lakes for the growth of Microscystis aeruginosa. Ecology, 38:551-556.

Gilbert, J.J. 1967 Asplanchna and postero-lateral spine production in Brachionus calyciflorus. Arch. Hydrobiol., 64:1-62.

________________ 1980 Observations on the susceptibility of some protists and Rotifers to predation by Asplanchna girodi. Hydrobiologia, 73:87-91.

Gliwicz, Z.M. 1975 Effect of zooplankton grazing on photosynthetic activity and composition of phytoplankton. Verh. Internat. Verein. Limnol., 19:1490-1497.

Golterman, H.L. 1960 Studies of the cycle of elements in freshwater. Acta. Bot. Neerl., 9:1-58.

Green, J. 1972 Latitudinal variation in associations of planktonic Rotifera. J. Zool. Lond.,167:31-34.

Green, J.D. 1976 Population dynamics and production of calanoid copepod Calamoecia lucasi in a northern New Zealand lake. Arch. Hydrobiol. Supplement, 50:313-400.

Gunther, E.E. 1936 A report on the oceanographical investigations in the Peru Coastal current. Discovery Rep., 13:107-276.

Hagedorn, H. 1971 Experimentelle Untersuchungen uber den Einfluss der Thiamins auf die naturliche Algenpopulation des Pelagials. Arch. Hydrobiol., 68:382-399.

Harris, J.E. 1924 Physical factors involved in the vertical migration of plankton. Quart. J. Micr. Sci. London, 94:537-550.

Hauer, J. 1937 Zur kenntnis der Rotatorienfauna der Eichener Sees. Beitr. naturk. Forsch. Sudwdtl., 2: 165-173.

________ 1938 Die Rotatorien von Sumatra, Java und Bali. Arch. Hydrobiol., Suppl. 15:296-384, 507-602.

Hensen, V. 1887 Uber die Bestimmung des Planktons oder des im Meere treibenden Materials an Pflanzen und Tieren, 5. Ber. Kommiss. wiss. Unters. Dt. Meere 12-16, 1-108.

________ 1895 Ergebnisse der Planktonexpedition der Humboldtstiftung, Lipsius & Tischer, Kiel and Leipzig.

Hobbie, J.E. 1964 Carbon-14 measurements of primary production in two arctic Alaskan lakes. Verh. Int. Ver. Limnol. 15:360-364.

Hrbacek, J. 1977 Competition and predation in relation to species composition of freshwater zooplankton mainly Cladocera. In Aquatic Microbial Communities. ed. J. Cairns, Garland Reference Library of Science and Technology, 15:305-353.

________ & M. Hrbackova-Esslova 1960 Fish stock as a protective agent in the occurence of slow developing dwarf species and strains of the genus Daphnia. Int. Rev. ges. Hydrobiol. 45:355-358.

________ & ________ 1966 The taxonomy of the genus Daphnia and the problem of 'Biological indication'. Verh. Int. Vero. Limnol., 16:1661-1667.

Huet, M. 1970 Traite de pisciculture Bruxelles, Ch. de Wyngaert.

Hutchinson, G.E. 1941 Limnological studies in Connecticut. Ecol. Monogr., 11:21-60.

________ 1944 Limnological studies in Connecticut. VII. A critical examination of the supposed relationship between phytoplankton periodicity and Chemical Changes in lake waters. Ecology, 25:3-26.

________ 1961 The paradox of the plankton. Am. Naturalist, 95:137-147.

Hutchinson, G.E. 1975 A treatise on Limnology. III. Aquatic Macrophytes and Attached Algae. New York, John Wiley & Sons, Inc.

Ivanova, M.B. 1969 The influence of active water reaction on the filtration rate of Cladocera. Pol. Arch. Hydrobiol. 16:115-124.

Jacobson, T.R. & G.W. Comita 1976 Ammonia-Nitrogen excretion in _Daphnia pulex_. Hydrobiologia, 51:195-200.

Javornicky, P. & J. Komarkova 1978 The changes in several parameters of plankton primary productivity in Slapy Reservoir 1960-1967, their mutual correlations and correlations with the main ecological factors. Hydrobiological Studies, 2:155-211.

Jennings, H.S. 1918 The wheel animalcules (Rotatoria). Chap. XVII in Ward and Whipple's Fresh-water Biology, pp. 553-620.

Jhingran, V.G. 1980 Fish and Fisheries of India. Hindustan Publishing Corporation (India).

Kofoid, C.A. 1897 On some important sources of error in the plankton method. _Science_, N.S. 6.

Krastz, W.C. 1931 A quantitative net plankton survey of east and west reservoirs near Akron, Ohio. Ohio Jour. Sci., 31:475-500.

Kristiansen, J. 1971 Phytoplankton of two Danish lakes, with special reference to seasonal cycles of the nannoplankton. Mitt. Internat. Verein. Limnol., 19:253-265.

Krogh, A. & E. Berg 1931 Uber die chemische Zusammensetzung des Phytoplanktons ausdem Fredericksborg. Schlosse und ihre Bedeutung fur die Maxima der Cladoceren. _Int. Rev. d. ges. Hydrobiol. u. Hydrogr._, 25:204-218.

Kryuchkova, N.M. 1972 Role of phyto- and zooplankton in the self-purification processes (on) the example of biological purifying ponds _Gidrobiol. Zh._, 8(5), 106-111.

Kuznetsov, S.I. 1959 _Die Rolle der Mikroorganismen im Stoffkreislauf der Seen_. Berlin, Veb Deutscher Verlag der Wissenschaften.

Lauterborn, R. 1900 Der Formenkreis von _Anuraea cochlearis_. Verh. _nat._ med. Ver., Heidelberg.

Lei, C. & K.B. Armitage 1980 "Growth, development and body size of field and laboratory population of _Daphnia ambigua_ Oikos, 35:31-48.

Lewkowicz, M. & S. Lewkowicz 1975 The role of zooplankton in self-purification of the pond after five years of fertilization with sugar wastes. Pol. Arch. Hydrobiol., 22:211-326.

Ljachnovic, V.P. 1962 Organiceskoe udobrenie prudov. Vopr-Rybn-Chozj Belorusi, 4, 73-100.

Lohmann, H. 1908 Untersuchungen zur Festellung des vollstandigen Gehaltes des Meeres an Plankton. Wissensch. Meeresunters. 10:131-370.

Mac Arthur, J.W. & W.H.T. Baillie 1929 Metabolic activity and duration of Life I influence of temperature on longevity in *Daphnia magna*. Jour. exp. Zool., 53:221-242.

McCracken, M.D., R. Middaugh & R.S. Middaugh 1980 A chemical characterisation of an algal inhibitor obtained from *Chlamydomonas*. Hydrobiologia, 70:271-276.

McIntire, C.D. & C.E. Bond 1960 Effects of artificial fertilization on plankton and benthos abundance in four experimental ponds. Oregon Agr. Exp. Sta. Techn. Bull. No. 1423:303-312.

McQueen, D.J. 1969 Reduction of zooplankton standing stocks by predaceous *Cyclops bicuspidatus thomasi* in Marion Lake, British Columbia. J. Fish. Res. Bd. Canada, 26:1605-1618.

Michael, R.G. 1962 Seasonal events in a natural population of the cladoceran *Ceriodaphnia cornuta* Sars and observations on its life cycle. J. Zool. Soc. India, 14:211-218.

________ 1964 Diurnal variation of the plankton correlated with physico-chemical factors in three different ponds. Ph.D. Thesis, Univ. of Calcutta, 1964, pp 75-115.

________ 1969 Seasonal trends in physico-chemical factors and plankton of a freshwater fish pond and their role in fish culture. Hydrobiologia, 33:144-160.

Munawar, M. 1970 Limnological studies of freshwater ponds of Hyderabad, India. I. The Biotype. Hydrobiologia, 35(1):127-162.

________ & I.F. Munawar 1976 A lakewide study of phytoplankton biomass and its species composition in Lake Erie, April-December 1970. J. Fish. Res. Board. Can., 33:581-600.

Naumann, E. 1917 Beitrage zur kenntnis des Teichnannoplanktons II. Uber das Neuston des Susswassers. Biol. Zbl., 37:98-106

Naumann, E. 1921 Spezielle Untersuchungen Uber die Ernahrungsbiologie des Tierischen Limnoplanktons. I. Uber die Technik des Nahrungserwerbs beiden Cladoceren und ihre Bedeutung fur die Biologie der Gewassertypen. Lunds Univ. Arsskr. n.f., Avd. 2, 14:1-48.

——— 1923 Spezielle Untersuchungen Uber die Ernahrungsbiologie des Tierischen Limnoplanktons. II. Uber den Nahrungswerb und die naturliche Nahrung der Copepoden und der Rotiferen des Limnoplanktons. Lunds Univ. Arsskr. n.f., Avd. 2, 19:3-17.

——— 1929 Grundlinien der experimentellen Planktonforschung. Die Binnengewasser, Bd. VI. 100 pp.

Navaneethakrishnan, P. & R.G. Michael 1971 Egg production and growth in *Daphnia carinata* King. Proc. Ind. Acad. Sci., LXXIII(3) B: 117-123.

Needham, J.G. & P.R. Needham 1962 A guide to the study of Freshwater Biology. Holden-Day, Inc., San Francisco. 108 pp.

Nelson, P.R. & W.T. Edmondson 1955 Limnological effects of fertilizing Bare Lake, Alaska. Fish. Bull. 102, U.S. Fish and Wildlife Service. Vol. 56.

Nygaard, G. 1949 Hydrobiological studies on some Danish ponds and lakes. Part II. The quotient hypothesis and some new or little known phytoplankton organisms. Kongel. Danske Vidensk. Selskab. Biol. Skrift., 7(1), 293 pp.

——— 1955 On the productivity of five Danish waters. Verh. Int. Ver. Limnol., 12:123-133.

Ogle sby, R.T. 1977 Relationships of fish yield to lakes phytoplankton standing crop, production and morphoedaphic factor. J. Fish. Res. Bd. Can., 34:2271-2279.

Ostwaldt, W. 1902 Zur Theorie des Planktons. Biol. Zentralbl., 22:596-605, 609-638.

Parker, R.A. 1960 Competition between *Simocephalus vetulus* and *Cyclops viridis*. Limnol. Oceanogr., 5(2): 180-189.

Pearsall, W.H. 1923 A theory of diatom periodicity. J. Ecol., 11:165-183.

Pennak, R.W. 1944 Diurnal movement of Zooplankton Organisms in Some Colorado mountain Lakes. Ecology, 25: 387-403

Pennak, R.W. 1953 Freshwater Invertebrates of the United States. The Ronald Press Co., New York 769 pp.

——— 1957 Species composition of limnetic zooplankton communities. Limnol. and Oceanogr. 2.

——— 1973 Some evidence for aquatic macrophytes as repellents for a limetic species of Daphnia. Int. Rev. ges. Hydrobiol., 58:569-576.

Philipose, M.T. 1960 Freshwater phytoplankton of inland fisheries. Proc. Symp. Algology, I.C.A.R., New Delhi, 1959, pp. 272-291.

Plew, W.F. & R.W. Pennak 1949 A seasonal Investigation of the Vertical Movements of Zooplankters in an Indiana Lake. Ecology, 30:93-100.

Pomeroy, L.R., H.M. Mathews & H.S. Min 1962 Excretion of phosphate and soluble organic phosphorus compounds by zooplankton. Limnol. Oceanogr., 8:50-55.

Pourriot, R., C. Rougier & D. Benest 1980 Hatching of Brachionus rubens O.F. Muller resting eggs (Rotifers) Hydrobiologia, 73: 51-54.

Prasad, B. 1916 J. Asiatic Soc. Bengal., 12:142-145.

Prescott, G.W. 1960 Biological disturbances resulting from algae populations in standing waters. Spl. Publ. No. 2, Pymatuning Laboratory of Field Biology 22-37.

Provasoli, L. 1958 Nutrition and ecology of Protozoa and algae. Ann. Rev. Microbiol. 12:279-308.

Pyrina, I.L. 1966 Pervicnaja produkcija fitoplanktona Ivanskogo, Rybinskogo i Kufbysevskogo vodochranilisca v zavisimosti ot nekotorych factorov. In: Produktivnost i krugovarot organiceskogo vescestva ve unutrennych vodsemach. Moskva, pp 249-270.

Reynolds, C.S. 1971 The ecology of planktonic blue-green algae in the North Shropshire meres. Fld. Stud., 3: 409-432.

——— & A.E. Walsby 1975 Water blooms. Biol. Rev. 50:437-481.

Rigler, F.H. 1956 A tracer study of the phosphorus cycle in lake water. Ecology, 37:550-562.

Rodhe, W., R.A. Vollenweider & A.Nauwerk 1956 The primary production and standing crop of phytoplankton. Perspectives in marine biology. Symp. Scripps Inst. Oceanogr., Univ. Calif.

Rosenberg, M. 1939 Algal physiology and organic production. Ann. Appl. Biol., 26(1):172-174.

Ruttner, F. 1914 Die Verteilung des Planktons in Susswasserseen. Abderhalden Fortschr. 10.

——— 1931 Hydrographische und hydrochemische Beobachtungen auf Java, Sumatra und Bali. Arch. f. Hydrobiol., Suppl. Bd. VIII, pp. 197-460.

——— 1953 Fundamentals of Limnology. University of Toronto Press. 307 pp.

Saunders, G.W. 1972 The transformation of artificial detritus in Lake water. Mem. Ist. Ital. Idrobiol., 29 (Suppl.):261-288.

Schaperclaus, W. 1961 Lehruch der Teichwirtschaft Berlin-Hamburg P. Parey Verl.

Schroder, R. 1959 Die Vertikalwanderungen des Crustaceenplanktons der Seen des sudlichen Schwarzwaldes. Arch. Hydrobiol. Suppl. 25.

Schroeder, G.L. 1978 Autotrophic and heterotrophic production of microorganisms in intensively manured fish ponds and related fish yields. Aquaculture, 14:303-325.

Schroter, C. & O. Kirchner 1896 Die Vegetation der Bodensees. Lindau, Bodensee Forsch., 9, T1. 1:1-122, T1.II:1-86.

Sewell, R.B.S. 1934 Studies on the bionomics of freshwaters in India, II. On the fauna of the tank in the Indian Museum Compound and seasonal changes. Int. Rev. ges. Hydrobiol & Hydrogr., 31(3-4): 36.

Seymour-Sewell, R.B.S. 1934 A study of the fauna of the salt lakes, Calcutta. Rec. Indian Mus., 36:45-121.

Shapiro, J. 1973 Blue-green algae: Why they become dominant. Science, 179:382-384.

Singh, V.P. 1960 Phytoplankton ecology of the inland waters of Uttar Pradesh. Proc. Symp. Algology, ICAR New Delhi, 243-271.

Smith, G.M. 1950 The fresh-water Algae of the United States, 2nd ed. New York, McGraw-Hill Book Co., vii, 719 pp.

Sorokin, Y.I. & E.B. Paveljeva 1972 On the quantitative characteristics of the pelagic ecosystem of Dalnee Lake (Kamchatka). Hydrobiologia, 40:519-552.

Stagenberg, M. 1968 Toxic effects of Microcystis aeruginosa Kg. extracts on Daphnia longispina O.F. Muller and Eucypris Virens Jurine. Hydrobiologia, 32:81-87.

Steel, J.A. 1975 The management of Thames Valley reservoirs. Water Research Centre Symposium: The effects of storage on water quality. Medmenham.

Steemann-Nielsen, E. 1962 On the maximum quantity of plankton chlorophyll per surface unit of a lake or the sea. Int. Rev. ges. Hydrobiol., 47:333-338.

__________ & E.G. Jorgensen 1962 The physiological background for using Chlorophyll measurements in hydrobiology and a theory explaining daily variations in Chlorophyll concentration, Arch. Hydrobiol., 58: 349-357.

Storch, O. 1924 Morphologie und Physiologie der Fangapparate der Daphniden. Erg. u. Fortschr. d. Zool. 6.

__________ 1925 Der Fangapparat von Diaptomus. Ztschr. vgl. Physiol. 3.

Straskraba, M. 1963 Share of the littoral region in the productivity of two fish ponds in southern Bohemia. Rozpravy Ceskosl. Akad. Ved, Rada Matem. Prir. Ved, 73(13), 64 p.

__________ 1965 The effect of fish on the number of invertebrates in ponds and streams. Mitt. Int. Ver. Limnol., 13:106-127.

__________ 1967 Quantitative study on the littoral zooplankton of the Poltruba Backwater with an attempt to disclose the effect on fish. Rozpravy Ceskosl. Akad. Ved, Rada Matem. Prir. Ved, 77(11):7-34.

Strom, K.M. 1924 Studies in the ecology and geographical distribution of fresh-water algae. Rev. Algologique. 1:127-155.

St[illegible], W. & J.L. Morgan 1962

Swar, D.B. & 1980 Some studies on the ecology of Limnetic crustacean zooplankton in lakes Begnas and Rupa, Pokhara Valley, Nepal. Hydrobiologia, 70: 235-245.

Swingle, H.S. & E.V. Smith 1939 Fertilizers for increasing the natural food for fish in ponds. Trans. Amer. Fish. Soc. 68:126-135.

Tilzer, M.M. 1973 Diurnal periodicity in the phytoplankton assemblage of a high mountain lake. Limnol. Oceanogr., 18:15-30.

Utermohl, H. 1925 Limnologische Phytoplankton-studien. Arch. Hydrobiol. Suppl. 5

Utermohl, H. 1958 Zur Vervollkommnung der quantitativen Phytoplankton Methodik. Mitt. Int. Ver. Limnol., 9:1-58.

Vaas, K.F. & M. Sachlan 1953 Limnological studies in diurnal fluctuations in shallow ponds in Indonesia. Verh. Int. Ver. Limnol., 12:309-319.

________ & A. Vass-Van Oven 1959 Studies on the production and utilisation of natural food in Indonesian carp ponds. Hydrobiologia, 12 : 308-392.

Van Oye, P. 1934 Quelques donnees sur l'ecologie des Desmidiees. Bull. Soc. Roy. Bot. Belg., 67(1):65-75.

Venkataraman, G.S. 1962 Mineral nutrition of Anacystis montana Dr. and Dy. Proc. natn. Inst. Sci. India 20B:77-80.

Venkataraman, K. & S.V. Job 1979 The influence of temperature on oxygen consumption of Daphnia carinata King (Cladocera: Daphnidae). Curr. Sci., 48(1):24-25.

________ & ________ 1980 Effect of temperature on the development, growth and egg production in Daphnia carinata King (Cladocera: Daphnidae). Hydrobiologia, 68:217-224.

Vijayaraghavan, S. 1967 Limnological studies of some tropical ponds. Ph.D. Thesis - Madurai University (unpublished).

________ 1970 Seasonal events in a natural population of Daphnia carinata King. Proc. Ind. Acad. Sci., Sect. B, 71(5):193-203.

Vincent, W.F. 1978 Survival of aphotic phytoplankton in Lake Tahoe throughout prolonged stratification. Verh. Internat. Verein, Limnol., 20:401-406.

Vollenweider, R.A. 1968 The scientific basis of lake and stream eutrophication, with particular reference to phosphorus and nitrogen as eutrophication factors. Tech. Rep. OECD. Paris. DAS/CSI/68, 27:1-182.

Von Dehn, M. 1930 Untersuchungen uber die verdauung bei Daphnien. Z. Vergl. Physiol. 13:334-358.

Walter, B. 1969 Inter-relations of Cladocera and algae. Ph.D. Thesis. Westfield Coll., Univ. London.

Warren, E. 1900 On the reaction of Daphnia magna (Straus) to certain changes in its environment. Quart. J. Microsc. Sci. 43:199-224.

Welch, P.S. 1952 Limnological Methods. McGraw-Hill Book Co., Inc., New York.

Wesenberg-Lund, C. 1900 Von dem Aphangigkaitverhaltnis zwischen dem Bau der Planktonorganismen und dem specifischen Gewicht des Susswassers. Biol. Centralbl., 20:606-619; 644-656.

West, W. & G.S. West 1912 On the periodicity of the phytoplankton of some British lakes. J. Linn. Soc. Botany, 40:395-432.

Wetzel, R.G. 1965 Nutritional aspects of algal productivity in marl lakes with particular reference to enrichment bioassays and their interpretation. Mem. Ist. Ital. Idrobiol., 18(Suppl.):137-157.

________ 1966 Productivity and nutrient relationships in marl lakes of northern Indiana. Verh. Int. Ver. Limnol., 16:321-332.

________ 1972 The role of carbon in hardwater marl lakes. In: G.E. Likens, ed. Nutrients and Eutrophication: The Limiting Nutrient controversy. Special Symposium, Amer. Soc. Limnol. Oceanogr. 1:84-91.

________ 1975 Primary production. In: B.A. Whitton, ed. River Ecology. Cambridge, Cambridge University Press, pp. 230-247.

Whitford, L.A. 1960 Ecological distribution of freshwater algae. Spl. Publ. No. 2. Pymatuning Laboratory of Field Biology, pp. 2-10.

Willemsen, J. 1980 Fishery aspects of eutrophication. J. Hydrobiological Bulletin Vol. 14 No.1/2, 12-21.

Williams, F.M. 1971 Dynamics of microbial populations. p.197-267. In B.C. Patton (ed.), Systems analysis and simulation in ecology Academic.

Wojcik, U. 1970 (Distribution of crustacean plankton in Lake Dgal Maly)- in Polish. Acta. Hydrobiol., 12: 295-307.

Wolk, C.P. 1973 Physiology and Cytological chemistry of blue-green algae. Bacteriol. Rev., 37:32-101.

Woltereck, R. 1908 Die naturliche Nahrung pelagischer Cladoceren und die Rolle des "Zentrifugenplanktons" im Susswasser. Int. Rev. 1.

________ 1909 Weitere experimentelle Untersuchungen uber die Artveranderung, speziell uber das Wesen quantitativer Artunterschiede bei Daphniden. Verh. D. Zool. Ges. 19.

Woltereck, R. 1913 Ueber Funktion, Herkunft und Entstehungsursachen der sogennanten Schwebefortsatze pelagischer Cladoceren. Zoologica, 67.

———— 1928 Bemerkungen uber die Begriffe "Reaktionsnorm" und "Klon". Biol. Zbl. 48.

Yan, N.D. & P. Stokes 1978 Phytoplankton of an acidic lake and its responses to experimental alterations of pH. Environ. Conser., 5:93-100.

Yao-Sung Lin 1976 Ecological studies of fish ponds in Clupei. Bull. Inst. Zool., Academia Sinica 17(1): 43-59.

Zafar, A.R. 1964 On the ecology of algae in certain fish ponds of Hyderabad-India. I. Physico-chemical complexes. Hydrobiologia, 23:179-195.

Zagorodnyaya, Yu. A. 1979 The dynamics of glycogen content in the copepod *Pseudocalanus elongatus*. Biol. Morya (Valdivost.) (1):79-82.

Zaret, T.M. & T.S. Suffern 1976 Vertical migration in zooplankton as a predator avoidance mechanism. Limnol. Oceanogr., 21:804-813.

PRIMARY PRODUCTION

INTRODUCTION

It is usually those flora which possess the green pigment chlorophyll, that can utilise the radiant solar energy to create from simple inorganic substances, new organic materials involving high energy bonds. This is referred to, as photosynthesis, or the conversion of carbon-dioxide, water and the kinetic energy of sun-light, into free oxygen and sugars, which is an energy binding re-duction. It is for this reason, that green plants are distinguished as autotrophs and in energy terms called enderogonic. This autotro-phic component of any ecosystem are the producers and form the first link of a food chain. Their importance on land, as open ecosystem, need no elaboration and all the more is so vital in aquatic bodies which are closed ecosystems. It is therefore, the rate of produc-tion or the primary productivity, which establishes the total life in an aquatic system.

These are only possible, depending on the algae or the total phytoplankton in waters. At any given time therefore, regardless of the taxonomic positions of the phytoplankton, a population belongs to three overlapping groups of metabolic activities: (a) Active or-ganisms - where cell number increases, (b) Neutral organisms - where cell number are more or less constant and (c) Inactive organ-isms - where cell numbers mostly decreasing, degenerating or decay-ing. Therefore, primary production will be affected by the respec-tive proportion of these three groups.

The earliest understanding of some fundamental processes in plants was by Priestly (1772), followed by the effect of light by Ingen-Housz (1779). Absorption of carbon-dioxide and evolution of oxygen was reported by Senebier (1783, 1788 and 1800) and Ingen-Housz (1796) and the first quantification by de Saussure (1804).

The identification of the pigment chlorophyll and coining the word was after Pelletier and Caventou (1818), though Grew in 1682 had recorded green and yellow pigments in leaf extracts.

Since then, light and carbon-dioxide being important for photosynthesis advocated by some, as the former and others the latter took place (Gilby, 1821; Daubeny, 1836; Berzelius, 1837a,b; Mohl, 1837, 1845, 1851 and 1855; Leibig, 1840, 1843a,b; Dumas and Boussingault, 1841; Draper, 1843 and 1844; Kutzing, 1843; Hunt, 1848; Cloez and Gratiolet, 1850). The extraction of the pigment either yellow-blue, yellow, brown seemed to be the next stage in the study of photosynthesis (Fremy, 1860 and 1865; Boussingault, 1864, 1868 and 1869; Cohn, 1865; Rosanoff, 1867; Millardet, 1869; Timiriazeff, 1869, 1871, 1877, 1883 and 1889; Van Tieghem, 1869 and Sorby, 1873). It was then that the physical and optical nature of chloroplasts was seen, and that the possibility of carbohydrates being formed, and further that a direct relationship existed between oxygen evolution and carbon-dioxide absorption was revealed (Boehm, 1873; Sorby,1873; Bernard, 1878; Weber, 1879; Stahl, 1880a,b; Schwarz, 1881; Detmer, 1882; Sachs, 1887; Engelmann, 1894).

From this time onwards, till the early part of the present century, various experiments were conducted to find the photosynthetic rates. They were done by varying light intensities, the use of different gases and in isolated chloroplasts (Girard, 1884; Kreusler, 1885 and 1890; Meyer, 1885; Bonnier and Mangin, 1886; Forbe, 1887; Schutt, 1888a,b; Reinke, 1893; Saposchnikoff, 1893 and 1894; Marcacci, 1895; Ewart, 1896, 1897a,b; Pfeffer, 1900; Blackman and Mathaei,1905 and 1911; Kniep and Minder, 1909; Mitscherlich, 1909 and 1921). Though Johnson (1903) pioneered the light and dark bottle method it was Osterhout and Hass (1917) and later Warburg (1919) who used phytoplankton and the Winkler's method for an indirect estimation of

It was thereafter that work on aquatic macrophytes and phytoplankton in relation to various factors and in particular nutrients and their effects on the producer organisms were undertaken (Ruttner, 1921; Briggs, 1922; Blackman, 1923; Putter, 1924; Gaardar and Gran, 1927; Thienemann, 1927; Marshal and Orr, 1928; Strom, 1928; Rawson, 1930; Wiebe, 1930; Emerson and Arnold, 1932; Fritsch, 1931; Birge and Juday, 1934; Harvey et. al., 1935; Gaffron and Wohl, 1936; Jenkin, 1937 and Mortimer, 1950 and 1955).

In the fifties, isolated chloroplasts known to use NADP and the discovery of cytochrome F was revealed (Arnon, 1951; Hill and Scarisbrick, 1951; Vishniac and Ochoa, 1951). Moreover, dark respiration was found out by Webster and Frenchnel (1952), when simultaneously the C^{14} method was discovered by Steeman Nielsen (1952) for regular analysis of the photosynthetic rate of planktonic algae. The oxygen deficit, as an index of aquatic productivity was shown by Hutchinson (1938) which was opposed by Rawson (1939) who attributed other morphological, edaphic and climatic factors for primary production. Riley (1940), was the first to identify reciprocal relationship between chlorophyll and productivity and Ruben et. al., (1941) revealed that oxygen evolved from water and not carbon-dioxide, during the process of photosynthesis. Brown (1953) confirms Ruben's finding and since then, works on isolated chloroplasts and algae were taken up with greater earnestness to identify the causative factors for the increase or decrease in photosynthetic rate (Arnon et. al., 1954; Fogg and Wolf, 1954; Dysens, 1955; Fogg and Westlake, 1955; Kratz and Myers, 1955; Rodhe, 1955 and 1962; Northcote and Larkin, 1956; Steeman Nielsen and Al Kholy, 1956; Hutchinson, 1957; Arnon, 1958; Ryther and Yentsch, 1958).

The concept of nutrients limiting production and the experiments directed towards understanding of both the quality and quantity responsible under field and laboratory conditions were initiated in the sixties of the present century. Some of these were the identification of molybdenum, phosphorus or nitrogen and chelated iron, all directly or indirectly affecting carbon fixation (Goldman, 1960; Steele and Yentsch, 1960; Evans, 1961; Rodhe, 1962; Schelske et.al., 1962; Talling, 1962; Yentsch, 1962; and Rodhe et.al.,1966). It was also during this period that the importance of the pigments in the chloroplasts and their association with light intensities were shown (Beyers et.al., 1963; Chance and Borner, 1963; Margalef, 1963a,b and 1968; Petterson and Parson, 1963; Yentsch and Menzel, 1963; Brown et.al., 1964; Jorgensen, 1964; Kandler, 1964; Steele, 1964; and Steeman Nielsen and Park, 1964).

Talling (1965) identified a population density less pronounced in equatorial lakes, while others attributed extracellular release to be a significant portion for the total carbon fixed (Fogg et.al., 1965; Wetzel, 1966a,b, 1967 and 1968; Dumont, 1968; Hamilton, 1969; Qasim et.al.,1969; Vijayaraghavan et.al.,1969; Adams, 1970; King, 1970; Golterman, 1971; Hickman, 1971; Sakamoto, 1971; Schindler and Holmgran, 1971). After the identification of causative factors, experiments both at micro- and macro levels were conducted. This was done in terms of permutation and combinations of varying amounts of nutrients and the manipulation of water bodies, to see the increase or decrease of the standing crop, directly related to the carbon fixed (Fee, 1973; Schindler and Fee, 1973; Stross et.al., 1973; Schindler, 1974; Goldman and Amezaga, 1975; Saunders et.al., 1975; Allen and Ocevski, 1976; Berman, 1976; Sreenivasan, 1976; Tilzer and Schwarz, 1976; Alfred and Chellapa, 1978).

The above works revealed the causative factors in the eutrophication process, thus classifying water bodies as highly productive. This helped in identifying not only the effects of additive phenomena of allochthonous material, but also the recycling nature within the system was understood. It was with this idea that in the late seventies, work was initiated on the relationship of the production efficiencies to that of bacteria-plankton (Berman, 1976; Haniffa, 1978; Matsuyama and Shirouzu, 1978; Jana, 1979; Khan and Zutshi, 1980; Rishi and Kachroo, 1981).

As mentioned in the earlier chapters in addition to the Indian works, the review of Gulati and Wurtz-Schulz (1980) and Michael (1980) reveal either one or more of the above mentioned phenomena studied elsewhere and available for Indian latitudes too. Further, a total analysis of primary production, with importance and relevance at the different latitudes and altitudes of the globe has been wonderfully brought in a concise form by Westlake et.al., 1980 and Brylynsky 1980.

In addition to the foregoing review of literature, where the operation of primary production and its importance either in fish ponds or in larger lakes, have been seen it is felt to identify aspects of primary production particularly in relation to fish yield. Such works on intensive fish culture ponds where primary productivity has been shown to be the one criteria related to total fish production exist (Khan and Siddique, 1971; Goodyear et. al., 1972; Wolny and Grygierek, 1972; Mellack, 1976; McConnell et. al., 1977; Oglesby, 1977; Pedro Noriega-Curtis, 1979; Ofur Zur, 1981; Hecky et. al., 1981; Yanlingling et. al., 1981).

MATERIALS AND METHODS

Despite the various techniques evolved for the estimation of primary productivity in freshwaters viz. light and dark bottle technique, chlorophyll method, C^{14} method, ATP measurements and dissolved inorganic carbon method, yet for the remoteness of the region, and the situation of our laboratory and along with the establishment of the new Department, we could not undertake all these, due to the lack of facilities, instrumentation and personnel. Therefore, the present investigation was confined only to the "light and dark bottle technique" after Gaarder and Gran (1927). The estimation of oxygen was done by the usual unmodified Wrinkler's method with the incorporation of Azide modification (APHA, 1975).

For the above estimation, water samples were collected from the surface in 125 ml glass stoppered light and dark bottles from each of the pond and pool . They were incubated <u>in situ</u> for 24 hrs. Simultaneously, replicates of water samples were taken from each pond and pool, where the bottles were left for incubation at the same time period for estimation of the initial oxygen values, which were fixed at the site with manganous sulphate and alkaline iodide solutions, before returning to the laboratory for oxygen titration and estimation. Similarly, the incubated light and dark bottles were collected the next day and immediately fixed and then returned to the laboratory for final oxygen estimations.

The results of the titrations were converted to gross oxygen production (light bottle - dark bottle), net oxygen production (light bottle - initial bottle), and the respiratory oxygen uptake (initial bottle - dark bottle). The oxygen values in mg/litre were converted to mg C/M^3 by multiplying it with a factor of 375.36 (Vollenweider, 1971).

RESULTS

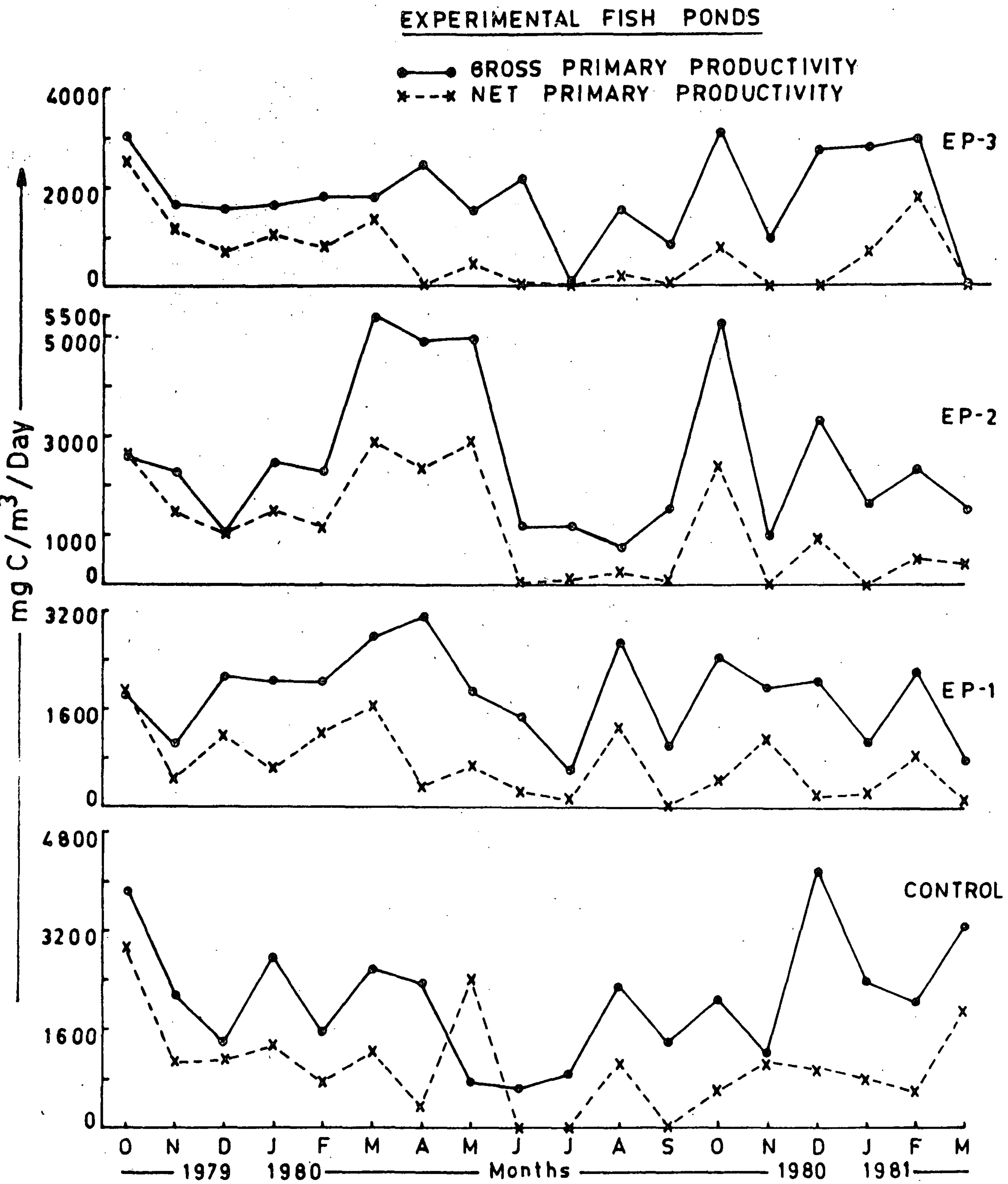
Primary productivity estimations were conducted in all the four experimental fish ponds and five circular plastic pools. Both gross primary productivity and net primary productivity were investigated and their results expressed as mg C/M^3/day. Though respiration values were also calculated it was not incorporated because net primary productivity reflected the overall respiration of the community, along with gross productivity values.

CONTROL POND : It was seen in the control pond that gross primary productivity values were nearly 4,000 mg C/M^3/day and represented the maximum as recorded in October, while the lowest value of 675 mg C/M^3/day was recorded in June during the first annual cycle. In the second cycle gross primary productivity values were above 4,000 mg C/M^3/day as recorded in the month of December and the minimum value of nearly 1,200 mg C/M^3/day in the previous month of November. The fluctuations further revealed peaks in the months of January, March, August, October and March, while gradual falls were observed in December, February, May, September and February during the first and second cycles in addition to the maximum and minimum values recorded. The general trend of fluctuation was observed to be summer minima, with frequent peaks during the rest of the season (Fig.10).

The net primary productivity values similarly for the first annual cycle showed a maximum of nearly 3,000 mg C/M^3/day in October, but recorded nil values in June and July. However, during the second cycle, net primary productivity values in this control pond, registered a minimum of 600 mg C/M^3/day in October and February and touched a peak in March with nearly 2,000 mg/C/M^3/day. In addition to the maximum and minimum values recorded, the months of March, May, August and November registered peaks of net primary productivity during both

Fig. 10 - Showing the magnitude of fluctuations seasonally of Gross primary productivity and Net primary productivity in the Control and Experimental Fish Ponds.

EP = Experimental Fish Ponds.



EXPERIMENTAL FISH PONDS
GROSS PRIMARY PRODUCTIVITY
NET PRIMARY PRODUCTIVITY
EP-3
EP-2
EP-1
CONTROL
mg C/m3/Day
4000
2000
0
5500
5000
3000
1000
3200
1600
4800
O N D J F M A M J J A S O N D J F M
1979 1980 Months 1980 1981

the cycles. The net productivity values were therefore nearly 49.6% that of the gross productivity irrespective of the seasons (Fig.10).

<u>EXPERIMENTAL FISH POND-1</u> : In this pond the maximum gross primary productivity value was recorded in April registering around 3,000 mg C/M^3/day, but it fell to a low level in July with 600 mg C/M^3/day during the first annual cycle. In the next cycle it was the month of October which showed the maximum value of 2,500 mg C/M^3/day and March recorded the minimum value of 750 mg C/M^3/day. Further, smaller peaks were also observed in December, August, December and February with similar minima in November, September and January for both the cycles (Fig.10).

Net primary productivity values as observed were maximum in October recording 1,950 mg C/M^3/day and with a minimum value of only 37 mg C/M^3/day in September during the first annual cycle. In the second cycle however, a minimum value of 150 mg C/M^3/day was recorded in March, while the maximum net primary productivity in this pond was seen in November representing 1,130 mg C/M^3/day. The fluctuations further revealed peaks in the months of December, March, August and February with a fall in November, April, June and December in addition to the maximum and minimum recorded for both the cycles. In this pond the net primary productivity was 39.1% of the gross primary productivity irrespective of the seasons (Fig.10).

<u>EXPERIMENTAL FISH POND-2</u> : The gross primary productivity values in this pond showed the highest value in comparison to all the other ponds, recording a maximum of 5,400 mg C/M^3/day in March, while the lowest value was obtained in August with only 713 mg C/M^3/day during the first annual cycle. Similarly, during the second cycle an almost equal magnitude of gross primary productivity as maximum was obtained in October recording 5,255 mg C/M^3/day with a drop to 975 mg

C/M^3/day as minimum in the subsequent month of November. In addition to the maxima and minima recorded, the following months were seen to have peaks of lower magnitudes in October, January, May, December and February with a fall in December, June, January and March during both the cycles (Fig.10).

In the same pond the net primary productivity values obtained, however, were not so significantly high in relation to the values obtained for the other ponds. The maximum value of nearly 3,000 mg C/M^3/day was recorded in May and in the subsequent month of June dropped to nil value during the first annual cycle. The month of October during the second cycle registered the maximum value of 2,400 mg C/M^3/day, but the subsequent months of November and January recorded nil values. Similar peaks of smaller magnitudes were also observed during both the cycles in October, March and December and their falls in December, February and September. The net primary productivity was 45.1% to that of gross primary productivity (Fig.10).

EXPERIMENTAL FISH POND-3 : The gross primary productivity value in this pond was recorded maximum in October representing 3,000 mg C/M^3/day and minimum values of 150 mg C/M^3/day in July during the first annual cycle. In the next cycle, the month of October again recorded the maximal peak value of 3,200 mg C/M^3/day, while in March nil values were recorded. The trend of fluctuations further recorded peaks in the months of April, June, August, December and February and with a fall in November, May, September and November in addition to the minimum and maximum recorded inclusive of both the cycles (Fig.10).

The maximum net primary productivity in this pond was recorded in October as 2,500 mg C/M^3/day and a drop to nil value in July during the first annual cycle. In the second cycle, the net primary productivity values were maximum in February recording 1,700 mg C/ M^3/day but again fell to nil values in November, December and March. In addition to the maxima and minima, comparatively smaller peaks were also observed in the months of March, May, October and January, while their falls were recorded in December, April, June, November and March during both the cycles over the season. The net primary productivity percent values in this pond was 35.1% observed to that of gross primary productivity irrespective of the seasons (Fig.10).

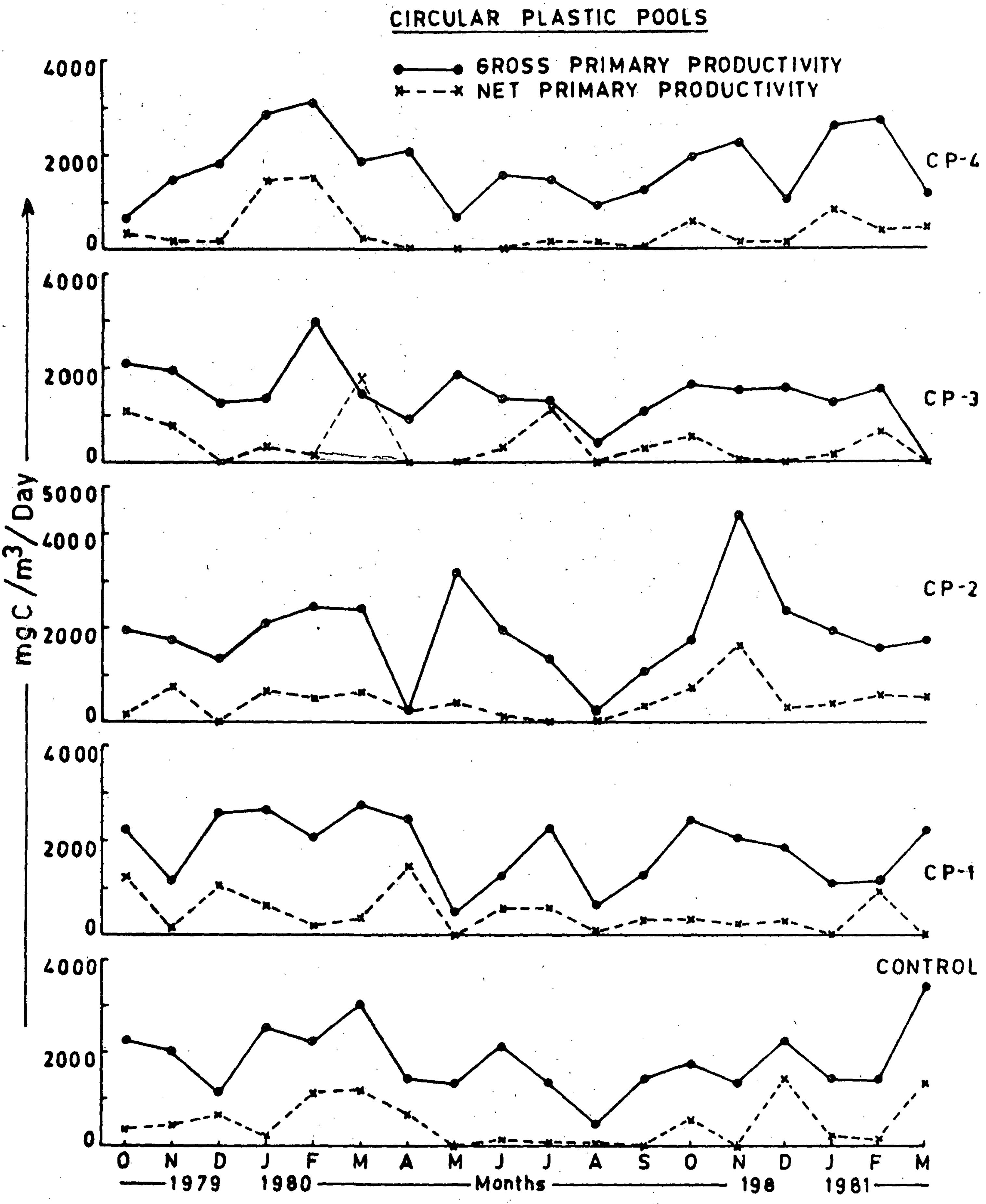
The primary productivity values in the five circular plastic pools showed relatively lower values of productivity in relation tp those obtained in the ponds.

<u>CONTROL POOL</u> : In this control pool, the maximum value of gross primary productivity was obtained in March showing nearly 3,000 mg C/ M^3/day and a minimum of 450 mg C/M^3/day in August during the first annual cycle. March of the second cycle recorded 3,450 mg C/M^3/day as the maximum and November the minimum value of 1,350 mg C/M^3/day. The fluctuations in addition to the peaks and minimal levels, showed peaks of lower magnitudes in October, January, June, October and December. Similarly they fell in December, February, April, November and January during the first and second cycles (Fig. 11).

The maximum value of net primary productivity was recorded in March with 1,163 mg C/M^3/day, and thereafter a gradual decrease till it recorded nil value in May during the first annual cycle. In the next cycle, maximum net primary productivity was obtained in December recording 1,426 mg C/M^3/day and showed nil value in November. The trend of fluctuation over the entire period of study further recorded peaks in December, February, October and March, while their falls were registered in January, November and January during the first ano second cycles. It was therefore observed that the net

Fig. 11 - Showing the magnitude of fluctuations seasonally of Gross primary productivity and Net primary productivity in the Control and Circular Plastic Pools.

CP = Circular Plastic Pools.


CIRCULAR PLASTIC POOLS
GROSS PRIMARY PRODUCTIVITY
NET PRIMARY PRODUCTIVITY
CP-4
CP-3
CP-2
CP-1
CONTROL
mgC/m3/Day
4000
2000
0
5000
O N D J F M A M J J A S O N D J F M
1979 1980 Months 198 1981

primary productivity was 26.6% of the gross primary productivity irrespective of the seasons (Fig.11).

POOL-1 : The gross primary productivity was seen to be maximum in this pool in March recording 2,740 mg C/M^3/day and dropped to a minimum of 450 mg C/M^3/day in May during the first annual cycle. In the next cycle, October and January recorded the maximum and minimum values with 2,470 mg C/M^3/day and 1,126 mg C/M^3/day respectively. Peaks of lower magnitudes were also observed in October, January, July and March while they fell in November, February, August and February during both the first and second cycles (Fig. 11).

Similarly in this pool-1, the maximum and minimum values of net primary productivity were obtained in April and May recording nearly 1,426 mg C/M^3/day and nil values respectively during the first annual cycle. In the second cycle February recorded maximum values of 975 mg C/M^3/day but nil values during January and March. The trend of fluctuations was further seen to have smaller peaks in October, December, June and July with a fall in November, February and August during the first and second cycles. In this pool also the net primary productivity showed 26.4% similar to that of the control pool (Fig. 11).

POOL-2 : The maximum value of gross primary productivity during the first annual cycle was obtained in May registering 3,190 mg C/M^3/day and the minimum value in August with only 262 mg C/M^3/day. During the second cycle howe er, the maximum peak was recorded in November which was 4,542 mg C/M^3/day and a minimum of 1,538 mg C/M^3/day in February. The fluctuations further revealed peaks in the months of February and March and with a fall in December, April and January (Fig. 11).

The maximum value for net primary productivity in this pool-2 was observed in November of the first annual cycle recording nearly 770 mg C/M^3/day but recorded nil values in December, July and August during the same period. In the second cycle however, the maximum net primary productivity reached a peak of 1,652 mg C/M^3/day in November while the subsequent month of December recorded a minimum of 375 mg C/M^3/day. In addition to the maximum and minimum recorded, the trend in the fluctuations of net primary productivity revealed smaller peaks in January, March, May and October and falls in February, June and December. The net productivity was observed to be 24.8% to that of gross primary productivity in this pool (Fig. 11).

POOL-3 :In this pool February and August registered the maximal and minimal values of gross primary productivity recording nearly 2,928 mg C/M^3/day and 450 mg C/M^3/day during the first annual cycle respectively. In the second cycle, the maximal and minimal values were obtained in October and March recording 1,689 mg C/M^3/day and nil values respectively. The trend of seasonal fluctuation in addition to the maximum and minimum recorded, revealed peaks of smaller magnitude in October, May and February and falls in December, April, June and January during the first and second cycles (Fig. 11).

The net primary productivity was observed as maximum during the first annual cycle in March recording 1,538 mg C/M^3/day, however it recorded nil values in December, April, May and August. During the second cycle February recorded 675 mg C/M^3/day as maximum and December and March were nil. The net primary productivity fluctuation also recorded peaks in October, July and October during the first and second cycles. In this pool, the net primary productivity percent value was the highest with 27.4% to that of gross primary productivity irrespective of the seasons (Fig. 11).

POOL-4 : In this pool-4, a gradual trend of increase in the gross primary productivity from October where the minimum value recording 630 mg C/M^3/day touched a peak of nearly 3,080 mg C/M^3/day in February during the first annual cycle. The next cycle revealed February and December as maximum and minimum values recording 2,702 mg C/M^3/day and 1,052 mg C/M^3/day respectively. The trend of seasonal fluctuation in addition to the maximum and minimum recorded, revealed peaks of smaller magnitudes in January, April, June and November and a fall in March, May, August and March during both the first and second cycles (Fig.11).

The net primary productivity in this same pool showed a maximum in February recording 1,426 mg C/M^3/day and nil in April, May and June during the first annual cycle. During the second cycle, maximum net primary productivity value was obtained in January as 1,426 mg C/M^3/day and minimum in November with nearly 150 mg C/M^3/ day. The fluctuations further revealed smaller peaks in the months of January and October and they fell in March and February during both the cycles. The net primary productivity percent values was 22.3% to that of the gross primary productivity irrespective of the seasons (Fig.11).

DISCUSSION

Primary productivity is the basic energy source for metabolic processes occurring in the biosphere. The amount of incoming radiant energy which is transformed into chemical energy by the photosynthetic processes, determines the productivity of the ecosystem. This, in any aquatic system involves the reduction of carbon-dioxide to produce organic materials, commonly called as autotrophic production. Therefore, primary productivity in aquatic systems depends primarily on the photosynthetic activity of autotrophic organisms. However, this is controlled by the interactions of many factors, physical, the nutrient level and the structure and function of the biota itself.

The gross primary productivity and net primary productivity values in the present investigation was calculated after analysis by the classical light and dark bottle method (Gaarder and Gran, 1927). Though the method has its own drawbacks, our idea was to find out the relative proportion not only between the systems under consideration but to arrive at conclusions based on the correlation between these values and fish growth over the seasons.

The gross primary productivity values ranged from 0 mg C/M^3/day to nearly 5500 mg C/M^3/day in the Experimental Fish Ponds. Though in Experimental Fish Ponds-1 and 3, the fluctuation and the range of these gross primary productivity values seemed to be more or less the same, they were also the lowest records of all the ponds undertaken. In fact these two ponds revealed values even lower than the control pond in certain months. The maximum range and the highest value was seen in Experimental Fish Pond-2. In any case all the values observed were true of eutrophic situation. As far as their seasonality was concerned, all of them irrespective of fertilization, revealed a more or less a spring and autumn maxima and a summer minima.

In contrast to the gross primary productivity values in these fish ponds the net primary productivity values revealed far less, and in most cases nearly half of what was observed as gross primary productivity. Once again Experimental Fish Ponds-1 and 3 showed the values far less than the control pond. In fact pond-2 also revealed at certain occasions lesser values than that of the control pond, though not as significant as the others. The seasonality in their fluctuation was however similar to that of gross primary productivity. In most cases the net primary productivity values touched nil. Such instances indicate that respiration exceeds production. Similar values have been recorded by Prowse (1969), Ganapati and Sreenivasan (1970) which also revealed the eutrophic nature of the system concerned.

In contrast to the Experimental Fish Ponds, the five Circular Plastic Pools showed gross primary productivity values much less than the Experimental Fish Ponds. The range was however on the higher side in relation to the eutrophic systems and here again with the exception of Circular Plastic Pool-2, the other pools showed values lesser than the control pool. The seasonality of fluctuation however was similar to that of the Experimental Fish Ponds. In these pools it was however observed that the minimum and the maximum gross primary productivity values ranged from 2740 mg C/M^3/day to 4541 mg C/M^3/day.

The net primary productivity values were definitely low and in fact not only half, but in certain cases even lower than half of the gross primary productivity values in these Circular Plastic Pools. Though Circular Plastic Pool-2 did reveal higher values, it was not very significant from that of the maximum values obtained, either in the control pool or the other Circular Plastic Pools. The seasonality of net primary productivity was more or less similar to their gross primary productivity values.

The gross primary productivity values in Experimental Fish Pond 2 of nearly 5500 mg C/M^3/day and the control pond as 4204 mg C/M^3/day, the latter value which was more or less similar to the Circular Plastic Pool-2 as 4541 mg C/M^3/day was nearly the same as reported by several workers on organic production in fish ponds. Hepher (1962) observed a production rate in fertilized ponds ranging between 3000 mg C/M^3/day to nearly 6000 mg C/M^3/day. However, Sreenivasan (1964) gave a maximum production figure of 13,700 mg C/M^3/day, though Boyd (1973) found in ponds where artificial diet and fertilizers were used, the production being in the range of 1000 mg C/M^3/day to 2700 mg C/M^3/day. Similarly Nuriga-Curtis (1979) found higher rates of production with the maximum range of 8500 mg C/M^3/day with an average of nearly 5000 mg C/M^3/day in manured ponds. Ofur Zur (1981) has reported the highest production figures in fish ponds to nearly 10,090 mg C/M^3/day and has attributed two main reasons, either to the higher available nutrient and/or to the constant rich supply of carbon-dioxide to the water by fish respiration. It is however known that higher production levels in fish ponds comes directly or indirectly from the results of unutilized food and fish excrement. In addition, it is suggested that turbulence in such fish ponds produced, constantly brings up algae from the deeper zones to the surface waters where light conditions are optimal, thus accounting for greater production (Boyd, 1972). This is further documented by the fact that succession in algal species into various assemblages in different seasons would be indicative of maximal peaks at different times of the year within the same system (Schelske and Stromer, 1971). It has been pointed out by Hulbert et. al.,(1960), Menzel and Ryther (1961a) and Prasad and Nair (1963) that in tropical waters production is moderate throughout the year with little oscillation. Average chlorophyll concentrations as observed by various workers were much higher in the fertilized ponds than in the unfertilized ponds, and as there is a correlation between the standing crop of phytoplankton (Chlorophyll content) and primary production (Edmondson, 1955; Gessner 1949; Manning and Juday, 1941; Ryther and Yentsch, 1958) one would expect higher production in these ponds and pools receiving larger amount of fertilizers; but such was not always the case as encountered in the present investigation, even though chlorophyll estimations have not been done. The reason for this may be in the fact that an increase in the standing crop reduces light penetration and so photosynthesis decreases in the deeper layer to an extent that leads to a net loss in production when the whole water column is summed. (Donald et. al., 1970).

Such variation in primary production is due probably to the fact that the photosynthesis under completely natural conditions is highly variable from time to time and place to place, moreover any sample of water which is enclosed in a bottle is obviously not under natural condition. It is subject to much reduced turbulence and the large glass surface surrounding it provides a favourable attachment substrate for bacterial development. These two factors are probably of prime importance in reducing the photosynthetic rate below that which is likely to occur under natural conditions and in increasing the respiration rate above that which is representative of the natural community.

In the present investigation respiration exceeding production is seen more commonly and especially the net primary productivity values both in the Experimental Fish Ponds and Circular Plastic Pools were recorded nil at various occasions. Photorespiration (Goldsworthy, 1970) is a mechanism known to cause an apparent decrease in the net photosynthetic rate also called photoinhibition. The oxidation of photosynthetically produced glycolate, consume oxygen and produces carbon-dioxide in the light, leading to an apparent decrease in the observed photosynthetic rate. It is known that the photosynthetic rate decreases with time if light is optimum and continuous (Lex et. al.,1971; Dohler and Koch, 1972; Van den Driesche and Bonotto, 1972). However since primary production within the subsurface layer of optimal light exhibits such a great regional variation relatively its determination should be valuable in particular for the biological characterization of different waters and in such small man made ecosystem.

The results of the present investigation have however shown that the kinetics of photosynthesis in the Experimental Fish Ponds and Circular Plastic Pools in these regions are fundamentally similar to that observed elsewhere in the world, while tropical ponds may tend to have absolute rates of photosynthesis, in general, whether fertilized or not the functioning of these water bodies are alike throughout the world.

Quantitative studies have been made for enhancement of primary production by enrichment with inorganic salts (Menzel et. al., 1963; Tranter and Newell, 1963; Ichimura, 1967; Thomas, 1969; Eppley et. al.,1971; Thomas et. al.,1974; Dunstan and Tenore, 1972; Ryther et. al.,1972). However, the present investigation has clearly revealed an increase in primary production levels both gross and net in the fish ponds and plastic pools due to organic wastes and especially cow-dung as exemplified by the maximal records of these values of primary productivity in pond-2 and pool-2. In addition to cow-dung as an organic fertilizer by itself there seemed to be certain inhibition when this was used along with inorganic fertilizers (N.P.K.). In such cases the levels decreased both at gross and net levels of primary production as seen for pond-1 and pool-4. However, pond-2 did have NPK as inorganic fertilizer in addition to organic manure as cow-dung and such an inhibitory effect is probably overcome by supplementary feedings. This, if true, should have had maximal production levels similarly in pool-4 which was only second to the pool 2. The reasons for such differences is not very clear cut and would probably be attributed to the fact that allochthonous materials added to any system if it is near to natural as in the case of dug out ponds would be different to laboratory experiments as Circular Plastic Pools, where the turnover of nutrients to a large extent depends upon the soil of an aquatic system which was not available in the pools.

The determination of primary production in fish ponds besides giving information on the magnitude of organic production has its practical considerations. Fertilization of fish ponds has become a common practise in many parts of the world. By increasing the production of autotrophs through fertilization there may be a considerable increase in fish production, although much remains to be learnt about the optimum amount and frequency of fertilization.

Strictly interpreted the production of a water body can be a question only of that organic substance which is formed by photoautotrophic and chemo-autotrophic plants in addition to the inorganic nutrients and the energy irradiated into the water. Primary production is therefore the basis of the whole biogenic metabolic cycle with the remainder being consumption or decay. Therefore it should be particularly noted that so far as consumers are concerned it is a question not of true production at that level but probably the reconstruction of organic substances already present in the system enhanced to larger levels of quantities by the influence of man or fertilization as in fish ponds (Schwoerbel, 1970).

The choice of suitable biological methods for such practical studies in India is always a compromise between money and accuracy of the results. It is quite impossible to choose a method in a given situation (the remoteness of the region), which really measures the degree of trophy because this would refer to the rate of organic matter supplied by or is present in a water body per unit time. In other words for such applied studies, the fundamental aspects of a measure which would differentiate between the rate of autochthonous production and the rate from allochthonous sources. In the present investigation a remote understanding to this concept has been in the idea of maintaining control systems indicative possibly of the above phenomena. Still one would not be able to definitely identify the contributions to production of allochthonous materials probably due to the time dependent behaviour of autotrophic organisms and to the dynamic nature of primary production processes (Denman, 1977). This is due to the complicated processes of photosynthesis involving several different pigments which vary with systematic groups. Moreover the same pigment may also occur in different *in vivo* forms when they are associated with macromolecule complexes in different ways in biological membranes.

The present aquatic systems both fish ponds and circular plastic pools investigated for primary production levels simulated well to that of established equilibrium systems. This was probably indicative that the actual or potential productivity of such new systems are greater during the first few years. Subsequently a balance may be struck between the allochthonous nutrients, their assimilation and subsequent store or release thereafter.

REFERENCES

Adams, G.F. 1970 Soluble carbohydrates as a factor influencing gross primary productivity and bacterial population in lakes. Journal of the Arizona Academy of Science 6(1):5-7.

Allen, H. & B.T. Ocevski 1976 Limnological studies in a large, deep, oligotrophic Lake (Lake Ohrid, Yugoslavia). Arch. Hydrobiol. 77(1):1-21.

A.P.H.A. 1975 American Public Health Association, American water works Association and water pollution control Federation, 1975. Standard methods for the examination of water and wastewater. Am. Public Health Assoc., Washington D.C., 14th ed., 1193 pp.

Arnon, D.I. 1951 Extracellular photosynthetic reactions. Nature 617:1008.

__________ 1958 The role of micronutrients in plant nutrition with special reference to photosynthesis and nitrogen assimilation. Proc. Conf. Ohio. agric. Exp. Sta., (1957):1-33.

__________, M.B. Allen & F.R. Whatley 1954 "Photosynthesis by isolated chloroplasts". Nature 174:394.

Berman, T. 1976 Release of dissolved organic matter by photosynthesizing algae in Lake Kinneret, Israel. Freshwat. Biol. 6:13-18 (1976).

Bernard, C. 1878 Lecons sur les phenomenes de la vie commun aux animaux et aux vegetaux. Paris, 1878.

Berzelius, J.J. 1837a Ueber die gelbe farbe der blatter im herbst. Ann. der. Chem. 21:257-262.

__________ 1837b Einige untersuchungen uber die farbe, welche das laub verschiedener baume im herbst vor dem abfallen annimmt. Pogg. Ann. der Phys. u. Chem., 42:422-433.

Beyers, R.J., J. Larimer, H.T. Odum, R.B.Parker & N.E. Armstrong 1963 Directions for the determination of changes in carbon-dioxide concentration from changes in pH. Publ. Inst. Mar. Sci. Univ. Texas, 9:454-489.

Birge, E.A. & C. Juday 1934 "Particulate and dissolved organic matter in Wisconsin lakes". Ecol. Monogr. 4:440-474.

Blackman, F.F. 1923 The Biochemical Problems of Chloroplastic Photosynthesis. Brit. Ass. Adv. Sci., Rep. 90th Meeting, Hull, 1922. Publ. London, 1923.

__________, & G.L.C. Matthaei 1905 Experimental Researches on Vegetable Assimilation and respiration. IV. A Quantitative study of Carbon-dioxide Assimilation and Leaf Temperature in Natural Illumination. Proc. Roy. Soc., B, 76:402-460.

Blackman, F.F. & A.M. Smith | 1911 | Experimental Researches on Vegetable Assimilation and Respiration. IX. On Assimilation in Submerged Water-Plants and its relation to the concentration of Carbon Dioxide and other factors. Proc. Roy. Soc., B, 83:389-412.

Boehm, J. | 1873 | Ueber die Respiration von Landpflanzen. Sitzungsber. k. Akad. Wiss. Wien., Math-Nat. Cl., 67, Abt. 1, 219-251.

Bonnier, G. & L. Mangin | 1886 | Researches sur l'action chlorophyllienne separee de la respiration. Ann. Sci. nat., Bot., 7e Ser, 3:1-44.

Boussingault, J.B. | 1864 | De la vegetation dans l'obscurite. Ann. Sci. nat., Bot., 5e Ser., 1:314-324.

________ | 1868 | Agronomie, Chimie agricole et physiologie. Vol. 4. Paris 1868.

________ | 1869 | Sur les fonctions des feuilles. Ann. sci. nat., Bot., 5e Ser, 10:331-343.

Boyd, C.E. | 1972 | Sources of Carbon-dioxide for nuisance blooms of algae. Weed. Sci. 20:492-497.

________ | 1973 | Summer algal communities and primary production in fish ponds. Hydrobiologia, 41:357-390.

Briggs, G.E. | 1922 | Experimental Researches on Vegetable Assimilation and Respiration. XVI. The Characteristic of Subnormal Photosynthetic Activity Resulting from Deficiency of Nutrient Salts. Proc. Roy. Soc., B, 94:20-35.

Brown, A.H. | 1953 | "The effects of light on respiration using isotopically enriched oxygen". Am. J. Botany 40:719.

Brown, S.R., D.C. Hamilton & C.R. Meyer | 1964 | Chlorophyll a derivatives in freshwater lakes. Proc. 7th conf. on Great Lakes Research : 140 (Abstr.).

Brynlinsky, M. | 1980 | Estimating the productivity of lakes and reservoirs. In LeCren, E.D. and R.H. Lowe-McConell (eds.) The functioning of freshwater ecosystems. Cambridge University Press, 588 pp.

Chance, B. & W.D. Bonner | 1963 | The temperature insensitive oxidation of cytochrome f in green leaves. A preliminary biochemical event of photosynthesis, p 66. In photosynthetic Mechanisms of green plants. N.A.S.-N.R.C. Publ. 1145 pp.

Cloez, S. & P. Gratiolet | 1850 | Recherches sur la vegetation. Comp. rend. acad. Sci. 31:626-629.

Cohn, F. 1865 Ueber einige algen von Helgoland, In:"Beitrage zur naheren kenntnis und vertreitung der algen", herausgegeben von L. Rabenhorst, Heft 2, 19, Leipzig, 1865.

Daubeny, C. 1836 On the action of light upon plants, and of plants upon the atmosphere. Phil. Trans. Roy. Soc., London, 149-176.

Denman, K.L. 1977 Short term variability in vertical chlorophyll structure. Limnol. Oceanogr. 22:434-441.

Detmer, W. 1882 Ueber die Einwirkung verschiedener Gase, insbesondere des Stickstoffoxydulgases auf Pflanzenzellen. Landw. Jahrb., 11:213-232.

Dohler, G. & R. Koch 1972 Die wirkung monochrametischen lichts auf die extracollulare Glykolsaure-Ausscheidung und die lichtatmung bei der Blaualge Anacystis nidulans Planta. 105:352-359.

Donald, J.Hall, William E.Cooper & Earl E. Werner 1970 An experimental approach to the production dynamics and structure of freshwater animal communities. Limnol. Oceanogr., 15:839-928.

Draper, J.W. 1843 On the decomposition of carbonic acid gas and the alkaline carbonates by the light of the sun. Phil. Mag., Ser. 3(23):161-175.

________ 1844 Note on the decomposition of carbonic acid by the leaves of plants under the influence of yellow light. Phil. Mag., Ser. 3(25):159-173.

Dumas, J.B. & 1841 Essai de statique chimique des etres organises. Paris, 1841, 3[e] edit., 1844.

Dumont, H.J. 1968 Een limnologische studie van het Donk-meer (Oost-Vlaanderen).-Doctor's thesis, Gent, 222 pp. (Unpublished).

Dunstan, W.M. & K.R. Tenore 1972 Intensive outdoor culture of marine phytoplankton enriched with treated sewage effluents. Aquaculture, 1:181-192.

Dysens, L.N.M. 1955 Role of cytochrome and pyridine nucleotide in Algal photosynthesis. Science, 121:210.

Edmondson, W.T. 1955 Factors affecting productivity in fertilized salt water. Deep-sea Res., 3:451-464.

Emerson, R. & 1932 "A seperation of the reactions in photosynthesis by means of intermittent light". J. Gen. Physiol. 15:391.

Engelmann, T.W. 1894 Die Erscheinungsweise der Sauerstoffausscheidung chromophyllhaltiger Zellen im Licht bei Anwendung der Bakterienmethode. Verhandl. Kon. Akad. Wetensch. Amsterdam, Sect. 2, Deel. 3, No.11, 10+iv: 1894; Pflugers Arch. f.d. ges. Physiol., 57:375-386:1894.

Eppley, R.W., A.F. Carlucci, O. Holm-Hansen, J.D. Kiefer, J.J. McCarthy, E.Veenrick & P.M.William 1971 Phytoplankton growth and composition in shipboard cultures supplied with nitrate, ammonium, or urea as the nitrogen source. Limnol. and Oceanogr. 16(5):741-751.

Evans, J.H. 1961 "Growth of Lake Victoria phytoplankton in enriched cultures". Nature 189:417.

Ewart, A.J. 1896 On Assimilatory Inhibition in Plants. Journ. Linn. Soc., Bot., 31:364-461.

________ 1897a Further observations upon Assimilatory Inhibition. Journ. Linn. Soc., Bot., 31:554-576.

________ 1897b The relations of Chloroplastid and Cytoplasma. Bot. Centralbl., 72:289-296.

Fee, E.J. 1973 A numerical model for determining integral primary production and its application to Lake Michigan. J. Fish. Res. Board Can. 30:1447-1468.

Fogg, G.E. & M. Wolf 1954 Nitrogen metabolism of blue-green algae. Symposium Soc. Gen. Microbiol. 4:99-125.

________ & D.F. Westlake 1955 The importance of extracellular products of algae in freshwater. Verh. internat. Verein Limnol. 12:219-232.

________, C. Nalewajko & W.D. Watt 1965 Extracellular products of photosynthesis. Proc. R. Soc. Lond. (B). 162:517-534.

Forbes, S.T. 1887 The lake as a microcosm. Bull. Peoria (Illinois) Scientific Assoc., 1887:77-87. Reprinted in Bull. Ill. nat. Hist. Surv., 15:537-550 (1925).

Fremy, E. 1860 Recherches sur la matiere colorante verte des feuilles. Comp. rend. acad. Sci.,50:405-412.

________ 1865 Recherches chimiques sur la matiere verte des feuilles. Comp. rend. acad. Sci., 61:188-192.

Fritsch, F.E. 1931 Some aspects of the ecology of fresh-water algae. Jour. Ecology, 19:233-272.

Gaarder, T. & H.H. Gran 1927 Production of plankton in the Oslo Fjord. Rapp. Cons. Explor. Mer. 42:1-48.

Gaffron, H. & K. Wohl 1936 Zur theorie der assimilation. Naturwissenschaften, 24:81.

Ganapati, S.V. & A.Sreenivasan 1970 Energy flow in natural aquatic ecosystems in India. Hydrobiol. : 66(4):458-498.

Gessner, F.	1949	Der Chlorophyllgehalt im Sie undseine photosynthetische. Valenz ab geophysikalisches problem. Schweiz, Z. Hydrol., 11:378-410.
Gilby, W.H.	1821	Sur la *respiration des plantes*. *Ann. de chim.* et. Phys., 2 Ser., 17:64-72.
Girard, A.	1884	Recherches sur la saccharogenie dans la betterave. Comp. rend. acad. sci., 97:1305-1308 : 1883 : 99 : 808-811 : 1884.
Goodyear, C.P., C.E. Boyd & R.J. Beyers	1972	Relationships between primary productivity and mosquito fish (Gambusia affinis) production in large microcosms. Limnol. Oceanogr. 17(3) : 445-450.
Goldman, C.R.	1960	Molybdenum as a factor limiting primary productivity in Castle Lake, California. Science 132, 1016-1017.
____________ & E. De Amezaga	1975	Spatial and temporal changes in the primary productivity of Lake Tahoe, California-Nevada between 1959 and 1971. Verh. Internat. Verein. Limnol. 19:812-825.
Goldsworthy, A.	1970	Photorespiration. Bot. Rev. 38:321-340.
Golterman, H.L.	1971	The determination of mineralization losses in correlation with the estimation of net primary production with the oxygen method and chemical inhibitors. Freshwat. Biol. 1:249-256.
Grew, N.	1682	The anatomy of plants, with an idea of a philosophical history of plants. London, 1682.
Hamilton, D.H.	1969	"Nutrition limitations of a summer phytoplankton growth in Cayuga Lake". Limnol. Oceanogr. 14:579-590.
Haniffa, M.A.	1978	Secondary productivity and energy flow in a tropical pond. Hydrobiologia, 59:49-65.
Harvey, W.H., L.H.N. Cooper, M.V. Lebour & F.S. Russell	1935	Plankton production and its control. J. Mar. biol. Ass. U.K. 20, 407-441.
Hecky, R.E., E.J. Fee, H.J. Kling & J.W.N. Rudd	1981	Relationship between primary production and fish production in Lake Tanganyika. Trans. Am. Fish. Soc., 110:336-345.
Hepher, B.	1962	Primary production in fish ponds and its applications of fertilization experiments. Limnol. Oceanogr. 7(2):131-136.
Hickman, M.	1971	Standing crop and primary productivity of the epipelon of two small ponds in north Somerest, U.K. Oecologia 6(3):238-253.

Hill, R. & R. Scarisbrick 1951 The haematin compounds of leaves. New Phytol. 50:98.

Hulbert, E.M., J.H. Ryther & R.R.L. Gullard 1960 The phytoplankton of the Sargasso sea of Bermuda. J. Cons. perm. int. Explor. Mer. 25: 115-128.

Hunt, R. 1848 On the coloured glass employed in glazing the new palm house in the Royal Botanic Garden at Kew. British Ass. Adv. Sci., Rep. 17th Meeting, Oxford : 1847; Publ. London, 1848.

Hutchinson, G.E. 1938 On the relation between the oxygen deficit and the productivity and Typology of lakes. Internat. Rev. d.ges. Hydrobiol. u. Hydrogr., 36: 336-355.

________ 1957 A treatise on limnology Vol. I. J. Wiley & Sons, New York, 1015 pp.

Ichimura, S. 1967 Environmental gradient and its relation to primary productivity in Tokyo Bay. Records of Oceanographical works in Japan 9(1):115-128.

Ingen-Housz, J. 1779 "Experiments upon vegetables, discovering their great power of purifying the common air in the sunshine and of injuring it in the shade and at night; to which is joined a new method of examining the accurate degree of salubrity of the atmosphere", London.

________ 1796 "Food of Plants and the Renovation of the soil". Appendix to the outlines of the fifteenth Chapter of the Proposed General Report from the Board of Agriculture, London.

Jana, B.B. 1979 Primary production and bacterioplankton in fish ponds with mono and polyculture. Hydrobiologia 62(1):81-87.

Jenkin, P.M. 1937 Oxygen production by the diatom <u>Coscinodiscus excentricus</u> Ehr. in relation to submarine illumination in the English Channel. J. mar. biol. Ass. U.K. 22, 301-343.

Jonsson, B. 1903 Assimilationsversuche bei verschiedener Meerestiefen. Nyt. Mag. Nat. 41:1-22.

Jorgensen, E.G. 1964 Adaptation to different light intensities in the diatoms <u>Cyclotella menaghiniana</u> Kutz. Physiol. Plant., 17:136-145.

Kandler, O. 1964 Reported at the Xth Int. Bot. Congress, Edinburgh.

Khan, A.A. & A.Q. Siddique 1971 Primary production in a tropical fish pond at Aligarh. Hydrobiologia., 37:447.

Khan, M.A. & D.P. Zutshi 1980 Primary productivity and Trophic status of a Kashmir Himalayan Lake. Hydrobiologia, 68:3-8.

King, D.L. 1970 "The role of carbon in eutrophication". J. Water. Poll. Control. Fed. 42:2035-2051.

Kniep, H. & F. Minder 1909 Uber den Einfluss verschiedenfarbigen Lichtes auf die Kohlensaureassimilation. Zeitschr. f. Bot., 1:619-650.

Kratz, W.A. & J. Myers 1955 "Photosynthesis and respiration of three blue-green algae". Pl. Physiol., Lancaster 30:275-280.

Kreusler, U. 1885 Ueber eine Methode zur Beobachtung der Assimilation und Athmung der Pflanzen und uber einige diese Vorgange beeinflussende Momente. Landw. Jahrb., 14:913-965.

________ 1890 Beobachtungen uber Assimilation und Athmung der Pflanzen. IV. Mittheilung. Verhalten bei hoheren Temperaturen; Kohlensaureausscheidung seiterrs getodeter Exemplare; Kohlensaureverbrauch, wennOber-und Unterseite der Blatter denn Licht zugewendet. Landw. Jahrb., 19:649-668.

Kutzing, F.T. 1843 Phycologia generalis oder anatomie, physiologie und systemkunde der Tange. Leipzig : 1843.

Lex, M., W.B. Silvester & W.D.P. Stewart 1971 Photorespiration and nitrogenase activity in blue-green alga Anabaena cylindrica. Proc. Roy. Soc., Lond. Biol. Sci. 180:87-102.

Liebig, J. 1840 "Die organische Chemie in ihrer Anwendung auf Agricultur und Physiologie". 1840.

________ 1843a "Die Wechselwirthschaft". Ann. Chem. u. Phar., 46:58-97.

________ 1843b Chemistry in its Application to Agriculture and Physiology, Third Edition, London, 1843.

Manning, W.M. & R.E. Juday 1941 The chlorophyll content and productivity of some lakes in Northeastern Wisconsin. Trans. Wisconsin Acad. Sci., Arts. Lett., 3:363-393.

Marcacci, A. 1895 Studis comparativo dell' azione di alcuni alcaloidi sulle piante nella oscurita e all luce. Nuovo giorn. bot. ital., N.S. 2:222-227.

Margalef, R. 1963a "On certain unifying principles in ecology". Am. Nat. 97:357-374.

________ 1963b Algunas regularidades en la distribucion a escala pequena y media de las poblaciones marinas de Fitoplancton y en sus caracteristicas functionales. Inv. Pesq. 23:169-230.

Margalef, R. 1968 "Perspectives in ecological theory", University of Chicago Press. Chicago, 111 p.

Marshall, S.M. & A.P. Orr 1928 The photosynthesis of diatom cultures in the sea. Jour. Mar. Biol. Assoc. U.K. 16:321-364.

Matsuyama, M. & E. Shirouzu 1978 Importance of photosynthetic sulphur bacteria Chromatium sp. as an organic matter producer in Lake Kaiike. Jap. J. Limnol. 39(3):103-111.

McConnell, W.J., Steven Lewis & James E. Olson 1972 Gross photosynthesis as an estimator of potential fish production. Trans. Am. Fish. Soc., 106(5):417-428.

Mellack, J.M. 1976 Primary productivity and fish yields in tropical lakes". Trans. Am. Fish. Soc., 105:575-580.

Menzel, D.W. & J.H. Ryther 1961a Annual variation in primary production of the Sargasso sea off Bermuda. Deep Sea Res. 7: 282-288.

________, E.M. Hulburt & J.H. Ryther 1963 The effects of enriching Sargosso sea water on the production and species composition of the phytoplankton. Deep-Sea Research 10, 209-219.

Meyer, A. 1885 Ueber die Assimilationsproducte der Laubblatter angiospermer Pflanzen. Bot. Zeit., 43:417-423, 433-440, 449-457, 465-472, 481-491, 497-507.

Millardet, A. 1869 Sur la nature du pigment des Fucoidees. Ann. sci. nat. Bot., 5e Ser. 10:59-64. 1869; Comp. rend. acad. sci., 68, 462-466 : 1869.

Mitscherlich, E.A. 1909 Das Gesetz des Minimus und das Gesetz des abnehmenden Bodenertrages. Landw. Jahrb., 38: 537-552.

________ 1921 (Unter Mitwirkung von F. Duhring und S.V. Sancken), "Das Wirkungsgesetz der Wachstumsfaktoren". Landw. Jahrb., 56:71-93.

Mohl, H.V. 1837 Untersuchungen uber die anatomischen verhaltnisse des chlorophylls, Inaug.-Diss., Tubingen, 1837. (Ein Inaug-Diss., welche.......... unter dem Prasidium von H. Mohl vorlegt W. Michler.).

________ 1845 "Vermischte Schriften botanischen Inhalts", Tubingen, 1845.

________ 1851 "Grundzuge der Anatomie und Physiologie der vegetabilischen Zellen", Braunschweig, 1851. (English Edit., "Principles of the Anatomy and Physiology of the Vegetable Cell", London, 1852).

Mohl, H.V.	1855	"Ueber den Bau des Chlorophylls". Bot. Zeit., 18, 89-99, 105-115, (1855).
Mortimer, C.H.	1950	"The use of models in the study of water movement in stratified lakes". Verh. int. Ver. Limnol. 11:254-260.
____________	1955	"Some effects of the earth's rotation on water movements in stratified lakes". Verh. int. Ver. Limnol. 12:66-77.
Northcote, T.G. & P.A. Larkin	1956	Indices of lake productivity in British Columbia lakes. J. Fish. Res. Board Can. 13:515-540.
Ofur Zur	1981	Primary production in intensive fish ponds and a complete organic carbon balance in the ponds. Aquaculture, 23:197-210.
Osterhout, W.J.V. & A.R.C. Haas	1917	An adaptation of Winkler's Method to Biological Work. Journ. Biol. Chem. 32:141-146.
Patterson, J. & T.R. Parsons	1963	Distribution of chlorophyll a and degradation products in various marine materials. Limnol. Oceanogr., 8:355-356.
Pedro Noriega-Curtis	1979	Primary productivity and related fish yield in intensely manured fish ponds. Aquaculture; 17:335-344.
Pelletier, J. & J.B. Caventou	1818	Sur la matiere verte des feuilles. Ann. Chim. et Phys., Ser. 2, 9, 194-196.
Pfeffer, W.	1900	Pflanzenphysiologie, Zweite Aufl., Band I., 1897: English Edit. "The Physiology of Plants", Vol. I., Oxford, 1900.
Prasad, R.R. & P.V.R. Nair	1963	Studies on organic production. I. Gulf of Mannar. J. Mar. Biol. Ass. India. 5:1-26.
Priestley, J.	1772	"Observations on different kinds of air". Phil. Trans. Roy. Soc. London, 62, 147-264.
Prowse, G.A.	1969	Energy flow in relation to productivity in fresh and brackish waters. A paper read in Intern. Congress Conference of the Pacific Science Ass. held at the University of Malaya during May : 6-12.
Putter, A.	1924	Der Umfang der kohlensaurereduktion durch die Planktonalgen Pflug. Arch. Ges. Physiol. 205: 293-312.
Qasim, S.Z., S. Wellershaus, P.M.A. Bhattathiri & S.A.N. Abidi.	1969	Organic production in a tropical estuary. Proc. Ind. Acad. Sci., 69B(2):51-94.

Rawson, D.S. 1930 The bottom fauna of Lake Simcoe and its role in the Ecology of the lake. Univ. Toronto Studies, Publ. Ont. Fish. Res. Lab., No. 40; 1-183.

__________ 1939 Some physical and chemical factors in the metabolism of lakes. In Problems of Lake Biology, Publ. Am. Assoc. Adv. Sci., No. 10, pp. 9-26.

Reinke, J. 1893 Die Abhangigkeit des Ergrumens von der Wellenlange das Lichts. Sitzungsber. k. Preuss. Akad. Wiss. Berlin, 3:527-540.

Riley, G.A. 1940 Limnological studies in connecticut. Part III. The plankton of Linsley Pond. Ecol. Monogr. 10:279-306.

Rishi, V. & P. Kachroo 1981 Effect of sewage and fertilizers on phytoplankton of Doodhghanga. Geobios, 8:160-162.

Rodhe, W. 1955 Can plankton production proceed during winter darkness in sub-arctic lakes? Verh. internat. Verein. Limnol. 12:117-122.

__________ 1962 Sulla produzione di fitoplancton in laghi transparenti di alta montagna. Mem. Ist. Ital. Idrobiol. 15:21-28.

__________, J.E. Hobbie & R.T. Wright 1966 Phototrophy and Heterotrophy in high mountain lakes. Verh. internat. Verein. Limnol. 16: 302-313.

Rosanoff, S. 1867 Observations sur les fonctions et les proprietes de pigments des diverses algues. Mem. soc. sci. nat. Cherbourg., 13:195-214.

Ruben, S., M. Randall, M.Kamen & J.L. Hyde 1941 Photosynthesis with radioactive carbon V. J. Am. Chem. Soc. 63:877.

Ruttner, F. 1921 Das elektrolytische Leitvermogen verdunnter Losungen unter dem Einfluss submerser Gewachse I., Sitzungsber. Akad. Wiss. Wien, Math.-nat. Kl., Abt. I, 130:71-108.

Ryther, J.H. & C.S. Yentsch 1958 Primary production of continental shelf waters off New York. Limnol. and Oceanogr. 3:327-335.

__________, W.M. Dunstan, T.R. Kenore & J.E. Hugenin 1972 Controlled eutrophication-increasing food production from the sea by recycling human wastes. Bioscience, 22, 144-152.

Sachs, J. 1887 Lectures on the Physiology of Plants, English Edit., Oxford, 1887.

Sakamoto, M. 1971 Chemical factors involved in the control of phytoplankton production in Experimental Lakes Area, northwestern Ontario. J. Fish. Res. Board Can., 28:203-213.

Saposchnikoff, W. 1893 Beitrag zur kenntniss der Grenzen der Anhaufung vom kohlenhydraten in den Blattern. Ber. deut. bot. Ges., 11:391-393.

__________ 1894 Proteins and Carbohydrates of the Green Leaf as Products of Assimilation. (in Russian), Tomsk, 1894 (Abstr. in Bot. Centralbl., 63, 246-251:1895).

Saunders, G.W.Jr. W.P. Coffman, R.G. Michael & S. Krishnaswamy 1975 Photosynthesis and extracellular release in ponds of South India. Verh. Internat. Verein. Limnol. 19:2309-2314.

Saussure, Theod. De. 1804 "Recherches chimiques sur la vegetation". V. Nyon, Paris.

Schelske, C.L., F.F. Hooper & E.J. Heartl 1962 Responses of a marl lake to chelated iron and fertilizer. Ecology 43:646-653.

__________ & E.F. Stoermer 1971 Eutrophication, silica and predicted changes in algal quality in Lake Michigan. Science, 173:423-424.

Schindler, D.W. 1974 "Eutrophication and recovery in experimental lakes: Implications for lake management". Science 184:897-899.

__________ & S.K. Holmgren 1971 Primary Production and phytoplankton in the experimental Lakes Area, northwestern Ontario, and other low-carbonate waters and a liquid scintillation method for determining ^{14}C activity in photosynthesis. J. Fish. Res. Bd. Canada 28:189-201.

__________ & E.J. Fee 1973 Diurnal variation of dissolved inorganic carbon and its use in estimating primary production and CO_2 invasion in lake 227. J. Fish. Res. Board Can. 30:1501-1510.

Schutt, F. 1888a Ueber das Phycoerythrin. Ber. deut. bot. Ges., 6:36-51.

__________ 1888b Weitere Beitrage zur kenntniss des Phycoerythrins. Ber. deut. bot. Ges., 6:305-323.

Schwarz, F. 1881 Zur kritik der Methode des Gasblasenzahlens an submersen Wasserpflanzen. Unter. bot. Inst. Tubingen, 1:97-104.

Schwoerbel, J. 1970 Methods of hydrobiology freshwater biology. Pergamon Press Ltd. Headington Hill Hall, Oxford, England.

Senebier, J. 1783 "Memoires physico-chimiques, sur l'influence de la lumiere solaire pour modifier les etres des trois regnes de la nature et surtout ceux du regne vegetal", 3 vols., Geneve.

——— 1788 "Experiences sur l'action de la lumiere solaire dans la vegetation", Geneve, 1788.

——— 1800 "Physiologie Vegetale, contenant une description des organes des plantes, et une exposition des phenomenes produits par leur organisation", 5 vols., Geneve, 1800.

Sorby, H.C. 1873 On comparative vegetable chromatology. Proc. Roy. Soc., 21:442-483.

Sreenivasan, A. 1964 Limnological studies and fish yield in three upland lakes of Madras State, India. Limnol. Oceanogr., 9:564-575.

——— 1976 Limnological studies of and primary production in temple pond ecosystems. Hydrobiol. 48(2): 117-123.

Stahl, E. 1880a Ueber den Einfluss von Richtung und Starke der Beleuchtung auf einige Bewegungserscheinungen im Pflanzenreiche. Bot. Zeit., 38:297-304, 321-343, 345-357, 361-368, 377-381, 393-400, 409-413.

——— 1880b Ueber den Einfluss der Lichtintensitat auf structur und Anordnung des Assimilationsparenchyms. Bot. Zeit., 38:868-874.

Steele, J.H. 1964 A study of production in the Gulf of Mexico. J. Mar. Res., 22:211-222.

——— & C.S. Yentsch 1960 The vertical distribution of chlorophyll. J. Mar. Biol. Assoc. U.K., 29:217-226.

Steemann Nielsen, E. 1952 The use of radioactive carbon (C^{14}) for measuring organic production in the sea. J. Cons. Intern. l'Explor. Mer. 18:177-140.

——— & T.S. Park 1964 On the time course in adaptation to low light intensities in marine phytoplankton. J. Cons. Int. Explor. Mer., 29:19-24.

Strom, K.M. 1928 Recent Advances in Limnology. Proc. Linn. Soc. London, pp 96-110.

Stross, R.G., S.W. Chisholm & T.A. Downing 1973 Causes of daily rhythms in photosynthetic rates of phytoplankton. Biol. Bull. 145: 200-209.

Talling, J.F. 1962 Freshwater algae. In: Physiology and Biochemistry of Algae. R.A. Lewin (ed.), pp.743-753. Academic Press, New York.

Talling, J.F. 1965 The photosynthetic activity of phytoplankton in east African Lakes. Int. Rev. ges. Hydrobiol., 50:1-32.

Thienemann, A. 1927 Der Bau des Seebeckens in seiner Bedeutung fur das Laben im See. Verh. Zool. Bot. Ges. 77:87-91.

Thomas, W.H. 1969 Phytoplankton nutrient enrichment experiments of Boja California and in the Eastern equatorial Pacific Ocean. J. Fish. Res. Bd. Canada, 26(5):1133-1145.

____________, D.L.R. Seibert & A.N. Dodson 1974 Phytoplankton enrichment experiments and bioassays in natural coastal sea water and in sewage outfall receiving waters off Southern California. Estuarine and coastal Marine Science, 2, 191-206.

Tilzer, M.M. & K. Schwarz 1976 Seasonal and vertical patterns of phytoplankton light adaptation in a high mountain lake. Arch. Hydrobiol. 77(4):499-504.

Timiriazeff, C. 1869 Uber die resultate einer spectralanalyse des Chlorophylls. Bot. Zeit., 27:884-885.

____________ 1871 Spectral analysis of Chlorophyll (in Russian), St. Petersburg. 1871.

____________ 1877 Recherches sur la decomposition de l'acide carbonique dans le spectre solaire par les parties vertex des vegetaux. Ann. Chim. et phys., 5e Ser. 12:355-396.

____________ 1883 La distribution de l'energie dans le spectre solaire et la chlorophylle. Comp. rend. acad. sci., 96:375-376.

____________ 1889 Sur la rapport entre l'intensite des radiations solaire et la decomposition de l'acide carbonique par les vegetaux. Comp. rend. acad. sci., 109:379-382.

Tranter, D.J. & B.S. Newell 1963 Enrichment experiments in the Indian Ocean. Deep-Sea Research, 10:1-9.

Van Den Driessche, T. & S. Bonotto 1972 In *vivo* activity of the chloroplasts of *Acetabularia* in continuous light and in light dark cycles. Arch. Biol. 83:89-104.

Van Tieghem, P. 1869 Respiration des plantes submergees a la lumiere d'une bougie; lieu de formation dez gaz. Comp. rend. acad. sci., 69:482-486.

Vijayaraghavan, S., P. Navaneethakrishnan & R.G. Michael 1969 Diel cycle of dissolved carbohydrates in two freshwater pond. Proceeding of Ind. Acad. Sci. LXX(4):157-168.

Vishniac, W. & S. Ochoa	1951	Photochemical reduction of pyredine nucleotides by spinach extracts and coupled carbon dioxide fixation. Nature, 167:768.
Vollenweider, R.A.	1971	A manual on methods for measuring primary production in aquatic environment. IBP Handbook No. 12. Blackwell Scientific Publications, Oxford. 213 pp.
Warburgh, O.	1919	Uber die Geschwindigkeit der photochemischen Kohlensaurezersetzung in lebenden Zellen. I., Biochem. Zeitschr., 100:230-270.
Weber, C.	1879	Ueber specifische Assimilationsenergie. Arb. bot. Inst. Wurzburg, 2:346-352.
Webster, G.C. & A.W. Frenkel	1952	"Some respiratory characteristics of the glue-green alga, Anabaena". Pl. Physiol., Lancaster, 28:63-69.
Westlake, D.F., M.S. Adams, M.E. Bindloss, G.G. Ganf, G.C. Gerloff, U.T. Hammer, P. Javornicky, J.F. Koonce, A.F.H. Marker, M.D. McCraken, B. Moss, A. Nauwerck, I.L. Pyrina, J.A.P. Steel, M. Tilzer & C.J. Walters.	1980	Primary production. In. LeCren, E.D. and R.H. Lowe-McConnel (eds.). The functioning of freshwater ecosystems, Cambridge University Press, 588 pp.
Wetzel, R.G.	1966a	Nutritional aspects of algal productivity in marl lakes with special reference to enrichment bioassays and their interpretation, p. 139-157. In. Primary productivity in aquatic environments. Univ. of California Press, Berkeley, Calif.
________	1966b	Productivity and nutrient relationships in marl lakes of northern Indiana. Verh. Int. Ver. Limnol. 16:321-332.
________	1967	Variations in productivity in Goose and hypereutrophic Sylvan lakes, Indiana. Invest. Ind. Lakes Streams. 7:147-184.
________	1968	Dissolved organic matter and phytoplanktonic productivity in marl lakes. Mitt. Int. Verh. Limnol., 17:72-85.
Wiebe, A.H.	1930	Investigations on plankton production in fish ponds. Bull. U.S. Bur. Fish., 46:137-176.

Wolny, P. & E. Grygierek | 1972 | Intensification of fish ponds production. Pages 563-571 in Z. Kajak and A. Hillbricht -Ilkowska, eds. Productivity problems of freshwaters. Polish Scientific Publishers, Warsaw.

Yanling liang, John Mellack & Ji Wang | 1981 | Primary production and fish yield in Chinese ponds and lake. Trans. Am. Fish. Soc., 110:346-350.

Yentsch, C.S. | 1962 | Measurements of visible light absorption by particulate matter in ocean. Limnol. Oceanogr., 7:207-217.

______________ & D.W. Menzel | 1963 | A method for the determination of phytoplankton chlorophyll and phaeophytin by flourescence. Deep-Sea Res., 10:221-231.

FISH GROWTH AND PRODUCTION

INTRODUCTION

Biological studies of fish and in particular culture aspects, abound in literature for freshwater, brackish and marine systems from various countries. Though such studies are essential prerequisites for a proper understanding and management of fisheries in any region or country, for the present investigation only those which are immediately pertinent have been reviewed below.

The earliest attempt of fish culture in freshwater ponds was usually an all or non-response, primarily due to lack of causative factors being identified in the regulation of fish growth. It was known that the fish was produced for food in ponds in China in 500 B.C. The record of such a practice in Chinese literature is after Fan Lai in 475 B.C. entitled "the classic of fish culture". In addition, the transportation of small fry in bamboo baskets written in 1243 by Chow Mit of the Sung dynasty has been elaborately outlined in his book "Kwei Sin Chak Shik" and the earliest record of collection of carp fry from rivers along with methods for rearing them in ponds is described in a complete book of agriculture by Hew (1639). All these three references have been quoted by Hora and Pillay (1962) in the "Introduction to a Handbook of Fish Culture". The Chinese with such background and experience gained through generations carried their traditional knowledge of carp culture to countries like Malaysia, Taiwan, Indonesia and Thailand where they migrated and settled.

The fish culture practices in the Indian sub-continent does not lack far behind that of the Chinese. The earliest record, indicative of fish cultured in reservoirs is mentioned in Kautilya's "Arthasastra" (321 and 300 B.C.). Here a mention of poisoning fish in reservoirs in time of wars by secret means is indicative of this flourishing culture of fish (quoted by Hora and Pillay, 1962). The other document of such practices in fish could be traced to the encyclopedia of King Somesvara called "Monasoltara" compiled in 1127 (quoted by Hora and Pillay, 1962) described the methods of fattening fish in ponds.

Since then, though no records are available, however from time immemorial, methods for collections of carp spawns from rivers and stocking the freshwaters and particularly warm water ponds adjoining each house was passed down from generation to generation. It was not until the end of the 19th century, that this practice spread gradually to other States of India.

The earliest work to be traced for Indian warm-water fish culture is that of Prashad (1919) who briefly described conditions of carp culture and mortality of fry. The early twentieth century was confined to workers other than Indians like Brithwhistle (1931), who identified sandy soil ponds to yield high quality fish flesh. The management of fish ponds in China where the bottom mud after draining of the water was used as fertilizers for fields was shown by Hoffman (1934).

The earliest information on the fertilization of fish ponds and in particular inorganic fertilizers, could be traced to Swingle and Smith (1938, 1939, 1941 and 1942), Howell in (1942) related the production of fish in both fertilized and unfertilized fish ponds. Swingle and Smith (1947) with their improvement in technology proved that a higher production could be achieved by a combination of organic and inorganic fertilizers. Ness (1949) reviewed such fertilization practices in fish ponds particularly in Europe. Ball (1949 and 1950) described the effects of fertilization and production of fish which gave comparatively higher yield in contrast to the unfertilized ponds and lakes.

The beginning of fifties was marked by the incorporation of various nutrients to small bodies of water to understand the mechanism of increased fish production (Probst, 1950; Ball and Tanner, 1951; Barrett, 1953; Nelson and Edmondson,1955; Hepher, 1958 ; Bank, 1959; Shaperclaus, 1959, 1966; and McIntre and Bond, 1960). It was Alikunhi (1952) who described the qualitative composition of food for spawns and fry of Indian major carps. Maciolek (1954) and Mortimer and Hickling (1954), provided a total review of artificial fertilization of lakes and ponds.

The classification of cultured fishes according to their feeding behaviour in surface, column or bottom waters was identified by Das and Moitra (1955). The correction of acidity of water by the application of lime was identified by Wurtz in (1956). The correction by lime and the addition of fertilizers along with supplementary feeding in the form of silk-worm pupae in Japanese ponds, giving rise to an increased production of fish was shown by Shimadata (1957). Simultaneously, Kawamoto (1957) identified the importance of stocking densities of fish in ponds.

Thereafter a real ecological understanding in relation to the stocking of fish with the right combination, ratio and rate of stocking enabling to realise a fish biomass, equivalent to the "carrying capacity" of that environment was identified (Yashouv, 1959; Hickling, 1962, 1967).

The direct relationship of both phyto- and zooplankton in relation to nutrients and trout productivity was shown by Weatherly and Nicolls (1955) and Smith (1951). Since then, the totality of such cultural aspects were not only identified, but also different systems were provided for the different ages of the fish, like nursery, rearing and stocking ponds and detailed work on the stocking rate, growth, mortality, feeding regimes and production have been done by numerous workers both in India and abroad (Alikunhi, 1952; Alikunhi et. al., 1955; Ibrahim, 1957; Chaudhuri, 1960; Hora and Pillay, 1962; Lakshmanan et. al., 1967, 1968; Ling, 1967; Shell, 1967; Huet, 1970; Hickling, 1971; Alikunhi et. al., 1971; Wlodek, 1971; Sneed et. al., 1972; Singh et. al., 1972; Sharma et. al., 1975 and Jhingran, 1975).

Workers therefore, started the use of nutrients and did various permutations and combinations either individually or in combination, responsible for increased growth of fish (Hepher, 1952, 1958, 1962, 1963; Wrobel, 1962; Hickling, 1962; Janecek, 1963; Schaperclaus, 1966; Banerjea and Mandal, 1965; Banerjee and Banerjee, 1967; G.och, 1966; Wolny, 1967; Lin and Chen, 1967; Fijan, 1961; Rabanal, 1967; Prowse, 1968; Yankavichuyte, 1970; Lin, 1970; Donald et. al.,1970; Wood Carle et. al., 1971; Parova, 1971; Polishchuk et. al.,1974; Wahby, 1974; Dimitrov, 1974; Saha et. al.,1976; Boyd, 1976; Boyd et. al.,1978; Grover et. al.,1976; Rzanicanin et. al., 1977; Lewkowicz et. al.,1977; Sen et. al.,1978; Mi-El Samra et.al., 1979).

The polyculture of fishes identified by Indian fish culturists paved a new possible mechanism for increased production by utilization of all available ecological niches in a pond commonly referred to as composite fish culture (Hora and Pillay, 1962). Numerous workers have studied such composite fish culture in managed systems with addition of both organic and inorganic fertilizers and supplementary feedings and have resulted in high production (Chimit, 1961; Ling, 1961; Rabanal, 1968; Swingle, 1968 and Yashouv, 1968, 1969).

The use of artificial feeding or supplementary food and such practices have been very well reviewed (Hora and Pillay, 1962; Ling, 1967; Shell, 1967; Hickling, 1971; Khan, 1971 and Sneed et. al.,1972). In India, particularly with the identification of the foregoing technology, maximum fish production has been obtained. This has been observed from an applied angle of achieving the highest yield with the manipulation of organic and inorganic fertilizers and supplementary feeds. Moreover the combination of Indian major carps and exotic carps have been tried out and high production figures have been shown in experiments conducted at the Cuttack Experimental Station (Lakshmanan et. al., 1971; Singh et. al., 1972; Sinha et. al., 1972, 1973; Chaudhuri et. al., 1974, 1975; and Chakrabarty et. al., 1976).

The use of organic fertilizers alone and the importance and the efficacy of applying organic manure in the form of swine, poultry wastes yielding high fish production and in addition maintaining cattle and poultry farms as a concept of total integrated agro-ecosystem was not only identified but became an accepted technique in many parts of the world (Bardach et. al., 1972; Schroeder, 1974, 1975a,b; Sharma, 1974; Buck et. al., 1976; Rappaport et. al., 1977; Stickney et. al., 1978; Rappaport and Sarig, 1978 ; Nabila, 1978; Pedro-Noriega-Curtis, 1979).

A comprehensive picture of fish production in India is outlined and compiled in a most readable form with comparative figures for the different states of India by Jhingran (1980).

With this in background the present investigation was carried out in a region where no data exists, namely the State of Nagaland, either for actual or potential fish production. Since the experimental station was at a lower altitude and the work being of a pioneering nature, only one species of the Indian major carp, Labeo rohita (Rohu) was taken up to study its growth rate and production in the ponds and in circular plastic pools under differential nutrient manipulations.

MATERIALS AND METHODS

After the initial management of the experimental ponds and plastic pools were completed, fingerlings of Labeo rohita (Rohu) were stocked during the 6th and 7th of October, 1979. The fingerlings stocked were three to four months old, which were reared from spawns produced by hypophysation conducted during the months of June and July at the fish farm where the experimental ponds were chosen. Prior to stocking, the fish fingerlings were netted with a nursery net and almost equal length and weight were selected at random sampling. These selected fingerlings were then subjected to the analysis of length and weight measurements with the help of a Yamato Balance and graduated measuring board (Plate-3).

The procedure employed for estimating the weight of the specimens was done with the help of a thin plastic basin whose weight were taken earlier. Five specimens were then transferred into the basin and placed on the balance and the weight noted. The weight of the fish was the final weight minus the weight of the plastic basin. An average was worked out for each individual. The fish were immediately transferred into a plastic bucket containing water. The individual lengths were noted by placing it over the graduated board. The total, needed for stocking were all likewise analysed for length and weight and released into the ponds and pools.

Thereafter, monthly samplings of about 30% of the stocked fish from each pond and pool were done to check their growth rate. The methods employed for estimating the length and weight were the same, however, subsequent measurements of weight was done for individual specimens. The values thus obtained for both the parameters were brought under an average which constituted the growth rate of the fish population for that particular month under consideration.

Plate 3 : The experimental fish species Labeo rohita.

PLATE - 3

After rearing them for a period of eighteen months (October, 1979 to March, 1981) the entire stock was recovered after draining the ponds and pools and the final data on length and weight, survival and production were calculated for respective ponds and pools. The gross production of fish in the four experimental ponds and five circular plastic pools were calculated from the mean gross growth and survival of the fish. The net production figures were calculated on the basis of the final weight minus initial weight multiplied by the number of survivors. These figures were then computed to production in terms of kg/ha/yr.

RESULTS

For the final production and yield of Labeo rohita, the growth rate was studied, in relation to its length and weight over the seasons. The average length and weight of the fish stocked initially in all the ponds and plastic pools constituted 8.9 cm and 9.7 gm respectively. Eighteen months of rearing was done to observe their growth-rate in the different systems under the different manipulation of nutrient additions. In certain months the average length and weight of fish recorded is less than the previous month probably on account of inadequate sampling size hauled.

CONTROL POND : In the control pond when the growth in length was observed it revealed a very slow trend of increase throughout the period of study with the exception of the months of February during the first annual cycle and November and February of the second cycle. These months recorded sudden spurts of increase by 3.74, 4.5 and 4.6 cm. respectively (Fig. 12). The monthly average of length increment was only 1.1 cm. The total gain in length between the initial and final was 20.7 cm. Similarly the weight increment showed a gradual increase till May, while the subsequent month of June recorded a two-fold increase (10.76 gm) during the first annual cycle. The month of November recorded a maximum increase of 108.2 gm, which thereafter maintained a steady increase till harvest recording 389.65 gm (Fig. 13). In the eighteen months of growth the monthly average increment of weight was 21.6 gm. It was observed that the trend of increase was slow during the initial 3-4 months and the enhanced growth was discernible towards the end of the rearing period. Of the 150 fingerlings stocked in this control pond, only 76 numbers were harvested at the end of the study period indicating a survival percentage of only 50.6%. The gross production in this pond was 29.6 kg.

Fig. 12 - Showing the monthly growth-rate in length (cm) of Labeo rohita in the Control and the Experimental Fish Ponds.

EP = Experimental Fish Ponds.

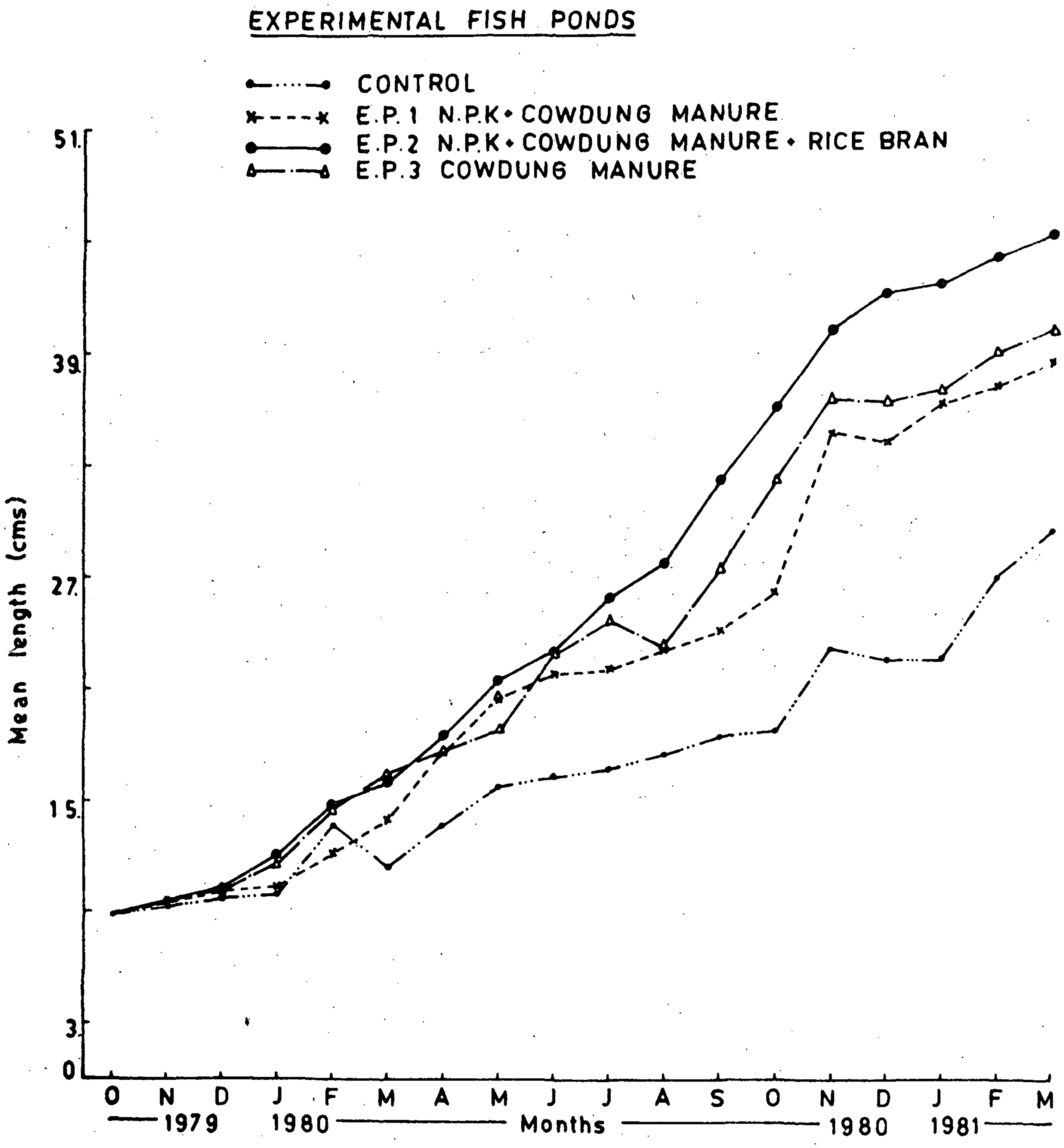
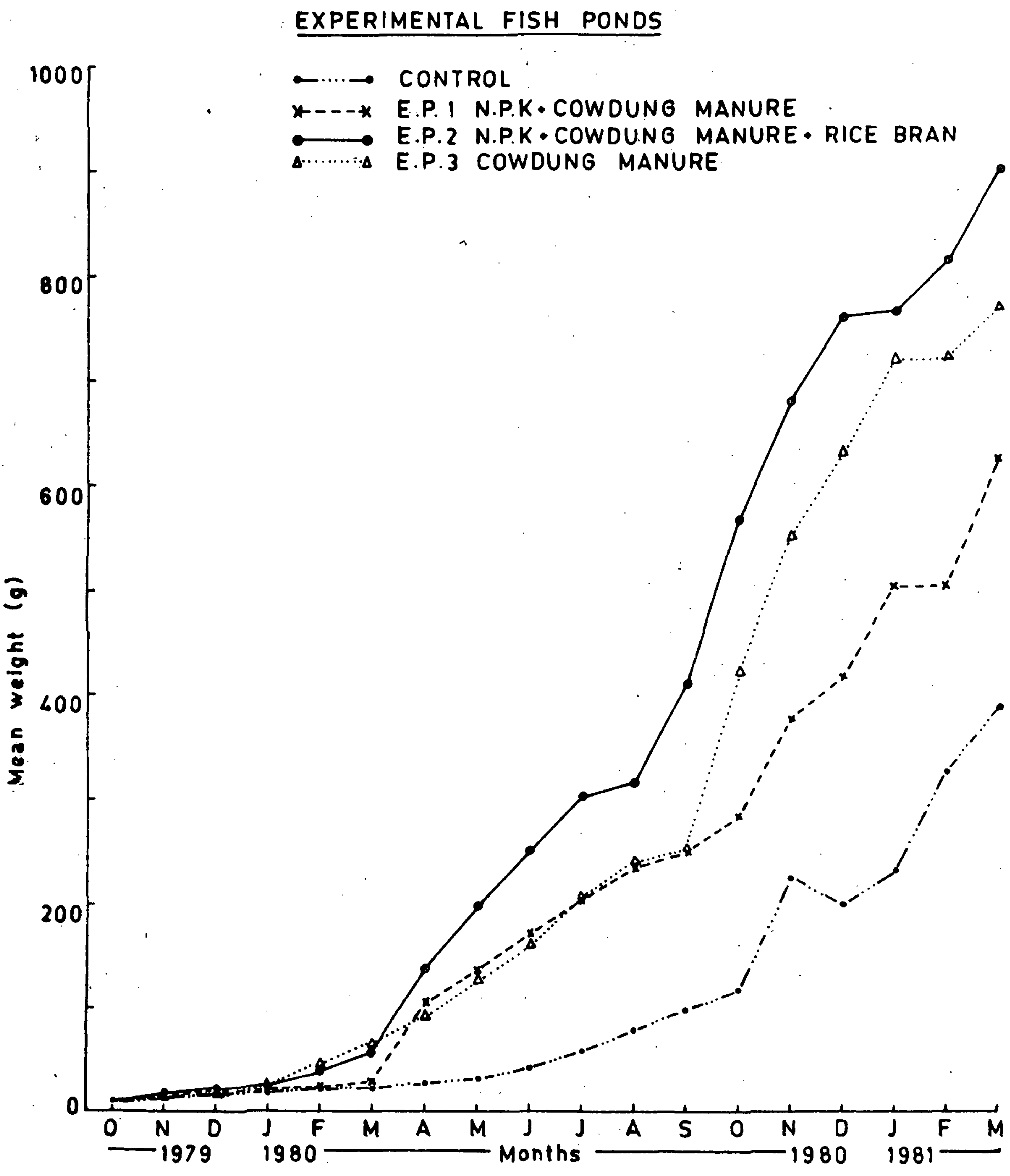

EXPERIMENTAL FISH PONDS
CONTROL
E.P.1 N.P.K+COWDUNG MANURE
E.P.2 N.P.K+COWDUNG MANURE+RICE BRAN
E.P.3 COWDUNG MANURE
Mean length (cms)
51
39
27
15
3
0
O N D J F M A M J J A S O N D J F M
1979 1980 Months 1980 1981

Fig. 13 - Showing the monthly growth-rate in weight (g) of *Labeo rohita* in the Control and the Experimental Fish Ponds.

EP = Experimental Fish Ponds.


EXPERIMENTAL FISH PONDS
CONTROL
E.P. 1 N.P.K + COWDUNG MANURE
E.P. 2 N.P.K + COWDUNG MANURE + RICE BRAN
E.P. 3 COWDUNG MANURE
1000
800
600
400
200
0
Mean weight (g)
O N D J F M A M J J A S O N D J F M
1979 1980 Months 1980 1981

This pond yielded a net production of 1,374 kg/ha/yr and a gross production of 1,410 kg/ha/yr (Table-XXI).

EXPERIMENTAL FISH POND-1 : The increase in length of the fish in this pond was seen to be quite steady during the initial 5-6 months. The maximum enhancement was recorded in April with 3.62 cm and in November with 8.7 cm during the first and second cycles respectively (Fig. 12). It attained an average length of 38.6 cm and recorded a mean gain of 30 cm. The monthly average increment was 1.7 cm (Table-XXI). When the weight was analysed it showed a very slow increase till March, but the subsequent month of April recorded a triple fold enhancement with 77.0 gm, which thereafter continued in a progressive fashion during the first annual cycle. The months of November, January and March recorded maximum enhancement with 95.68, 95.4 and 82.33 gm respectively during the second cycle. A mean weight of 625.8 gm was attained at the end of the experiment (Fig. 13). The monthly average increment of weight of fish in this pond was 34.2 gm. As in the control, the growth enhancement was more progressive towards the end of the rearing periods. At the end of the eighteen months of rearing, 72 fishes were harvested out of 106 fingerlings stocked, recording a 67.9% survival. The gross production was 45.05 kg in this pond. When production figures were worked out, it revealed a gross production of 3,337 kg/ha/yr and a net production of 3,285 kg/ha/yr. In term of production, the fishes in this pond-1 recorded the second highest yield next only to pond-2 (Table-XXI).

EXPERIMENTAL FISH POND-2 : The increase in length of the fish in this pond was seen to follow a steady and continuous trend of increase with maximum enhancement recorded in September, October and November registering 4.64, 3.7, 4.36 cm respectively during the first and second cycles. It attained a maximum average length of 45.4 cm

TABLE-XXI

Details of fish growth, survival and production of *Labeo rohita* in Control and Experimental Fish Ponds.

EP = Experimental Fish Ponds.

TABLE-XXI

	Date of stocking	Stocking rate/ha	No. stocked/pond	INITIAL		Recovery after 18 mths.	% Survival	FINAL		Gross Production/Pond (kg)		Net Production/Pond (kg)		Gross Production kg/ha		Net Production kg/ha		Gross Production g/m^2		Net Production g/m^2	
				Av. Length (cm)	Av. Weight (g)			Av. Length (cm)	Av. Weight (g)	18 Mths.	12 Mths.	18 Mths.	12 Mths.	18 Mths.	12 Mths.	18 Mths.	12 Mths.	18 Mths.	12 Mths.	18 Mths.	12 Mths.
CONTROL POND	6.10.79	10,000	150	8.9	9.7	76	50.6	29.5	389.6	29.61	19.74	28.87	19.25	2,115	1,410	2,062	1,374	211.5	141.0	206.2	137.4
EP-1	6.10.79	10,000	106	8.9	9.7	72	67.9	38.6	625.8	45.05	30.03	44.35	29.5	5,005	3,337	4,927	3,283	500.5	333.7	492.7	328.5
EP-2	7.10.79	10,000	140	8.9	9.7	102	72.8	45.4	904.2	92.2	61.46	91.23	60.8	6,585	4,390	6,516	4,344	658.5	439.0	651.6	434.4
EP-3	6.10.79	10,000	284	8.9	9.7	143	50.3	40.4	773.9	110.6	73.73	109.28	72.85	3,950	2,633	3,902	2,601	395.0	263.3	390.2	260.1

at the end of the rearing period. The mean gain in length between the initial and harvest was 36.5 cm and a monthly average increment of 2.1 cm (Fig. 12). When the gain in weight was seen, it showed a steady increase from October to March with the following month of April registering nearly a four-fold increase and thereafter continued progressively on the increase with the month of October and November registering the maximum enhancement with 155.9 and 113.31 gm respectively during the period of study (Fig. 13). On harvest an average weight of 904.26 gm was attained. The mean gain in weight between the initial and harvest was 894.56 gm showing a monthly average increase of 49.7 gm (Table-XXI). The numbers of fishes harvested after eighteen months of rearing was 102 out of 140 fingerlings stocked. It recorded the highest survival percentage of 72.8% in relation to all the other ponds and yielded a gross production of 92.2 kg. When the net and gross production was seen for this pond, a yield of 4,390 kg/ha/yr as gross production and 4,344 kg/ha/yr as the net production was obtained (Table-XXI). The fishes in this pond registered the maximum growth rate and production in comparison to all the other ponds.

EXPERIMENTAL FISH POND-3 : The growth in length revealed a more or less similar trend like that of pond-2. The maximum enhancement of length was registered in June with 4.25 cm. The fish in this pond attained an average length of 40.42 cm on harvest, thus showing a mean gain in length of 31.52 cm between the initial stocking and final harvest. It revealed a monthly average increase of 1.75 cm (Fig. 12). The gain in weight when seen in this pond showed a gradual initial increase, thereafter a rapid enhancement was registered till harvest, with maximum weight increase recorded in the months of October and November representing 170.6 gm and 129.9 gm respectively during the second cycle (Fig. 13). On harvest an average weight of 773.9 gm was attained. The mean gain in weight between the initial and harvest was 764.21 gm, thus showing a monthly average increment of 42.5 gm. The number harvested after eighteen months of rearing were only 143 out of 284 fingerlings. The survival percentage recorded in this pond was the lowest with only 50.3%. A gross production of 110.6 kg was achieved in this pond. When the production figures were worked out, it showed a gross production of 2,633 kg/ha/yr and a net production of 2,601 kg/ha/yr for this pond. Here, though the survival percentage was more or less similar to the control pond, yet it revealed nearly 4 times the gross production and double in terms of yield to that of the control (Table-XXI).

CIRCULAR PLASTIC POOLS

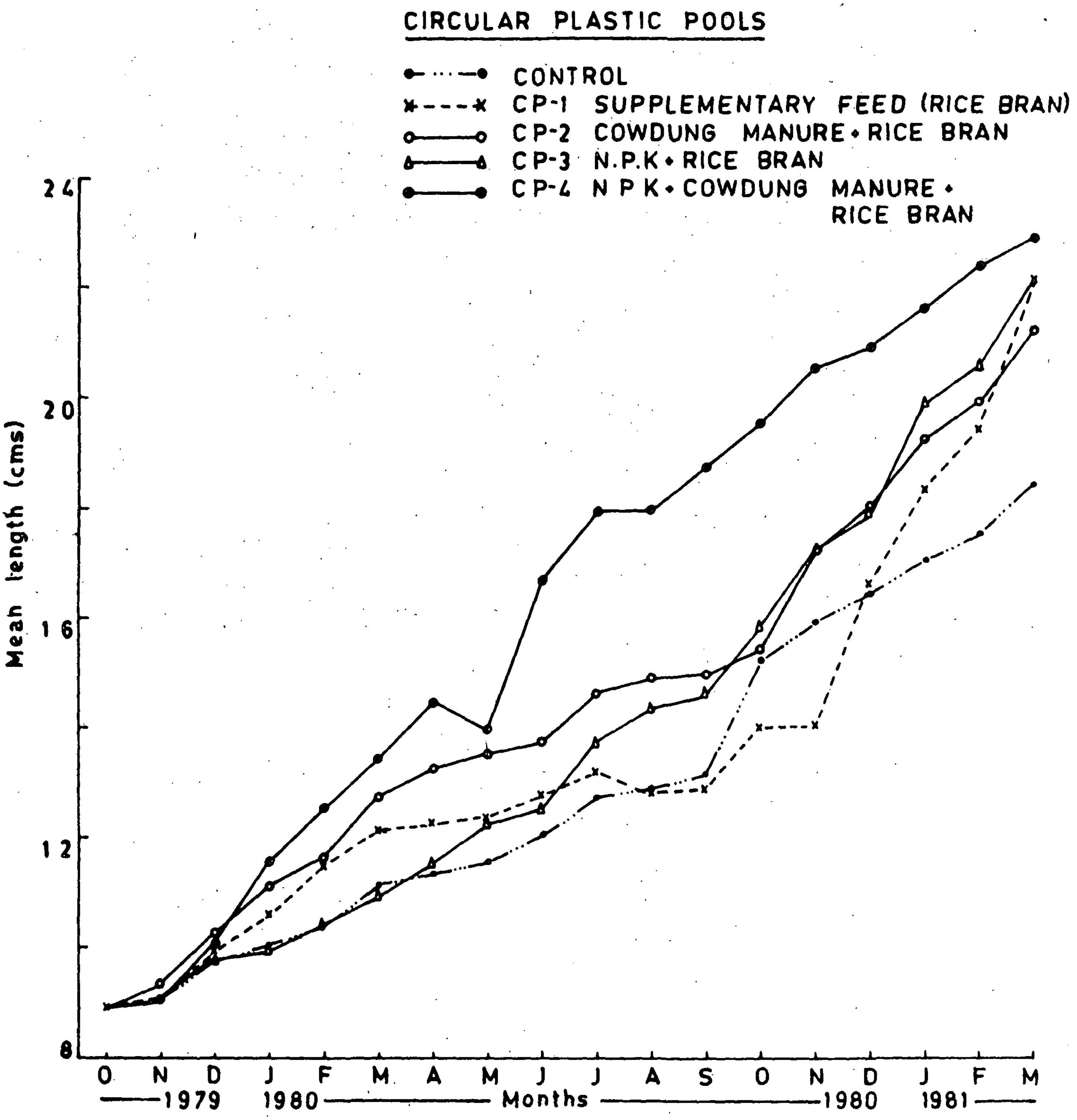
The increase in length and weight of the fish in the five circular plastic pools did not show significant growth over the entire season irrespective of the differential fertilization, in contrast to the experimental ponds.

CONTROL POOL : In the control pool, the trend of increase in length was more or less steady during the entire period of rearing. It attained an average length of only 18.43 cm at harvest, showing a mean gain of 9.53 cm and a monthly average increase of only 0.5 cm (Fig. 14). Similarly the increase in weight revealed a very slow enhancement. An average weight of 145.83 gm was achieved at harvest, showing a mean gain of only 136.2 gm and a monthly average increment of 7.6 gm (Fig. 15). The number harvested after eighteen months of rearing was 14 out of 20 fingerlings initially stocked. The survival percentage in this pool however, recorded the second highest figure with 70% next only to pool-1. The gross and net production in this pool were 2.041 and 1.905 kg respectively after the end of the rearing period (Table-XXII).

CIRCULAR PLASTIC POOL-1 : In this pool the fish attained an average length of 22.14 cm registering a mean gain of 13.24 cm in eighteen months of rearing and showed a monthly increase of only 0.7 cm (Fig. 14). When the weight gained was observed it recorded a little higher than control. It attained an average weight of 230.0 gm and a mean gain of 220.3 gm. The monthly average increment was 12.2 gm (Fig. 15). Out of 20 fingerlings stocked, 16 were harvested giving a survival percentage of 80%. This pool recorded the highest survival percentage in comparison to the other pools. The final gross and net production in this pool were 3.680 and 3.524 kg respectively (Table-XXII).

Fig. 14 - Showing the monthly growth-rate in length (cm) of *Labeo rohita* in the Control and the Circular Plastic Pools.

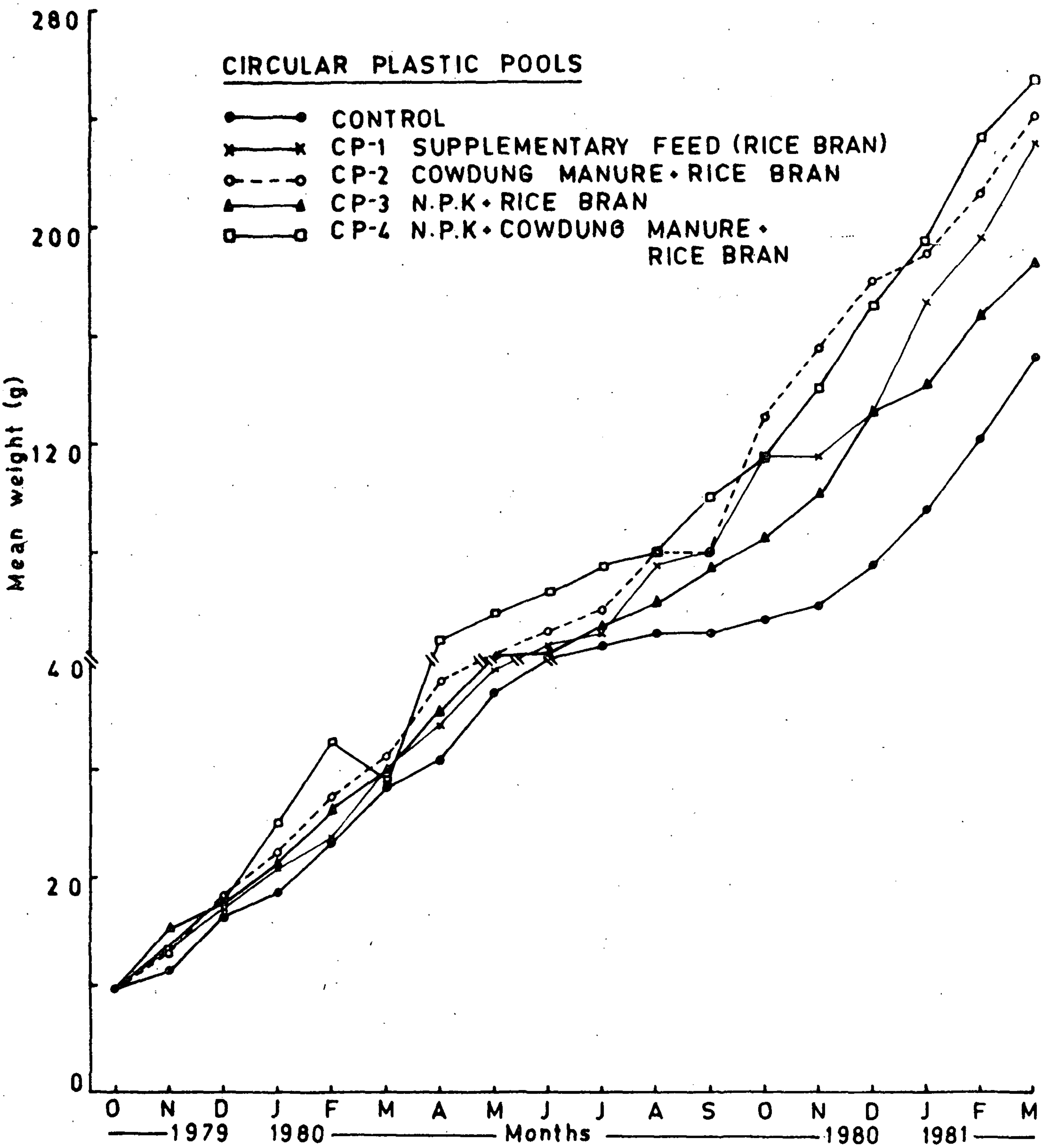
CP = Circular Plastic Pools.



CIRCULAR PLASTIC POOLS
CONTROL
CP-1 SUPPLEMENTARY FEED (RICE BRAN)
CP-2 COWDUNG MANURE + RICE BRAN
CP-3 N.P.K + RICE BRAN
CP-4 N P K + COWDUNG MANURE + RICE BRAN
Mean length (cms)
24
20
16
12
8
O N D J F M A M J J A S O N D J F M
1979 1980 Months 1980 1981

Fig. 15 - Showing the monthly growth-rate in weight (g) of <u>Labeo rohita</u> in the Control and the Circular Plastic Pools.

CP = Circular Plastic Pools.



CIRCULAR PLASTIC POOLS
CONTROL
CP-1 SUPPLEMENTARY FEED (RICE BRAN)
CP-2 COWDUNG MANURE + RICE BRAN
CP-3 N.P.K + RICE BRAN
CP-4 N.P.K + COWDUNG MANURE + RICE BRAN
Mean weight (g)
280
200
120
40
20
0
O N D J F M A M J J A S O N D J F M
1979 1980 Months 1980 1981

TABLE-XXII

Details of fish growth, survival and production of *Labeo rohita* in the Control and Circular Plastic Pools.

CP = Circular Plastic Pools.

TABLE-XXII

	Date of stocking	Stocking Rate/ Pool	INITIAL		Recovery after 18 months	% Survival	FINAL		Gross Production kg/ Pool		Net Production kg/ Pool		Gross Production kg/ha		Net Production kg/ha	
			Av. Length (cm)	Av. Weight (g)			Av. Length (cm)	Av. Weight (g)	18 Months	12 Months	18 Months	12 Months	18 Months	12 Months	18 Months	12 Months
CONTROL POOL	6.10.79	20	0.9	9.7	14	70	18.43	145.8	2.84	1.35	1.9	1.27	14,253.0	9,502.0	12,899.0	8,148.0
CP-1	6.10.79	20	8.9	9.7	16	80	22.14	230.0	3.68	2.45	3.52	2.34	25,698.0	17,132.0	24,244.0	15,778.0
CP-2	6.10.79	30	8.9	9.7	18	60	20.23	241.6	4.34	2.89	4.17	2.70	20,270.0	18,513.0	18,911.0	12,154.0
CP-3	6.10.79	20	8.9	9.7	12	60	22.02	186.2	2.23	1.48	2.11	1.41	15,603.0	10,402.0	14,249.0	9,048.0
CP-4	6.10.79	30	0.9	9.7	19	63.3	22.9	254.1	4.82	3.2	4.64	3.09	22,540.0	15,032.0	21,189.0	13,673.0

CIRCULAR PLASTIC POOL-2 : The fish in pool-2 revealed a steady increase in length and weight and their growth was more pronounced during the second cycle. It attained an average length of 20.23 cm revealing a mean gain of 11.33 cm. It recorded a monthly average increment of 0.62 cm (Fig. 14). The increase in weight was very steady during the initial 3-4 months, thereafter the trend was progressive towards the end of rearing. The maximum enhancement was registered in October with 50.0 gm (Fig. 15). The number harvested was 18 out of 30 stocked, thus showing a survival of only 60% and yielded a gross and net production of 4.348 and 4.174 kg respectively (Table-XII).

CIRCULAR PLASTIC POOL-3 : The fish in this pool also revealed a similar trend of enhancement in length and weight, and rate of increase was more discernible towards the later stages of study. It recorded an average length of 22.02 cms and a mean gain of 13.12 cms between the initial and harvest. The monthly average increase was only 0.72 cms (Fig. 14). The increase in weight was steady, with the months of November and March registering the maximum enhancement of 21.25 gm and 30 gm respectively (Fig. 15). An average weight of 186.25 gm was obtained and a mean gain of 176.55 gm was observed. It registered a monthly average weight increment of 9.8 gm. Out of 20 fingerlings stocked only 12 were harvested showing a survival of 60%.
A final gross and net production obtained in this pool was 2.235 and 2.119 kg respectively (Table-XXII).

CIRCULAR PLASTIC POOL-4 : The fish in this pool similarly showed a gradual increase in length and weight though the enhancement was more conspicuous towards the end of the study period. The increase in length was very gradual with a more or less same rate of increase each month. The fish attained an average length of 22.9 cm on harvest, revealing a mean gain of 14.0 cm and a monthly average increase of 0.8 cm (Fig. 14).

The increase in weight was very gradual in the initial months of October to March, thereafter the weight increment was very progressive. The maximum enhancement was registered in May and July with 10 gm each during the first annual cycle. However, in the next cycle the weight increase was maximum in December and February with 30.83 and 33.33 gm respectively (Fig. 15). The fish attained an average weight of 254.16 gm on harvest revealing a mean gain of 244.46 gm. The monthly average increment recorded was 13.53 gm (Table-XXII). On harvest only 19 fishes out of 30 fingerlings initially stocked survived, thus showing a survival of only 63.3%. This pool recorded the highest production in comparison to all the other pools. It yielded a gross and net production of 4.827 and 4.643 kg respectively (Table-XXII).

DISCUSSION

Fish culture is the art of raising and growing fish under controlled conditions in order to achieve the maximum yield. Although the supply of animal protein in India is far below the demand, it is only recently that sufficient interest has generated towards developing fish culture in the country. During the last two decades it has been very well documented and concluded that fish culture has a bright future in this land.

The productivity of most ponds in India is very high and the growth of the different cultivated species of fish has proved to be excellent. Moreover, the growing season for fish is more than twice that in European countries. Further, the economics of fish culture operations, appear to be favourable and the protein food produced in these ponds is less expensive than in other sectors of animal husbandry.

There is hardly any species of fish that cannot be cultivated under some condition or the other, but the basic consideration is of species that is worthwhile for culture under different situations. The criteria for selection of such a species would be (i) its natural adaptibility to grow fast; (ii) its food habits adapted to the types of living organisms present in the system; (iii) ability to adapt to crowded conditions especially at high stocking density rates; (iv) the tolerance of low dissolved oxygen content as and when it occurs; (v) easy handling and harvesting; and (vi) reproduction under controlled conditions.

It was with this idea, in the region under consideration, that the fish Labeo rohita (Rohu) was taken up for the present investigation. This species is considered as the tastiest of all the Indian

Major carps and it is a quick growing species, being a column feeder. Growth of 35 cm to 45 cm is normally expected in the first year from a well stocked pond. This species is known to have been used extensively in piscicultural practices for a long time in the East Indian States of West Bengal, Orissa and Bihar though the origin is largely unknown.

In the present investigation, two sets of experiments were conducted, on the growth, mortality and production on this species of fish Labeo rohita one in a natural conditions of dug out fish ponds and the other in Circular Plastic Pools. The results analysed revealed that in terms of mean gain in weight and mean gain in length, all the three fertilized fish ponds had much higher growth rates in contrast to the control. Moreover, it was observed that the sixth month was the turning point for an exponential increase in mean weight for the three Experimental Fish Ponds (Experimental Fish Ponds 1, 2 and 3) which were fertilized and the next phase of such a spurt gained in the mean weight occurred after the twelfth month. In contrast, the control pond though did have a spurt after the twelfth month, suddenly fell in the subsequent month to rise thereafter near the levels achieved in the three Experimental Fish Ponds. The maximum increase in the mean weight was observed in Experimental Fish Pond-2 with nearly 900 gm. This was about three times as much as that in the control pond, followed by Experimental Fish Ponds 3 and 1, which was only double of that of the control pond. The mean gain in weight which approximated nearly 900 gm for the study period of eighteen months is near the figures attributed to good production by other workers (Alikunhi, 1957, 1966; Jhingran, 1968).

The mean gain in length and the increment over the season was seen to have very little difference among the three Experimental

Fish Ponds-1, 2 and 3, which showed however nearly a one-third increase in relation to the control. In case of mean gain in length the fourth month seemed to be a turning point for a sudden spurt in the increase of their length which thereafter followed a steady trend of increase though with minor fluctuations. As in the case of gain in mean weight, the mean gain in length recorded maximum was in Experimental Fish Pond-2, followed again by Experimental Fish Ponds-3 and 1.

In contrast to the Experimental Fish Ponds in the Circular Plastic Pools, the mean gain in length and weight showed a steady increase from the initial to the end. There is some indication after the twelfth month to have a second phase of a spurt of increase in weight and this was true for all the pools including the control. Unlike the fish ponds, the mean gain in weight attained after eighteen months in the plastic pools were not very significantly different from that of the control. The maximum was however seen in Circular Plastic Pool-4 which was nearly 245 gms followed by Pool-2 and Pool-1 more or less equal and only 10 gm to 15 gm less than Pool-4, and finally Pool-3 and the control pool which showed nearly 100 gm less. A more or less similar situation was seen for the mean gain in length. Pool-4 had a mean gain in length of 14.0 cm followed by Pool-1 of 13 cm and Pool-3 and control showing nearly 10 cm. The only interesting aspect as seen in Pool-3 was that, though the mean gain in weight was very near the control, the length obtained was however near the highest attained of all the Circular Plastic Pools.

In Pakistan the growth of Rohu is reported as 680 gm under stocking density of 178 to 1332/ha (Rabanal, 1968). Similar growth rates are indicated in India under stocking densities of 3,750 and 3,385/ha by Alikunhi (1957) and Hora and Pillay (1962). However in the absence of survival rates, these stocking rates are considered very low when compared with the present study. The percentage survival in the present investigation among the ponds was seen to be the highest in Experimental Fish Pond-2, accounting for 73% followed by Pond-1 which was nearly 68%. However, pond-3 and control was only 50% survival and it is interesting to note that in pond-3, this 50% survival accounted for the mean gain in weight and length as the second highest.

Very little information is available on the growth rates in relation to fertilization. In the present study Experimental Fish Pond-2 which possessed maximum values was the one in which both organic and inorganic fertilizers in addition to supplementary feeding were administered. In pond-1, where only organic and inorganic fertilizers were given did not show any significant increase in comparison to the other ponds though well above the average obtained elsewhere for this species. The organic fertilized pond, pond-3 definitely showed higher growth rates both in terms of length and weight. The only conclusion to such differential growth rates as observed in the present investigation could probably be attributed to the one common factor NPK as inorganic fertilizer which seemed to inhibit some physiological response for the usual growth and mortality even though the food available in the ponds were more or less the same in terms of the general biota.

On a similar analysis in the plastic pools it was seen that the Circular Plastic Pool-1 revealed 80% survival followed by control pool with nearly 70% survival. All the other three pools had nearly 60% survival each, with pool-4 showing a little higher than 60%. Once again as in Experimental Fish Pond-2, Circular Plastic Pool-4 which was given organic and inorganic fertilizers and supplementary feeding showed the maximum growth rate even with a lower comparative survival rate. Pool-2 which was given only organic fertilizer and supplementary feeding came second only to pool-4 and probably could be attributed to the same phenomena as in the fish ponds. In fact supplementary feed alone as in pool-1 revealed the highest survival percentage with pool-3 as fourth, where inorganic fertilizers and supplementary feed were given.

Both these systems revealed whether large or small and whether artificial or natural, inorganic fertilization does tend to inhibit the actual growth of the fish at least as far as its size was concerned.

PRODUCTION :- In fish culture experiments it is the yield or production which is more important than the growth rate. However these figures are arrived at primarily by the percentage survival along with the mean growth attained. Whether for the total period under consideration of eighteen months or per annum, it was seen that once again among the Experimental Fish Ponds, Pond-2 revealed the maximum gross and net fish production. This is understandable as both the growth rate and the percentage survival was the highest in this pond. The gross and net production figures for the eighteen months period was 6585.0 kg/ha and 6516.0 kg/ha, while the annual production was 4390.0 kg/ha/yr as gross and 4344.0 kg/ha/yr as net. This was followed by Experimental Fish Pond-1 with gross and net production for eighteen month period as 5005.0 kg/ha and 4927.0 kg/ha respectively, while the annual figures were 3337.0 kg/ha/yr as gross and 3285.0 kg/ha/yr as net production, followed by Experimental Fish Pond-3, which gave a gross and net production figures of 3950.0 kg/ha and 3902.0 kg/ha for 18 months respectively and the annual gross and net production was 2633.0 kg/ha/yr and 2601.0 kg/ha/yr. Finally the control pond revealed a gross production of 2115.0 kg/ha/18 months and a net production of 2062 kg/ha/18 months, while it was 1410.0 kg/ha/yr as gross and 1374.0 kg/ha/yr as net production. In Experimental Fish Pond-2, the fish production showed nearly 3.5 times that of control pond. It is here that Pond-1 because of its higher percent survival came second in term of production in contrast to Pond-3 which is far low due to low percent survival in that pond. Once again organic and inorganic fertilization and supplementary feeding revealed maximum production figures.

Such production figures for the plastic pools becomes redundant as the stocking densities/hectare were very high, therefore the production figures were only confined to the gross and net production as (kg/pool) as attained per pool. These figures are more appropriate as they follow the growth rate as well as the incorporation of survival percentage is taken account of. The highest yield was in Circular Plastic Pool-4 with a gross production of 4.82 kg/18 months and 3.2 kg/yr and a net production of 4.64 kg/18 months and 3.09 kg/yr, followed by Pool-2 with a gross production of 4.34 kg/for 18 months and 2.89 kg/for one year, and a net production of 4.17 kg/18 months and 2.78 kg/yr. Pool-1 followed thereafter with gross production of 3.68 kg/18 months and 2.45 kg/yr and a net production of 3.52 kg/18 months and 2.34 kg/yr. Pool-3 revealed a gross and net production of 2.23 kg/18 months, 1.48 kg/yr and 2.11 kg/18 months, 1.41 kg/yr respectively and finally the control pool gave a gross and net production of 2.04 kg/18 months, 1.35 kg/yr and 1.90 kg/18 months, 1.27 kg/yr respectively.

Very little information is available on such monoculture experiments as most studies, incorporating fish culture practices have usually,if not always been on polyculture. In any case in India, fish yields from Experimental Fish Ponds have shown a phenomenal increase from the modest production of 600 kg/ha/yr (Jhingran, 1969) more than a decade ago to about 9000 kg/ha/yr and 5893 kg/ha/6 months in recent years (Jhingran, 1980). The figures obtained around the last decade for culture of Indian major carps alone ranges from 1437 to 2975 kg/ha/yr, where inorganic and organic fertilizers were applied along with supplementary feedings (Lakshmanan et. al., 1971; Singh et. al., 1972). The same workers reported around 2234 to 4210 kg/ha/yr for composite fish culture using similar organic and inorganic fertilizers with supplementary feed. Works on Indian major carps in very recent times have been shown by Das et. al., (1980) to be 4063.5 and 3841.5 kg/ha/13 months as gross and net production respectively.

However, in the present investigation it was seen even in the control pond a gross and net production of 2115 and 1374 kg/ha/yr obtained can be considered as high yield, as Sreenivasan (1964) reported 1400 kg/ha/yr as an average production for seven years in an unfertilized tropical pond in South India to be high in comparison to the Indian average.

The highest production in the present investigation is definitely related to organic manuring and such reports are in existence earlier and especially in Indian and Chinese fish ponds (Hickling, 1962; Hora and Pillay 1962; Lin, 1966; Rabanal, 1966; Bardach et. al., 1972).

In Chinese ponds where only animal manures, compost and offal were administered, an average production of 3000 kg/ha/yr, and a maximum of 7500 kg/ha/yr had been obtained in Central China (Yashouv, 1966). In Israel it was seen for common carps, that fertilization increased production to nearly four times and supplementary feeding with cereal grains increased it by fifteen times (Hepher, 1967). Similar reports in some former Congo ponds with very little management produced 100 to 1000 kg/ha/yr (mainly Tilapia) while these ponds with intensive management and supplementary feed produced nearly 4000 kg/ha/yr (Huet, 1957). It is known that unfertilized ponds in the tropics nearly produces 300 kg/ha/yr but if management is done properly to the extent as seen in Java fish ponds that even a supply of minerals from the hot springs have been reported to produce fish nearly 10,000 kg/ha/yr (Mortimer and Hickling, 1954).

In the present investigation, the attributes are very true in that maximal production levels have definitely been found in the ponds and pools where both organic and inorganic fertilizers and supplementary feeds were administered. However, organic fertiliz - tion with supplementary feeds seemed to enhance production levels and it is known that different fertilizers have different productive capacity (Mortimer and Hickling, 1954; Edmondson et. al., 1956). In addition, probably some of the synergic effects between the fertilizers themselves in such closed ecosystems as ponds and pools can affect the production figures. This may be true in the present investigation as in both the experiments, a control was maintained and hence the only factor causing variation could be attributed to the type of fertilization since all other environmental factors were similar. Reports exist for intense organic and chemical fertilization of fish ponds without supplementary feeds, where they are comparable to yields attained with conventional feed (Tan, 1970; Yashouv and Halevi, 1972; Schroeder, 1974; Schroeder and Hepher, 1976; Moav et.al., 1977; Wolhfarth, 1978).

The other aspect, furthermore is that organic fertilizers as manure for fish ponds invariably affects the biological and chemical condition of fish ponds as such, that the manure is digested by, and the nutrients thereby fixed by microorganisms that in turn are consumed by the fish (Schroeder, 1975). In contrast chemical fertilizers alone or in combination would probably increase the phytoplankton to cause a self-shading effect thereby reducing primary production which in turn affects the production of the fish. In our investigation probably this last aspect may have come into play to a large extent.

Increased growth-rate of fish in such monoculture or higher yields in term of production from the present study does reveal that maximal output in terms of fish yield was due primarily to the judicious administering of both organic and inorganic fertilization and to supplement the biota so created in the pond for food, by feed even if it is only rich in carbohydrate content (Rice bran) in the present investigation. However, fish production of an individual pond being high or low in a particular year, could be due to random variation of the organic development within the waters of individual ponds (Wolhfarth and Moav, 1968; Buck, 1970). In addition, as in the present experiment, when ponds and pools were taken simultaneously for a study we cannot eliminate the chance factor that may be in operation like (i) the differences in the timing of the degree of colonization of flora and fauna in the different ponds, and (ii) the differences in rates of the available nutrient being cycled through the individual systems. Whatever the case may be in a region at the foot hills of Nagaland, these experiments have proved beyond doubt that very high production figures can be obtained by simple scientific management of fish ponds even with monoculture of species like Labeo rohita. This has encouraged us to go further to the various attributes responsible for the functioning of such ecosystems and we hope to conduct polyculture (composite fish culture) with such randomized block design experiments.

REFERENCES

Alikunhi, K.H. 1952 On the food of young carp fry. J. Zool. Soc. India, 4:77-84

________ 1956 Fish culture techniques in India. Progr. Fish. Developm. India : 63-73.

________ 1957 Fish culture in India. Fm. Bull. Indian coun. Agri. Res., 20:144 p.

________ 1966 Synopsis of biological data on common carp <u>Cyprinus carpio</u> (Linneaus) 1758 (Asia and Far East) FAO World Symp. Warm-Water Pond Fish. Cult. Rome, No. FR/S, 31.1:80 (Mimeo).

________, H. Chaudhari & V. Ramchandran 1955 On the mortality of carp fry in nursery ponds and role of plankton on their survival and growth. Ind. J. Fish. Soc., 2:257-313.

________, K.K. Sukumaran & Parameswaran 1971 Studies on composite fish culture: Production by compatible combinations of Indian and Chinese carps. J. Indian. Fish. Assoc., 1(1):26-57.

Ball, R.C. 1949 Experimental use of fertilizer in the production of fish-food organisms and fish. Michigan State Coll. Agr. Expt. Sta., Sect. of Zool., Tech. Bull. 210, 28 p.

________ 1950 Fertilization of natural lakes in Michigan. Trans. Am. Fish. Soc., 78:146-155.

________ & H.A. Tanner 1951 The biological effects of fertilizer on a warm water lake. Mich. State Coll. Tech. Bull. 223-232.

Banerjea, S,M. & L.N. Mandal 1965 Inorganic transformation of water soluble phosphate added in fish ponds as in influenced by the nature of pond soils, J. Indian Soc. Soil. Sci., 13:167-173.

________ & S.C. Banerjee 1967 Fertilization of fish ponds with trace elements manganese for increased production of plankton. FAO Fish. Rep. (44) 3:132-152.

Bank, O. 1959 Phosphordringung und ihre Anwendung. Fiscbauer 10:1-3.

Bardach, J.E., J.H. Ryther & W.O. McLarney 1972 *Aquaculture: The farming and husbandry of* fresh water and marine organisms. Wiley-Interscience, New York, 868 p.

Barret, P.H. 1953 Relationship between alkalinity and absorption and regeneration of added phosphorus in fertilized trout lakes. Trans. Am. Fish. Soc., 82:78-90.

Boyd, E.Claude	1976	Nitrogen fertilizers effects on production of Tilapia in ponds fertilized with phosphorus and potassium. Aquaculture, 7(4):385-390,
Birthwhistle,W.	1931	Rearing of carps in ponds. Malayan Agr. J. 1931.
Buck, D.H., R.J. Baur & C.R.Rose	1976	Experiments in recycling swine manure in fish ponds. In: FAO Tech. Conf. on Aquaculture, Kyoto, Japan. FAO-FIR:AQ/Con/76/E. 29.5 p.
________,&C.F. Thoits & C.R.Rose	1970	Variation in carp production in replicate ponds. Trans. Am. Fish. Soc., 1:74-79.
Chakraborty,R.D., P.R.Sen, N.G.S. Rao & S.R.Ghosh	1976	Intensive culture of Indian major carps. In. FAO Tech. Conf. on Agri. Kyoto, Jap. 26th May '76. FAO-FIR:AQ/Conf/76/E 64. 9 p.
Chaudhuri, H.	1960	Experiments on induced spawning of Indian carps with pituitary injections. Indian J. Fish., 7(11):20-49.
________, R.D.Chakraborty, N.G.S.Rao, K. Janakiram, D.K. Chatterjee & S. Jena	1974	Record high production with intensive culture of Indian and exotic carps. Curr. Sci., 43:303-304.
________, ________, P.R.Sen, N.G.S. Rao & S. Jana	1975	Record yields by composite fish culture in freshwater ponds. Aqua. 6(4):343-355.
Chimits, P.	1961	Management of fish stocks in open systems. Introduction of exotic species. Third International Inland Fisheries Training Centre. Bogor, Expanded Programme to Technical Assistance, FAO. Rome 1:3.21:1-9.
Das, S.M. & S.K. Moitra	1955	Studies on the food of some common fishes of Uttar Pradesh. India. 1. The surface-feeders and the bottom-feeders. Proc. nat. Acad. Sci. India. 25 B(1 and 2):1-16.
Das, P.,D.Kumar, A.K.Ghosh, D.P. Chakraborty & U. Bhaumik	1980	High yield of Indian major carps against encountered hazards in a demonstration pond. J. Inland Fish. Soc. India. 12(1):70-78.
Dimitrov, M.	1974	Mineral fertilization of carp ponds in polycultural rearing. Aqua. 3(3):273-285.
Donald,J. Hall., William E.Cooper & Earl E. Werner	1970	An experimental approach to the production dynamics and structure of fresh-water animal communities. Limnol. Oceanogr. 15:839-928.
Fijan, N.	1961	Problems in carp pond fertilization. FAO. Fish. Rep. (44)3:423 p.

Gooch, B.C. 1966 Appraisal of N.American fish culture fertilization studies. FAO World Symp. Warm-water pond fish cult. FAO Fish Rept. 44(3):13-26.

Grover, John H., D. Renato & Recometa 1976 Production and growth of milk fish, common carp and cat fish in fertilized freshwater ponds. Kalikasan 5(2), 193-206.

Hepher, B. 1952 The fertilization of fish ponds 2.Nitrogen. Bamidgeh, 4(10-12):220-223.

________ 1958 On the dynamics of phosphorus added to fish ponds in Israel. J. Limnol. Oceanogr. 3(1): 84-100.

________ 1962 Ten years of research in fish pond fertilization in Israel. 1.The effect of fertilization on fish yields. Limnol. Oceanogr. 14(2):29-38.

________ 1963 Ten years of research in fish pond fertilization. II.Fertilizer dose and frequency of fertilization. Limnol. Oceanogr. 15(4):78-92.

________ 1967 Some biological aspects of warm-water fish pond management: 417-28. In. The biological basis of Freshwater fish production (ed. S.D. Gerking) Oxford: Blackwell Scientific Publications.

Hickling, C.F. 1962 Fish culture. London: Faber and Faber. 295p.

________ 1967 Fish hybridization. FAO Fish-Rep.(44) 4:1-11.

________ 1971 Fish culture. 2nd Ed. London: Faber and Faber 317 p.

Hoffman, W.E. 1934 Preliminary notes on freshwater fish industry of South China, especially Kwanglung province. Lingan Univ. Sci. Bull.,No.5,70pp.

Hora, S.L. & T.V.R. Pillay 1962 Handbook on fish culture in the Indo-Pacific fisheries region. FAO. Fish. Biol. Tech. Paper 14.

Howell, H.H. 1942 Bottom organisms in fertilized and unfertilized fish ponds in Alabama. Trans. Am. Fish. Soc., 71:165-179.

Huet, M. 1957 Dix annees de pisciculture au Congo belge et au-Ruanda-Urandi Trav. St. Rich. Groenendaal (D) 22:159 p.

________ 1970 Textbook of fish culture. Fishing News. Ltd., London 436 p.

Ibrahim, K.H. 1957 Bionomics of forage fishes: Observations on the fecundity of three common species of minor barbels. J. Bombay Nat. Hist. Soc., 54(4):826-834.

Janecek, V.(Jr.) 1963 Results of comparative experiments with mineral nitrogenous fertilizers in a new type of experimental plant. Annual Report of Fisheries Res., Czechoslovakia 3:7-15.

Jhingran, V.G. 1968 Synopsis of biological data on Catla-catla (Hamilton, 1882). FAO Fish. Synops., (32) REV. 1: Pag. Var.

__________ 1969 Review on the present status of knowledge on induced breeding of fishes and problems for future research. FAO/UNDP Regional Seminar on Induced Breeding of cultivated fishes, Calcutta, FRI/IBCF/27:48 p (MIMEO).

__________ 1975 Fish and Fisheries of India. Hindustan Publishing Corporation (India) 954 pp.

Kawamoto, N.Y. 1957 Production during intensive carp culture in Japan. Prog. Fish. Cult., 1957 : 26-31.

Khan, M.A. 1971 Artificial feeding in composite fish culture. In: Workshop of First All India Coordinated Project on composite culture of Indian and Exotic fishes. Central Inland Fisheries Research Institute, Cuttack September 17-20 pp.

Lakshmanan, M.A.V., D.S. Murty, K.K.Pillai & S.C.Banerjee 1967 On a new artificial feed for carp fry. FAO. Fish. Rep. (44) 3:373-387.

__________, P.R.Sen, D.S. Murty & D.P. Chakraborty 1968 Preliminary study on the rearing of carp fingerlings. Indian. J. Fish. 15(1 and 2) : 40-52.

__________, K.K.Sukumaran, D.S.Murty, D.P. Chakraborty & M.T. Philipose 1971 Preliminary observations on intensive fish farming in fresh water ponds by the composite culture of Indian and exotic species. J. Inland. Fish. Soc. India 2:1-21.

Lewkowicz, M. & 1977 Organic and inorganic nutrient enrichment and the living conditions of carp fry in first rearing ponds: Physico-chemical factors and the Zooplankton. Acta. Hydrobiol. 18(3):235-258.

Lin, S.Y. 1970 The effect of phosphorus and nitrogen fertilizers on fish production in freshwater ponds. Chinese-American Joint Commission on rural Reconstruction, Tapei, Taiwan Fish. Series. No. 9:54-571

Lin, S.Y. & T.P. Chen	1967	Increase production in fresh-water fish ponds by the use of inorganic fertilizers. FAO. Fish. Rep. (44) 3:210-225.
Ling, S.W.	1961	Management of fish stocks in open systems population manipulation. Third International Inland Fisheries Training Centre, Bogor, Expanded Programme of Technical Assistance, FAO, Rome, 1:3.21, 1-9.
————	1966	Feeds and feeding of warm-water fishes in ponds in Asia and the Far East. Proc. Symposium on warm-water pond fish culture. FAO. Fish. Rep. No. 44, Vol. 3, p. 291-309.
————	1967	Feeds and feeding of warm-water fishes in ponds in Asia and the Far East. FAO. Fish. Re. (44)3:291-309.
Maciolek, J.A.	1954	Artificial fertilization of lakes and ponds. U.S. Dept. Inter. Fish and Wildl. Ser. Special Science. Report. Fisheries No.113, 40pp.
Moav, R., G.Wohlforth, G.L. Shroeder, G. Hulata & H.Barash	1977	Intensive polyculture of fish in freshwater ponds. I. Substitution of expensive feeds by liquid cow manure. Aquaculture, 10:25-43.
Mortimer, C.H. & C.F. Hickling	1954	Fertilizers in fish ponds. Fish. Publ. Lond. (5):155 p.
Nabila, F.Bishara	1979	Fertilizing fish ponds III. Growth of <u>Mugil capito</u> in Egypt by pond fertilization and feeding. Aquaculture 16:47-55.
Nelson, P.R. & W.T.Edmondson	1955	Limnological effects of fertilizing Bare Lake, Alaska. Fishery Bulletin 102, Fishery Bulletin of the Fish and Wildlife Service. 56:415-436.
Ness, J.C.	1949	Development and status of pond fertilization in Central Europe. Trans. Am. Fish. Soc., 76:335-358.
Parova, J.	1971	Analysis of the efficiency of mineral fertilization in fish pond management. Bul. Vyzk. Ustav. RYB. VODN, 8(1), 24-31, 3 refs.
Pedro Noriega-Curtis	1979	Primary productivity and related fish yield in intensely manured fish ponds. Aquaculture, 17:335-344.
Polishchuk, V.S., V.P.But, G.N. Maryutina & T.Tu Malykhina	1974	Effect of fertilizers and dense stocking in fattening ponds on the hydrochemical regime and natural food base. UZB BIOL ZH 17(4): 43-45.
Prashad, B.	1919	The importance of fisheries. Proc. 3rd Entomological meeting : 908-909.

Probst, E. 1950 Teichdungung Die Bedeutung des phosphorus. Allg. Fisch. Ztg., 89:191-194.

Prowse, G.A. 1968 The latin square fertilizer trials. Trop. Fish. Cult. Res. Inst. Wkg. pap (1):28p.

Rabanal, H.R. 1966 Stock manipulation and other biological methods of increasing production of fish through pond fish culture in Asia and the Far East. Proc. World Symposium on warm-water pond fish culture. FAO Fish. Rep.No.44(4) : 274-288.

__________ 1967 Inorganic fertilizers for pond fish culture. FAO. Fish. Rep. (44)3:164-179.

__________ 1968 Stock manipulation and other biological methods of increasing production of fish through pond fish culture in Asia and the Far East. FAO. Fish. Rep. (44)4:274-288.

Rappaport, U. & S. Sarig 1977 Observations on the use of organic fertilizers in intensive fish farming at the Ginosar Station in 1976. Bamidgeh, 29(2), 57-70.

__________ & __________ 1978 The results of manuring on intensive growth fish farming at the Ginosar Station ponds in 1977. Bamidgeh., 30:27-36.

Rzanicanin, B. & I. Balzer 1977 Fertilizing ponds water: critical review. Poljopr. Znan Smotra 37(47):11-18.

Saha, G.N., K. Raman, D.K. Chatterjee & S.R. Ghosh 1976 Relative response to three nitrogenous fertilizers in different pond soils in relation to primary productivity, plankton and survival and growth of Labeo rohita spawn. J. Inland. Fish. Soc. 7:162-172.

Schaperclaus, W. 1959 Die karpfenteichswirt schaft in der Deutscke Demokratischen Republik Sitz. Ber. Bd. VII. Hft. 7. Deutsche Akad. Landwirtschaftuiss. Berlin.

__________ 1966 Steigerung der karpferertage in Teicher durch Stickstoff dungung (N-Dungun-gsversuehe in kauppa 1965). Dtsch. Fisch. Ztg. 13(1):6-14.

Schroeder, G.L. 1974 Use of fluid cowshed manure in fish ponds. Bamidgeh, 26(3):84-96.

Schroeder, G. 1975a Some effects of stocking fish in waste treatment ponds. Water. Res., 9:591-593.

__________ 1975b Night-time material balance for oxygen in fish ponds receiving organic wastes. Bamidgeh, 27:65-74.

Schroeder, G. & B. Hepher 1976 Use of agriculture and urban wastes in fish culture. Presented at the FAO Technical Conference on Aquaculture, Kyoto, Japan, 26 May - 2 June, 1976. 3 pp.

Samra, i-El. & J. Olah 1979 Significance of nitrogen fixation in fish ponds. Aquaculture 18:367-372.

Sen, P.R., N.G.S. Rao, R.D. Chakraborty, S.L.Kar & S. Jena 1978 Effect of addition of fertilizers and vegetation on growth of Major carps in ponds containing grass carp. Prog. Fish. Cult. 40(2):69-70.

Sharma, B.K. 1974 On the survival and growth of Major carp spawn in nurseries manured with organic fertilizers. J.Zool. Soc. India. 26(1-2), 157-158.

Sharma, M.P. & S.D. Kulshreshthra 1975 Effect of certain fertilizers, feeds and cobalt chloride on the production and survival of young ones of the common carp Cyprinus carpio L. Bull. Basrah. Nat. Hist. Mus. Univ. Basrah 2, 27-35.

Shell, E.W. 1967 Feeds and feeding of warm-water fish in North-America. FAO. Fish. Rep.44(3):310-325.

Shimadata, M., K. Nakamura, H. Koyama, T. Ito & J. Toi 1957 Effect of fertilization and significance of artificial feeding to fish production. Bull. Freshwater Fish. Res. Lab., Fisheries Agency, Tokyo Vol. 7, No. 1.

Singh, S.B., K.K. Sukumaran, P.C. Chakrabarti & M.M. Bagchi 1972 Observation on composite culture of exotic carps. J. Inland Fish. Soc. India. 4:38-50.

Singh, V.R.P., M.Vijaya Gupta, M.K.Banerjee & Dhirendra Kumar 1973 Composite fish culture at Kalyani, West Bengal. J. Inland. Fish. Soc. India, 5:201-2 207.

Smith, M.W. 1961 Bottom fauna in a fertilized natural lake and its utilization by trout (Salvelinus fontinalis) as food. Verhandl. Intern. Ver. Theoret. Agnew Limnol. 14:722-726.

Smith, E.V. & H.S. Swingle 1939 The relation between plankton production and fish production in ponds. Trans. Am. Fish. Soc., 68:309-315.

______ & ______ 1941 The use of fertilizer for controlling several submerged aquatic plants in ponds. Trans. Am. Fish. Soc., 71:94-101.

______ & ______ 1942 Organic materials and fertilizers for fish ponds. Trans. Am. Fish. Soc., 72:97-102.

Sneed, K.E., W.H. Hasting & D.K. Harry	1972	Accomplishments and future priorities in warm-water fish nutrition. In: Progress in Fishery and Food Science, University of Washington College of Fisheries, 50th Anniversary Celebration Symposium, University of Washington-Publication in Fisheries- New Series, V:151-157.
Stickney,R.R. & J.H. Hesby	1978	Tiliapia production in ponds receiving swine wastes. In: R.O. Smitherman, W.L. Shelton and J.H. Grover (Editors) Culture of Exotic fishes, Symp. Proc. Fish Culture Station, American Fisheries Society, Bethesda, Md., PP.90-101.
Swingle, H.S.	1968	Fish kills caused by phytoplankton blooms and their prevention. FAO, Fish. Rep. 44(5): 407-411.
________ & E.V. Smith	1938	Fertilizers for increasing the natural food for fish ponds. Trans. Am. Fish. Soc., 68: 126-135.
________ & ________	1947	Management of farm fish ponds. Alabama. Polytech. Inst., Agr. Expt. Sta., Bull.254, 30p.
Tang, Y.A.	1970	Evaluation of balance between fishes and available fish foods in multi-species fish culture ponds in Taiwan. Trans. Am. Fish. Soc. 99:708-718.
Wahby, S.D.	1974	Fertilizing fish ponds. I Chemistry of the waters. Aqua. 3(6):245-259.
Weatherly, A. & A.G. Nicholls	1955	The effects of artificial enrichment of a lake. Aust. J. Marine Freshwater Reseources 6:443-468.
Wlodek, J.M.	1971	Biomass and production of carps fry in different fingerlings ponds. Pol. Arch. Hydrobiol. 18(2), 247-264, 10 refs.
Wolfarth, G.W.	1978	Utilization of manure in fish farming proceedings of Conference on Fish Farming and Wastes. London, England, 4-5 Jan. 1978. PP. 78-95.
________ & R. Moav	1968	The relative efficiency of experiments conducted in undivided ponds and in ponds divided by nets. FAO. Fisheries Reports. 1(44): 487-492.
Wolny, P.	1967	Fertilization of warm-water fish ponds in Europe. FAO. Fish. Rep. (44)3:64-81.

Wood, Carle & Tommy L.Sheddan	1971	Norris Reservoir fertilizer study: 1.Effects of fertilizers on food chain organisms and fish production. J. Tenn. Acad. Sci. 46(3): 81-90
Wrobel, S.	1962	Wphyne nawozenia ozotowo-fosforowego na sklad chemiczny wody, productije pierwotna fiftoplanktony i przresty ryb ne stawach. Acta. Hydrobiol. Krakois. 2:151-204.
Wurtz, A.	1956	Ertragesteizerung in Teichen mit saurem Boden durch Hoferkultur. D. Fischerei Zeit. Oct. 3. 1956.
Yankavichyute, G.Y.	1970	Effect of organic mineral fertilizers on the development of phytoplankton in cultivated carp ponds: Tr. Akad. Nauk. Lit. SSR Ser. V. Biol. Nauk. 1. 81-95 Illus. (Engl. Sum).
Yashouv, A.	1959	Studies on the productivity of fish ponds I. Carrying capacity. Proc. Tech. pap. gen. Fish. Coun. Mediterr. 5:409-419.
________	1966	Mixed fish culture- an ecological approach to increase pond productivity. Proc. World Symposium on warm water pond fish culture. FAO Fish. Rep. No. 44(4):258-273.
________	1968	Mixed fish culture- an ecological approach to increase pond productivity. FAO. Fish. Rep. (44)4:258-273.
________	1969	Mixed fish culture in ponds and the role of tilapia in it. Bamidgeh 21(3):75-92.
________ & A. Halevi	1972	Experimental studies on polyculture in 1971. Bamidgeh 24(2):31-39.

GENERAL DISCUSSION AND RECOMMENDATION

GENERAL DISCUSSION AND RECOMMENDATION

After completion of such a study for fish growth and yield in fertilized experimental fish ponds and circular plastic pools and obtaining the results of the analysis of the physico-chemical parameters, the biota and the primary production relations, it was felt to see the intricate mechanisms affecting one another and primarily their effect on the growth of the selected species Labeo rohita. This was found primarily essential to determine the cause and effect in such man-made ecosystems in order to be able to predict in the future the events that occur in such manipulated and perturbed aquatic systems.

The present investigation revealed an existence of a cyclic development of the pulses of the various factors undertaken individually for the detailed seasonal study. However, the time in which the annual pulses were initiated or terminated, got displaced to some extent. In addition, the magnitude of a pulse also vary considerably from one season to the other. It was, therefore, felt that the incorporation of the statistical analysis of correlation coefficient between all these variables would possibly highlight the causative factor or factors responsible for phyto- or zooplankton growth, primary production and fish production.

A perusal of the Tables-XXIII, XXIV, XXV and XXVI which show these correlation coefficients, identifies the intricate relationships between the variables at statistically significant levels.

In the experimental fish ponds undertaken for the present study, the correlation observed in the control pond was seen between phosphate and both total zooplankton and total plankton at $P>0.05$ level positively. Similar positive relationships existed and was highly significant ($P>0.01$) between total phytoplankton and oxygen.

TABLE-XXIII

Correlation table, showing the correlation coefficients among the physico - chemical and primary productivity and biota undertaken for the Control and Experimental Fish Ponds.

A - Gross primary productivity

B - Net primary productivity

C - Total phytoplankton

D - Total zooplankton

E - Total plankton

F - Mean length (fish growth)

G - Mean weight (fish growth)

1 - Air temperature

2 - Water temperature

3 - pH

4 - Conductivity

5 - Total alkalinity

6 - Carbon dioxide

7 - Oxygen

8 - Silicate

9 - Phosphate

10 - Nitrate

EP = Experimental Fish Ponds.

TABLE-XXIII

CONTROL POND

	1	2	3	4	5	6	7	8	9	10
A	(-) 0.337	(-) 0.381	(+) 0.233	(-) 0.172	(+) 0.072	(-) 0.115	(+) 0.220	(-) 0.273	(+) 0.261	(+) 0.339
B	(-) 0.106	(-) 0.239	(+) 0.073	(+) 0.073	(+) 0.139	(-) 0.091	(+) 0.392	(+) 0.401	(-) 0.091	(+) 0.458
C	(-) 0.248	(-) 0.276	(+) 0.143	(-) 0.256	(+) 0.241	(+) 0.303	(+)** 0.799	(-) 0.047	(+) 0.196	(+) 0.066
D	(+) 0.141	(+) 0.133	(+) 0.289	(-) 0.027	(+) 0.089	(+) 0.132	(-) 0.218	(-) 0.310	(+)* 0.539	(-) 0.029
E	(+) 0.016	(-) 0.003	(+) 0.309	(-) 0.132	(+) 0.174	(+) 0.241	(-) 0.100	(-) 0.285	(+)* 0.545	(+) 0.082
F	(-) 0.149	(-) 0.096	(+) 0.241	(+) 0.348	(-) 0.089	(-) 0.380	(+) 0.172	(-) 0.185	(-) 0.001	(-) 0.365
G	(-) 0.350	(-) 0.321	(+) 0.175	(+) 0.207	(-) 0.119	(-) 0.303	(+) 0.227	(-) 0.235	(-) 0.049	(-) 0.230

EP-I

	1	2	3	4	5	6	7	8	9	10
A	(-) 0.079	(-) 0.027	(+) 0.152	(+) 0.046	(+) 0.244	(-)* 0.507	(+) 0.111	(-) 0.271	(+) 0.343	(-) 0.345
B	(-) 0.106	(-) 0.147	(+) 0.121	(-) 0.202	(+) 0.104	(-) 0.374	(+) 0.297	(+) 0.285	(-) 0.266	(-) 0.439
C	(-) 0.185	(-) 0.204	(-) 0.303	(+) 0.353	(+)** 0.624	(-) 0.416	(-) 0.223	(+) 0.002	(+) 0.022	(-) 0.142
D	(+)** 0.589	(+)** 0.602	(+) 0.086	(+) 0.453	(+) 0.344	(+) 0.180	(-) 0.102	(+)** 0.662	(-) 0.256	(+) 0.354
E	(+) 0.143	(+) 0.133	(-) 0.216	(+)* 0.535	(+)** 0.711	(-) 0.266	(-) 0.244	(+) 0.400	(-) 0.112	(+) 0.059
F	(-) 0.138	(-) 0.098	(-) 0.369	(+)* 0.563	(+) 0.081	(+) 0.040	(+) 0.089	(-) 0.148	(-) 0.047	(+)* 0.556
G	(-) 0.198	(-) 0.171	(-) 0.330	(+)* 0.488	(+) 0.032	(+) 0.056	(+) 0.007	(-) 0.189	(-) 0.094	(+)* 0.476

**=P>0.01
*=P>0.05

EP-2

	1	2	3	4	5	6	7	8	9	10
A	(+) 0.096	(+) 0.077	(-) 0.140	(-) 0.110	(-) 0.222	(+) 0.125	(-) 0.313	(+) 0.016	(+) 0.096	(+) 0.093
B	(+) 0.078	(+) 0.036	(-) 0.133	(-) 0.304	(-) 0.353	(+) 0.027	(-) 0.261	(-) 0.014	(-) 0.121	(+) 0.182
C	(-) 0.116	(-) 0.130	(-) 0.274	(-) 0.074	(+) 0.047	(+)* 0.518	(-) 0.345	(-) 0.019	(-) 0.205	(-) 0.058
D	(+) 0.064	(+)** 0.508	(-) 0.410	(-) 0.031	(-) 0.072	(+) 0.385	(-) 0.140	(+) 0.060	(-) 0.138	(+) 0.186
E	(-) 0.108	(-) 0.129	(-) 0.286	(-) 0.073	(+) 0.048	(+)* 0.520	(-) 0.339	(-) 0.015	(-) 0.285	(-) 0.046
F	(+) 0.114	(-) 0.095	(+) 0.086	(+)* 0.522	(+) 0.377	(+) 0.076	(+) 0.161	(+) 0.333	(+) 0.305	(-) 0.281
G	(-) 0.196	(-) 0.103	(+) 0.136	(+)* 0.476	(+) 0.346	(+) 0.031	(+) 0.219	(+) 0.282	(+) 0.248	(-) 0.255

EP-3

	1	2	3	4	5	6	7	8	9	10
A	(-) 0.156	(-) 0.161	(-) 0.226	(-)* 0.467	(-) 0.294	(-) 0.301	(+) 0.365	(-) 0.300	(+) 0.094	(-) 0.279
B	(-) 0.199	(-) 0.327	(-) 0.011	(-)** 0.624	(-) 0.087	(-) 0.217	(+) 0.102	(-) 0.087	(-) 0.239	(-) 0.373
C	(+) 0.108	(+) 0.138	(-) 0.251	(+) 0.163	(-) 0.240	(+) 0.061	(+) 0.024	(-) 0.263	(-) 0.158	(+) 0.367
D	(-) 0.055	(+) 0.058	(-) 0.175	(+) 0.180	(+) 0.071	(+) 0.069	(+) 0.275	(-) 0.077	(-) 0.092	(+) 0.273
E	(-) 0.309	(-) 0.192	(-) 0.286	(-) 0.120	(-) 0.446	(-) 0.150	(+) 0.363	(-) 0.344	(-) 0.094	(+) 0.089
F	(-) 0.118	(-) 0.083	(-)* 0.535	(+) 0.342	(-) 0.211	(-) 0.137	(+) 0.298	(+) 0.085	(+) 0.123	(+) 0.063
G	(-) 0.301	(-) 0.290	(-)* 0.524	(+) 0.172	(-) 0.276	(-) 0.213	(+) 0.455	(+) 0.086	(+) 0.072	(-) 0.071

TABLE-XXIV

Correlation table showing the correlation coefficients, among the primary productivity and biological parameters for the Control and Experimental Fish Ponds.

A - Gross primary productivity	1 - Net primary productivity
B - Net primary productivity	2 - Total phytoplankton
C - Total phytoplankton	3 - Total zooplankton
D - Total zooplankton	4 - Total plankton
E - Total plankton	5 - Mean length (fish growth)
F - Mean length (fish growth)	6 - Mean weight (fish growth)

EP - Experimental Fish Ponds.

TABLE-XXIV

CONTROL POND

	1	2	3	4	5	6
A	(+)** 0.664	(+) 0.404	(+)** 0.785	(+) 0.238	(+) 0.070	(+) 0.214
B		(+) 0.259	(-) 0.179	(-) 0.044	(-) 0.113	(+) 0.119
C			(+) 0.122	(+)* 0.527	(-)* 0.489	(-) 0.383
D				(+)** 0.907	(-) 0.182	(-) 0.206
E					(-) 0.363	(-) 0.338
F						(+)** 0.947

EP-1

	1	2	3	4	5	6
A	(+)* 0.519	(+) 0.364	(-) 0.215	(+) 0.202	(-) 0.218	(-) 0.228
B		(+) 0.296	(-) 0.122	(+) 0.192	(-) 0.450	(-) 0.450
C			(+) 0.001	(+)** 0.859	(+) 0.099	(+) 0.131
D				(+)* 0.512	(-) 0.050	(-) 0.122
E					(+) 0.059	(+) 0.050
F						(+)** 0.978

EP-2

	1	2	3	4	5	6
A	(+)** 0.860	(+) 0.407	(+)* 0.534	(+) 0.412	(-) 0.151	(-) 0.185
B		(+) 0.427	(+) 0.456	(+) 0.428	(-)* 0.518	(-)* 0.509
C			(+)** 0.681	(+)** 0.999	(-) 0.337	(-) 0.371
D				(+)** 0.698	(-) 0.354	(-) 0.385
E					(-) 0.347	(-) 0.382
F						(+)** 0.988

EP-3

	1	2	3	4	5	6
A	(+)* 0.517	(-) 0.098	(+) 0.349	(-) 0.035	(-) 0.035	(+) 0.027
B		(-) 0.252	(-) 0.053	(-) 0.246	(-) 0.412	(-) 0.262
C			(+) 0.298	(+)** 0.987	(+) 0.119	(+) 0.152
D				(+) 0.443	(+) 0.144	(+) 0.174
E					(+) 0.135	(+) 0.172
F						(+)** 0.963

TABLE-XXV

Correlation table showing the correlation coefficients among the physico-chemical and primary productivity and biota undertaken for the Control pool.

A- Gross primary productivity	1 - Air temperature
B- Net primary productivity	2 - Water temperature
C- Total phytoplankton	3 - pH
D- Total zooplankton	4 - Conductivity
E- Total plankton	5 - Total alkalinity
F - Mean length (fish growth)	6 - Carbon-dioxide
G - Mean weight (fish growth)	7 - Oxygen
	8 - Silicate
	9 - Phosphate
	10 - Nitrate

TABLE-XXV

CONTROL POOL

	1	2	3	4	5	6	7	8	9	10
A	(-) 0.269	(-) 0.323	(-) 0.140	(+) 0.045	(-) 0.025	(-) 0.143	(+) 0.400	(-) 0.018	(-) 0.220	(-) 0.232
B	(-)* 0.491	(-)* 0.477	(-) 0.245	(+) 0.249	(+) 0.178	(+) 0.008	(+) 0.061	(-) 0.061	(-) 0.115	(-) 0.063
C	(+)** 0.624	(+)* 0.570	(-) 0.362	(+) 0.008	(+) 0.292	(+) 0.243	(-) 0.371	(-) 0.273	(-) 0.083	(-) 0.011
D	(+)* 0.536	(+)* 0.519	(-) 0.133	(+) 0.088	(-) 0.001	(+) 0.185	(-) 0.120	(-) 0.234	(-) 0.142	(+) 0.063
E	(+)** 0.669	(+)** 0.616	(-) 0.356	(+) 0.023	(+) 0.269	(+) 0.256	(-) 0.362	(-) 0.291	(-) 0.101	(+) 0.001
F	(-) 0.178	(-) 0.276	(+) 0.201	(-) 0.161	(-) 0.296	(-) 0.430	(+) 0.219	(-) 0.424	(+) 0.050	(-) 0.043
G	(-) 0.240	(-) 0.334	(+) 0.271	(-) 0.143	(-) 0.262	(-) 0.458	(+) 0.419	(-) 0.371	(-) 0.056	(-) 0.153

TABLE-XXV Contd.

Correlation table showing the correlation coefficients among the physico-chemical and primary productivity and biota undertaken for the Circular Plastic Pools.

A	- Gross primary productivity	1	- Air temperature
B	- Net primary productivity	2	- Water temperature
C	- Total phytoplankton	3	- pH
D	- Total zooplankton	4	- Conductivity
E	- Total plankton	5	- Total alkalinity
F	- Mean length (fish growth)	6	- Carbon-dioxide
G	- Mean weight (fish growth)	7	- Oxygen
		8	- Silicate
		9	- Phosphate
		10	- Nitrate

CP = Circular Plastic Pools.

TABLE-XXV (Contd.)

CP=1

	1	2	3	4	5	6	7	8	9	10
A	(-) 0.297	(-) 0.303	(-) 0.201	(+) 0.096	(+) 0.317	(+) 0.087	(+) 0.193	(+) 0.278	(+) 0.250	(+) 0.141
B	(+) 0.020	(+) 0.056	(+) 0.073	(+) 0.052	(+) 0.291	(+)** 0.682	(-) 0.071	(+) 0.436	(+) 0.395	(+) 0.270
C	(+) 0.102	(-) 0.149	(-) 0.053	(-) 0.205	(+) 0.353	(-) 0.301	(+) 0.230	(-) 0.339	(-) 0.096	(-) 0.458
D	(+) 0.093	(+) 0.054	(-) 0.198	(+) 0.197	(+) 0.057	(-) 0.261	(+) 0.147	(-) 0.218	(+) 0.281	(-) 0.234
E	(-) 0.070	(-) 0.100	(-) 0.097	(-) 0.140	(+) 0.337	(-) 0.391	(+) 0.246	(-) 0.363	(+) 0.020	(-)* 0.477
F	(-) 0.256	(+) 0.334	(+) 0.173	(+) 0.063	(-) 0.320	(-) 0.120	(-) 0.296	(-) 0.228	(+) 0.199	(-) 0.161
G	(-) 0.296	(-) 0.365	(+) 0.275	(-) 0.018	(-) 0.431	(-) 0.085	(-) 0.404	(-) 0.257	(+) 0.208	(-) 0.274

CP=2

	1	2	3	4	5	6	7	8	9	10
A	(-) 0.340	(-) 0.363	(-) 0.035	(-) 0.029	(+) 0.024	(-) 0.453	(+) 0.207	(-) 0.317	(+) 0.026	(-) 0.083
B	(-)* 0.497	(-) 0.424	(-) 0.078	(-) 0.187	(-) 0.175	(-) 0.127	(+) 0.207	(-) 0.104	(-) 0.340	(+)** 0.598
C	(+) 0.203	(+) 0.132	(-) 0.252	(-) 0.101	(+)* 0.538	(+) 0.040	(+) 0.077	(+) 0.242	(+) 0.334	(+) 0.263
D	(+) 0.094	(+) 0.245	(-) 0.279	(-) 0.424	(-) 0.031	(+) 0.143	(-) 0.280	(-) 0.030	(+) 0.227	(+) 0.244
E	(+) 0.212	(+) 0.146	(-) 0.265	(-) 0.129	(+)* 0.521	(+) 0.049	(+) 0.060	(+) 0.233	(+) 0.341	(+) 0.273
F	(-) 0.086	(-) 0.260	(-)* 0.474	(+) 0.322	(-) 0.361	(+) 0.337	(-)** 0.595	(+) 0.065	(+) 0.280	(+) 0.105
G	(-) 0.277	(-) 0.416	(-) 0.346	(+) 0.130	(-) 0.454	(+) 0.313	(-)* 0.541	(+) 0.092	(+) 0.109	(+)* 0.570

CP=3

	1	2	3	4	5	6	7	8	9	10
A	(-) 0.198	(-) 0.177	(+) 0.066	(+) 0.195	(+) 0.382	(-) 0.034	(-) 0.014	(+) 0.078	(-) 0.253	(+) 0.175
B	(+) 0.186	(+) 0.179	(+) 0.185	(-) 0.068	(+) 0.292	(+) 0.200	(+) 0.071	(-) 0.085	(-) 0.282	(-) 0.220
C	(+) 0.280	(+) 0.256	(-) 0.230	(+) 0.075	(+) 0.018	(+) 0.215	(+) 0.271	(-) 0.214	(+)* 0.522	(+)** 0.620
D	(+)* 0.529	(+)* 0.515	(-)* 0.516	(-) 0.075	(-) 0.165	(+) 0.196	(-) 0.381	(-)* 0.515	(+) 0.124	(+) 0.317
E	(+) 0.299	(+) 0.275	(-) 0.249	(+) 0.071	(+) 0.011	(+) 0.221	(+) 0.253	(-) 0.233	(+)* 0.522	(+)** 0.627
F	(-) 0.206	(-) 0.286	(-) 0.217	(-) 0.213	(-)* 0.500	(+) 0.070	(-) 0.324	(+) 0.108	(-) 0.136	(-) 0.324
G	(-) 0.295	(-) 0.369	(-) 0.161	(-) 0.224	(-) 0.465	(+) 0.036	(-) 0.271	(+) 0.150	(-) 0.179	(-) 0.343

CP=4

	1	2	3	4	5	6	7	8	9	10
A	(-) 0.424	(-) 0.420	(+) 0.055	(+)** 0.619	(+) 0.198	(-) 0.280	(-) 0.317	(-) 0.013	(-) 0.041	(+) 0.067
B	(-)* 0.491	(-)* 0.471	(+) 0.131	(+)** 0.684	(+) 0.088	(-) 0.273	(-) 0.155	(-) 0.154	(-) 0.308	(-) 0.131
C	(+) 0.112	(+) 0.102	(+) 0.197	(+) 0.209	(+)** 0.671	(+) 0.419	(+) 0.280	(+)** 0.732	(+)** 0.652	(+)** 0.920
D	(-) 0.150	(-) 0.125	(-) 0.131	(+) 0.364	(+) 0.198	(-) 0.125	(+) 0.142	(-) 0.048	(-) 0.158	(+) 0.291
E	(+) 0.110	(+) 0.101	(+) 0.195	(+) 0.213	(+)** 0.672	(+) 0.417	(+) 0.281	(+)** 0.729	(+)** 0.649	(+)** 0.923
F	(+) 0.011	(-) 0.073	(-) 0.323	(-) 0.091	(-) 0.114	(+) 0.244	(-)** 0.684	(+) 0.143	(+) 0.195	(+) 0.034
G	(-) 0.269	(-) 0.337	(-) 0.201	(-) 0.167	(-) 0.216	(+) 0.229	(-)** 0.591	(+) 0.104	(+) 0.047	(-) 0.047

TABLE-XXVI

Correlation table showing the correlation coefficients among the primary productivity and biological parameters undertaken for the Control and Circular Plastic Pools.

A - Gross primary productivity	1 - Net primary productivity
B - Net primary productivity	2 - Total phytoplankton
C - Total phytoplankton	3 - Total zooplankton
D - Total zooplankton	4 - Total plankton
E - Total plankton	5 - Mean length (fish growth)
F - Mean length (fish growth)	6 - Mean weight (fish growth)

CP = Circular Plastic Pools.

TABLE-XXVI

CONTROL POOL

	1	2	3	4	5	6
A	(+)** 0.675	(+) 0.009	(-) 0.056	(+) 0.002	(+) 0.035	(+) 0.148
B		(-) 0.248	(-) 0.318	(-) 0.283	(+) 0.121	(+) 0.170
C			(+) 0.372	(+)** 0.986	(-) 0.131	(-) 0.172
D				(+)* 0.519	(-) 0.005	(-) 0.046
E					(-) 0.122	(-) 0.166
F						(+)** 0.945

CP-1

	1	2	3	4	5	6
A	(+) 0.455	(+) 0.135	(-) 0.364	(+) 0.036	(-) 0.139	(-) 0.163
B		(-) 0.211	(-) 0.261	(-) 0.258	(-) 0.325	(-) 0.342
C			(+) 0.227	(+)** 0.972	(+) 0.015	(+) 0.006
D				(+) 0.446	(+) 0.284	(+) 0.249
E					(+) 0.089	(+) 0.071
F						(+)** 0.968

CP-2

	1	2	3	4	5	6
A	(+)** 0.726	(+) 0.191	(-) 0.093	(+) 0.179	(+) 0.083	(+) 0.131
B		(+) 0.028	(+) 0.067	(+) 0.032	(+) 0.249	(+) 0.334
C			(+) 0.349	(+)** 0.997	(+) 0.138	(+) 0.086
D				(+) 0.411	(+) 0.263	(+) 0.280
E					(+) 0.153	(+) 0.103
F						(+)** 0.954

CP-3

	1	2	3	4	5	6
A	(+) 0.262	(-) 0.051	(-) 0.128	(-) 0.053	(-) 0.450	(-) 0.444
B		(-) 0.376	(-) 0.130	(-) 0.269	(-) 0.282	(-) 0.294
C			(+) 0.239	(+)** 0.990	(-) 0.178	(-) 0.203
D				(+) 0.246	(+) 0.142	(+) 0.095
E					(-) 0.157	(-) 0.179
F						(+)** 0.989

CP-4

	1	2	3	4	5	6
A	(+)** 0.605	(+) 0.090	(+) 0.281	(+) 0.088	(+) 0.110	(+) 0.072
B		(-) 0.184	(+) 0.400	(-) 0.183	(-) 0.092	(-) 0.022
C			(+) 0.173	(+)** 0.999	(-) 0.164	(-) 0.233
D				(+) 0.180	(-) 0.210	(-) 0.171
E					(-) 0.161	(-) 0.229
F						(+)** 0.918

In Experimental Fish Pond-1, gross primary productivity was negatively correlated with carbon-dioxide at P>0.05 level. Total alkalinity was correlated at very significant levels (P>0.01) positively with both total phytoplankton and total plankton. Similarly total zooplankton was related with air and water temperature, and silicate at P>0.01 levels. In this pond, conductivity was seen to be related to total plankton and mean length and nitrate with mean length and mean weight all positively at P>0.05 level.

In Experimental Fish Pond-2, net primary productivity with nitrate was highly significant and so also total zooplankton with air temperature, the latter as seen in Experimental Fish Pond-1. Further, oxygen with total phytoplankton and carbon-dioxide with total plankton was positively significant at P>0.05 levels and similarly conductivity with mean length and mean weight, and nitrate with mean weight.

Finally the Experimental Fish Pond-3 had very little correlation and was observed only between conductivity with both gross and net primary productivity which was positively significant at P>0.05 level, while pH was negative with mean length and mean weight of the fish at the same level of significance.

In addition to the correlation between the physico-chemical factors and the biota, phyto- and zooplankton, their totality, primary productivity both gross and net primary productivity and the growth of fish in terms of its length and weight were also analysed for correlation amongst themselves.

It was seen in all the Experimental Fish Ponds, mean length with mean weight of the fishes were highly positively correlated at P>0.01 level. Similarly gross primary productivity with net primary productivity was correlated except that in Experimental Fish Ponds-1 and 3, the level of significance was lower. High level of positive significance between total phytoplankton and total plankton were seen in all the ponds except in the control pond, where the level was at P>0.05. Similarly total zooplankton and total plankton was positively correlated in all the ponds except in pond-3. The level of significance observed in Experimental Fish Ponds-2 and control was at P>0.01, but at P>0.05 level in Experimental Fish Pond-1. In addition to the correlations, total zooplankton with gross primary productivity, in the control pond and total zooplankton with total phytoplankton in Experimental Fish Pond-2 were positively significant at P>0.01 level. Finally the control pond showed negative relationship at P>0.05 between total phytoplankton and mean length of the fish.

In the Circular Plastic Pools the correlation coefficient were similarly observed between gross and net primary productivity, physico-chemical parameters and the biota.

In the control pond the only statistical significance observed, was between air and water temperature both with net primary productivity negatively at P>0.05 and with total zooplankton positively at the same level. Similarly both air and water temperatures are highly significant positively with total plankton at P>0.01 level. The air temperature with phytoplankton was much more significant (P>0.01) than water temperature with total phytoplankton (P>0.05) both, however, positively. Therefore, generally the biota was positively significant both with atmospheric and water temperature but negatively with net primary productivity.

In Circular Plastic Pool-1, there were only two significant correlations. Net primary productivity with carbon-dioxide was highly and positively significant (P>0.01), while total plankton and nitrate was negatively significant at P>0.05 levels.

In Circular Plastic Pool-2, as in the control pond, net primary productivity with air temperature was negatively significant at P>0.05. Similar negative significances were observed between mean length and pH and mean weight with oxygen. Though mean length and oxygen also had a negative relationship the significance was at P>0.01 level. The others which were significant were positive at P>0.05 comprising of total phytoplankton with total alkalinity, total plankton with total alkalinity, mean weight both with nitrate and conductivity.

In Circular Plastic Pool-3 similar to the control pool, total zooplankton was significant with both air and water temperature positively at P>0.05. In this pool, both total phytoplankton and plankton were positively significant with phosphate at P>0.05 level while with nitrate at P>0.01 level. Total zooplankton with pH and silicate, and the mean length with total alkalinity were all negatively significant at P>0.05 level.

The last Circular Plastic Pool-4, like the control pool showed a negative correlation between net primary productivity with both air and water temperature. This pool showed a relationship between conductivity and both gross and net primary productivity positively at highly significant levels (P>0.01). Further, in this pool, all the three nutrients analysed, silicate, phosphate, nitrate and alkalinity were all seen to be significantly correlated to both total phytoplankton and total plankton at P>0.01 level. Finally, both the mean length and mean weight were negatively correlated with oxygen at P 0.01 level. In addition to the significances of the nutrients, total phytoplankton and total plankton was similar to pool-3, except that in the latter only phosphate and nitrate were found to be correlated, and in pool-2 to alkalinity though the significance was lower. In contrast, pool-1 showed a negative relationship between total plankton and nitrate.

When the correlation among the biotic factors were seen, it was observed that in all the pools the mean length with mean weight of the fish, and total phytoplankton with total plankton were seen to be positively significant at P>0.01 level. Similarly a correlation existed between gross and net primary productivity in all the Circular Plastic Pools except in pools-1 and 3. In addition, in the control pool, total zooplankton and plankton were significantly related at P>0.05 level positively.

These various correlation coefficient when observed, it was generally seen that irrespective of fertilization in all the ponds and pools, the mean length and mean weight of fish was significant, in that no effect played on their growth rates between these systems. In addition, it was the total phytoplankton and productivity which revealed some relationship as these correlation showed that total plankton was significantly correlated with total phytoplankton and therefore gross primary productivity and net primary productivity. It was only in Experimental Fish Ponds-1 and 2 and control Circular Plastic Pool, that total zooplankton was related in such a manner. Among the nutrients only Circular Plastic Pools-3 and 4 affected to a large extent the total phytoplankton. However, in Experimental Fish Ponds-1 and 2 and Circular Plastic Pool-2, nitrate was seen to effect the mean weight of the fishes.

It is known that plankton biomass is higher in fertilized than unfertilized systems (Manning and Juday, 1941; Gessner, 1949;

Edmonson, 1955; Ryther and Yentsch, 1958) and as observed in the present investigation where photosynthesis was related to the production figures but significant levels were not obtained as would be expected in ponds or pools receiving larger amount of fertilizers. Light penetration could be one factor which is inversely related to plankton standing crop and therefore photosynthesis, leading to a loss of net production.

Another observation seen in the present study was a relationship of total alkalinity to total phytoplankton as in Circular Plastic Pool-2 and Experimental Fish Pond-1. This total alkalinity again in pond-1 and pool-3 was correlated in two different ways, in the former positive, while in the latter negative. The reason could be attributed to that of photosynthesis mentioned above, which is known to convert bicarbonates to carbonates and the result of settling of the latter, indicated by a decrease in alkalinity. Therefore, a strong stratification of bicarbonate is indicative of high photosynthetic rates in any biotope. Further, when the bicarbonate alkalinity is high and the trophogenic zone is productive, a relatively small lowering of pH occurs resulting in well buffered waters (Hutchinson, 1957) as seen in most of the present systems. This may be true probably to a larger extent in Experimental Fish Pond-1 and Circular Plastic Pool-2. In addition, as the temperature of the water rises, its capacity to dissolve carbon-dioxide decreases and part of the free carbon-dioxide is given off. Therefore, the equilibrium of the carbonate-bicarbonate system is dependent to a large extent in the carbon-dioxide tension in the water. Lowering of this tension is known to cause transfer of bicarbonate to carbonate part of which may be precipitated (Pia, 1933). A continuous process going on in this fashion could probably be a result of the equilibrium state of pH. The main reasons probably for higher production in the more intensely fertilized ponds and pools could be the result of higher amount of nutrients that comes directly or indirectly and in addition from unutilized food and fish excrement. All this enables the possibilities of a constant supply of rich carbon-dioxide to water by active fish respiration. This abundant supply of carbon-dioxide could effect the ponds and pools ecology by keeping the pH constant and especially during noon time, indicating that in intensely manured ponds and pools, food utilization becomes less efficient beyond certain optimal levels (Swingle, 1947; Kuentzel, 1969; Boyd, 1973; Rappaport and Sarig, 1975, 1979).

Even average higher temperatures are to some degree more favourable to photosynthesis. The limitation on primary production that are imposed by nutrients would often render temperature effect unimportant in greatly changing natural production. In the present investigation the productivity patterns dominated by the regular enrichment, probably shortens the time required for nutrient depletion in relation to photosynthetic rate. Therefore, the differences in mean temperature could effect largely the metabolic processes that govern nutrient cycling than on photosynthesis itself.

The role of nutrients and especially those that were undertaken for the present investigation was seen to play very little role except with nitrate to the growth of the fishes and even as a limiting factor for phytoplankton, but with the only exception in Pools-3 and 4 where positive significant correlations existed. In case of phosphate, again the significance was among these two pools and to some extent in the control pond. It is seen that fertilization has definitely a higher percentage of phytoplankton densities (Hepher, 1963; Dobbins and Boyd, 1976) and therefore in case of phosphorus, an appreciable amount of this nutrient when added could be initially absorbed by the plankton community in a few hours. Hence, its utility is made available only when the plankton dies, which in a natural system usually gets locked up in the sediments. However, very little attributes could be assigned to the role of its limitation in nature in the systems studied. As consumers of particulate phosphorus, fishes probably contribute to remineralization in a manner similar to the positive feed back of zooplankton grazing on algae. Since fishes also prey on benthic and littoral organisms, the low but relatively constant level of phosphorus excreted may act to stabilise planktonic cycle which might otherwise exhaust available phosphorus and depend directly on remineralization through decomposition of allochthonous sources as in the present investigation, in addition to sedimentary generation as in the fish ponds. This, therefore, leads to a realization that nutrient concentration at the usual half uptake maximal rates do not necessarily reflect the growth capabilities of the biota and in particular phytoplankton (Caperon, 1972; Fuhs et.al. 1972; Rhee, 1973; Chisholm, 1974; Eppley and Renger, 1974). This is primarily due to the well documented hyperbolic relationship between growth and the intracellular concentration of nutrients in a wide variety of autotrophic species, and the recognition that algal growth rates are regulated more by intracellular reservoirs and only indirectly by external nutrient concentrations (Caperon, 1968; Drup, 1968).

Though, these were the intricate relationships between the abiotic and biotic factors and especially the autotrophs and invertebrates fauna, of which the latter seemed to play little effect on the growth of the vertebrate biota namely, fish. An ordinarily observed phenomena in the present investigation was the existence of a steady linear growth of the fishes which did not simultaneously synchronise with the other factors undertaken. This probably reflects that the fluctuating trend of seasonality in an aquatic system to a large extent has probably to be correlated with much shorter time intervals of fish growth. Such would indicate the causative factor or factors responsible for the sudden spurt in growth rate as observed in the weight of the fishes in most of the ponds. Further, such factorial relationships may not reveal a true picture to the intricate energy conversion values which decides the growth of a herbivore or carnivore.

It was, therefore, felt necessary to observe if there existed a relationship in conversion of autotrophic production to fish flesh and, if so, whether effected by differential fertilization. In the present investigation this could only be calculated for the ponds as pools had higher stocking densities of fish showing very high productivity figures. Table-XXVII reveals such a phenomena. A perusal of this shows that in the control pond the conversions (1-3%) were very near to the figures as indicated by Odum (1960) in natural system, where 1-2% is regarded as high yields. It therefore, seems that even under natural conditions without any inputs, if the stocking rate is optimum as in the present investigation, fish could convert autotrophic production for high yields in a region like Nagaland. However, in observing the conversion values of the fertilized ponds it was seen that Experimental Fish Pond-2 showed 6585.0 kg/ha/18 months that was higher than pond-1 (5005 kg/ha/18 months) (Table-XXI), yet in both the ponds the conversions were more or less the same. The conversion percent in Experimental Fish Ponds-1 and 2 was 4.6 to 7.6% and 4.3 to 7.1% respectively. Pond-3 had however the lowest conversion (3.3 to 6.0%) though higher than the control (1.8 to 3.0 %). Therefore, it is safe to say that a combination of fertilizers

TABLE-XXVII

Showing the percent conversion (autotrophic) of Gross and Net primary productivity to fish production for the Control and Experimental fish ponds.

EP = Experimental Fish Ponds.

TABLE-XXXII

	PRIMARY PRODUCTION				Fish Production Av. $g/m^2/day$	GPP:GFP	NPP:GFP	PERCENT OF	
	GPP Average $g^C/m^3/day$	GPP Converted algal wt.	NPP $g^C/m^3/day$	NPP Converted algal wt.				GPP	NPP
CONTROL POND	2.0	13.0 to 22.0	1.0	7.0 to 11.0	0.39	1:0.18 to 0.03	1:0.035 to 0.056	1.8 to 3.0	3.5 to 5.6
EP-1	1.85	12.0 to 20.0	0.77	5.0 to 9.0	0.91	1:0.46 to 0.076	1:0.101 to 0.182	4.6 to 7.6	10.1 to 18.2
EP-2	2.5	17.0 to 28.0	1.2	8.0 to 13.0	1.2	1:0.043 to 0.071	1:0.092 to 0.15	4.3 to 7.1	9.2 to 15.0
EP-3	1.75	12.0 to 19.0	0.7	5.0 to 8.0	0.72	1:0.038 to 0.06	1:0.09 to 0.144	3.8 to 6.0	9.0 to 14.4

both inorganic and organic is better than the individual fertilization (organic manuring only). However, looking back on the survival rates it seems that if a constant maintenance of a higher rate of survival is there, the single fertilizer as used in pond-3 would also very nearly equal those which were fertilized both organically and inorganically along with supplementary feeding. This indicates that a detailed study is needed to look into the intricate mechanisms of fish which from our present knowledge could be attributed, in the organic manured pond, to higher removal of oxygen by anaerobiosis which comes into play on addition of organic manure. In the present investigation it helps us to indicate the lower levels of organic manuring at larger space time intervals which might inhibit the mortality figures of fish. Whatever the case may be, in the present study, fertilization of ponds and pools resulted in higher phytoplankton productivity (Hepher, 196^) and subsequent increase in fish production/hectare (Smith and Swingle, 1938; Swingle and Smith, 1947; Hall et.al., 1970). Henderson et.al., (1970) has also suggested that fish yield may increase as a power function of primary productivity. Sreenivasan (1964a) has also found that fish production in tropical ponds was higher with the highest level of primary productivity. In the present investigation the gross photosynthesis measurements appear to be the most practical indices on which to base such fishing potential. The generality that fish yield may be predicted from gross photosynthesis has been adequately established. Goodyear et.al., (1972) demonstrated that the yield of mosquito fish (Gambusia affinis) and gross photosynthesis were closely correlated. Wolny and Grygierek (1972) showed the same for young carp Cyprinus carpio. Mellack (1976) in the analysis of data of Sreenivasan's (1972) found a convincing correlation for fish yield and gross photosynthesis in a series of tropical fish ponds.

The percent conversion of gross primary productivity to fish yield is better understood as a logarithmic increase in fish yield for every arithmetic increase in primary productivity. This implies that percent conversion increases, as primary productivity increases. This is very well seen in the present investigation.

In the recent review of the relationship between fish yield and primary production, Oglesby (1977), Mellack (1976) have concluded that annual production is theoretically and empirically a better predictor of fish yield from aquatic bodies than other suggested relationships between yield and environmental variables.

It was left now to understand after the present investigation the economics of the study and its application for immediate use in at least the region under consideration. Tables-XXVIII and XXIX, gives a broad understanding of a balance sheet and economic feasibility of this study for recommendation to local fish farmers as would be expected. Experimental Fish Pond-2 and Circular Plastic Pool-4 were the most profitable systems seen. Surprisingly enough, these two systems had the maximum inputs of expenditure in contrast to the other ponds and pools as both organic and inorganic fertilizers were applied in addition to supplementary feeding. The addition of NPK alone and supplementary feeding as in pool-3 showed a very unprifitable venture where the net profit was even lower than the control pool. In the ponds, there were very little differences between the organic fertilized ones and organic and inorganic fertilized ponds. In any case such data not being available for Nagaland, reveals aquaculture in freshwater systems is highly a profitable venture and could even be started with as low an expenditure of Rs.1000/- to Rs. 3000/- with an anticipated return of more than ten times the investment.

TABLE-XXVIII

An income-expenditure statements of accounts showing the economics of fish yield in the different Experimental Fish Ponds.

EP = Experimental fish Ponds.

TABLE-XXIX

An income-expenditure statements of accounts showing the economics of fish yields in the different Circular Plastic Pools.

CP = Circular Plastic Pools.

TABLE-XXVIII

	CONTROL POND	EP-1	EP-2	EP-3
GROSS PRODUCTION kg/ha/yr	1,410.00	3,370.00	4,390.00	2,633.00
ECONOMICS : CALCULATED/HECTARE				
1. INCOME @ Rs.10/-kg.	Rs.14,100.00	Rs.33,370.00	Rs.43,900.00	Rs.26,330.00
2. EXPENDITURE				
a) Pond preparations	Rs. 100.00	Rs. 100.00	Rs. 100.00	Rs. 100.00
b) Fingerlings @ Rs.95/-1000 Nos.	Rs. 950.00	Rs. 950.00	Rs. 950.00	Rs. 950.00
c) Fertilizer Cowdung @ Rs.0.50/20 kgs.	Rs. -	Rs. 667.00	Rs. 642.00	Rs. 642.00
d) NPK (10:8:4) @ Rs.0.70/kg	Rs. -	Rs. 621.00	Rs. 559.00	Rs. -
e) Cost of artificial feed Ricebran @ Rs.0.80/kg	Rs. -	Rs. -	Rs. 817.60	Rs. -
f) Labour charges	Rs. 180.00	Rs. 180.00	Rs. 180.00	Rs. 180.00
TOTAL :	Rs. 1,230.00	Rs. 2,518.00	Rs. 3,248.00	Rs. 1,872.00
3. NET PROFIT	Rs.12,870.00	Rs.30,852.00	Rs.40,652.00	Rs.24,458.00

TABLE-XXIX

	CONTROL POOL	CP-1	CP-2	CP-3	CP-4
GROSS PRODUCTION/ POOL (kg)	2.04	3.68	4.35	2.24	4.83
ECONOMICS : CALCULATED/POOL					
1. INCOME @ Rs.10/-kg	Rs. 20.40	Rs. 36.80	Rs. 43.50	Rs. 22.40	Rs.48.30
2. EXPENDITURE					
a) Fingerlings @ Rs.95/-/1000	Rs. 1.90	Rs. 1.90	Rs. 2.85	Rs. 1.90	Rs. 2.85
b) Fertilizers Cowdung @ Rs.0.50/20 kgs.	Rs. -	Rs. -	Rs. 0.25	Rs. -	Rs. 0.25
c) NPK (10:8:4) @ Rs.0.70/kg	Rs. -	Rs. -	Rs. -	Rs. 3.78	Rs. 3.78
d) Cost of artificial feed Ricebran @ Rs.0.80/kg.	Rs. -	Rs. 5.94	Rs. 9.34	Rs. 4.78	Rs.10.00
TOTAL :	Rs. 1.90	Rs. 7.84	Rs. 12.44	Rs. 10.46	Rs.16.88
3. NET PROFIT	Rs. 18.51	Rs. 28.96	Rs. 31.98	Rs. 11.94	Rs.31.42

The present study though, has tried to understand the academic prespective in such ventures it is gratifying to note that an extension to the fish farmers would have profitable returns. This is all the more so in a region like the state of Nagaland which has very little resource of its own and has to depend to a large extent on import of the necessary food for daily consumption.

The recommendation of this study will be interpreted in the local languages and propagated to one and all in the region which comprise of the largest composition of tribal sub-sects.

RECOMMENDATIONS

1. Stocking ponds constructed should be in the range of 140 m^2 to 300 m^2.
2. For low altitude like Dimapur a stocking density of 10,000 fingerlings/hectare is optimum.
3. Supplementary feeding around 1,000 kg/ha/yr given at 1% body weight daily is essential.
4. Organic fertilization alone at the rate of 25,000 kg/ha/yr and above, can be given in smaller quantities administered over larger spaced time intervals.
5. Inorganic fertilizers NPK (18:8:4) at the rate of approximately 900 kg/ha/yr may or may not be administered.
6. The spawn to fry or even fingerling stages could be easily stocked in plastic pools with the above management recommended for ponds and utilized as and when required for stocking ponds.
7. Preferably such pools can be maintained only with organic fertilizers with supplementary feeding.

REFERENCES

Boyd, C.E. 1972 Sources of CO_2 for nuisance blooms of algae. Weed. Sci. 20:492-497.

Caperon, J.C. 1968 Population growth responses of *Isochrysis galbana*. Ecology 49:866-872.

________ 1972 Nitrogen limited growth of marine phytoplankton. I. Changes in population characteristics with steady state growth rate. Deep-Sea Res., 19:601-618.

Chisholm, S.W. 1974 Studies on daily rhythms of phosphate uptake in *Euglena* and their potential ecological significance. Ph.D. Thesis, State University of New York at Albany, 106 pp.

Dobbins, D.A. & C.E. Boyd 1976 Phosphorus and potassium fertilization of sun fish ponds. Trans. Am. Fish. Soc. 105:536-540.

Donald, J. Hall, William E. Cooper & Earl E. Werner 1979 An experimental approach to the production dynamics and structure of freshwater animal communities. Limnol. Oceanogr. 15:839-928.

Droop, M.R. 1968 Vitamin B_{12} and marine ecology. 4. The kinetics of uptake, growth and inhibition of *Monochrysis lutheri*. J. Mar. Biol. Assoc. U.K. 48:689-733.

Edmondson, W.T. 1955 Factors affecting productivity in fertilized salt water. Deep-Sea Res., 3:451-464.

Eppley, R.W. & E.H. Renger 1974 Nitrogen assimilation of an oceanic diatom in nitrogen limited continuous culture. J. Phycol., 10:15-23.

Fuhs, G.W., S.D. Demmerle, E. Canelli & M. Chen 1972 Characterization of phosphorus limited plankton algae (with reflections on the limiting nutrient concept). Limnol. Oceanogr., Spec. Sympos., 1:113-132.

Gessner, F. 1949 Der chlorophyllagehalt im Sie und seine photosynthetische. Valenz ab geophysikalisches problem Schweiz, Z. Hydrol., 11:378-410.

Goodyear, C.P., C.E. Boyd & R.J. Beyers 1972 Relationships between primary productivity and mosquito fish (*Gambusia affinis*) production in large microcosms. Limnol. Oceanogr. 17(3):445-450.

Hepher, B. 1962 Primary production in fish ponds and its application of fertilization experiments. Limnol. Oceanogr. 7(2):131-136.

Hepher, B. 1963 Ten years of research in fish ponds fertilization II. Fertilizer dose and frequency of fertilization. Limnol. Oceanogr., 15(4):78-92.

Henderson, F., R.A. Ryder & A.W.Kudhongonia 1973 Assessing fishery potentials of lakes and reservoirs. J. Fish. Res. Board. Can. 30: 2000-2009.

Hutchinson, G.E. 1957 A treatise on Limnology, Vol. I. Geography, physics and chemistry. John Wiley and Sons, Inc., New York, N.Y. 1015 p.

Kuentzel, L.E. 1969 Bacteria carbon-dioxide and algal blooms. J. Water Pollut. Control Fed., 41:1737-1747.

Manning, W.M. & R.E. Juday 1941 The Chlorophyll content and productivity of some lakes in Northeastern Wisconsin. Trans. Wisconsin Acad. Sci., Arts-Lett., 3:363-393.

Mellack, J.M. 1976 Primary productivity and fish yields in tropical lakes. Trans. Am. Fish. Soc., 105: 575-580.

Odum, E.P. 1960 The role of tidal marshes in estuarine production. N.Y. State conservationist information Leaflet L.60. 4p.

Oglesby, R.T. 1977 Relationships of the fish yield of Lake phytoplankton standing crop, production and morphoedaphic factors. J. Fish. Res. Bd. Can., 34:2271-2279.

Parker, J.I., H.L. Conway & E.M. Yaguchi 1977a Seasonal periodicity of diatoms and silicon limitation in offshore lake, Michigan, 1975. J. Fish. Res. Board. Can. 34:552-558.

Pia, J. 1933 Kohlensaure und Kalk. Die Binnengewasser, 13:vii + 183 pp.

Rappaport, U. & S. Sarig 1975 The results of tests in intensive growth of fish at the Ginosar (Israel) Station ponds in 1974. Bamidgeh, 27(3):75-82.

________ & ________ 1978 The results of manuring on intensive growth fish farming at the Ginosar Station ponds in 1977. Bamidgeh, 30:27-36.

Rhee, G-Yull. 1973 A continuous culture study of phosphate, uptake, growth rate and polyphosphate in Scenedesmus sp. J. Phycol., 9:445-506.

Ryther, J.H. & C.S. Yentsch 1958 Primary production of continental shelf waters off New York. Limnol. and Oceanogr., 3:327-335.

Sreenivasan, A. 1964b The limnology, primary production and fish production in a tropical pond. Limnol. Oceanogr. 9:391-396.

______ 1972 Energy transformations through primary productivity and fish production in some tropical freshwater impoundments and ponds. Pages 505-514 in Z. Kajak and A. Hillbricht Iikowska, eds. Productivity problems in freshwater. Polish Scientific Publishers, Warsaw.

Swingle, H.S. 1947 Experiments on pond fertilization. Alabama Polytech. Inst., Agr. Expt. sta., Bull. 264, 34 p.

______ & E.V. Smith 1938 Fertilizers for increasing the natural food for fish ponds. Trans. Am. Fish. Soc., 68: 126-135.

______ & ______ 1947 Management of farm fish ponds. Alabama, Polytech. Inst. Agr. Expt. Sta., Bull. 254, 30 p.

Wolny, P. & 1972 Intensification of fish ponds production. In: Z. Kajak and A. Hillbricht-Ilkoska (Editors). Productivity problems of freshwaters. PWN. Polish Scientific Publishers, Warsaw, 918 p.