ON THE MORTALITY OF CARP FRY IN NURSERY PONDS AND THE ROLE OF PLANKTON IN THEIR SURVIVAL AND GROWTH*

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I. Introduction

As in China, collection of millions of early fry of major carps from rivers and stocking them in nurseries for rearing is a common practice in India, particularly in Bengal, Bihar and Orissa. Different types of ponds, small or large, seasonal or perennial, shallow or deep, are used as nurseries; and different methods of preparation of the ponds are followed. There is, however, very little reliable information about these practices, most of which are known only to a few farmers who keep the information as family secrets handed down from generation to generation. On such important aspects like the density of stocking and percentage of survival, also, our information is meagre. Even the expert fish farmer is unable to ensure that his nursery pond will yield a satisfactory return every year. On the other hand, reports

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of total failure in certain nurseries managed by such fish farmers are not uncommon. Even in ponds where they claim ' good ' results there is reason to believe that the percentage of survival of fry might not be very high when it is remembered that stocking invariably is very heavy and that predators are not always scrupulously eradicated. Exceedingly high mortality of carp fry in nursery ponds was reported from Orissa. In 1948, out of approximately 29,78,300 carp fry stocked in 18 nursery ponds in Balasore District, covering an aggregate water surface area of 4·88 acres, only 2,80,100 early fingerlings were recovered, representing an average survival of only 9·4%, the range being 4·3–29·3 per cent. Mortality thus ranged from 70·7 to 95·7 per cent. In the Zobra fish farm, Cuttack, out of about 5,75,000 fry stocked in 9 nursery ponds in 1949, only about 7,500 fingerlings could be recovered, representing the extremely low survival of 1·3 per cent. The general conditions under which carp culture is carried out in Bengal have been briefly mentioned by Prashad (1919) according to whom the large majority of the tiny fry stocked in ponds are either preyed upon by predators or die owing to lack of food; the latter also causing stunted growth of the very few that survive. Conditions in other states of India, where tiny fry of carps are collected and stocked in ponds for rearing, are similar, the survival of fry being generally poor.

Rather heavy mortality of fish fry in the early stages of rearing has been reported from other countries also. Krumholz (1949) reported that not more than 40 per cent of the Bluegill yolk fry stocked in the spring survived the first summer: while by the end of the second summer as few as 1 per cent and not more than 20 per cent of the original stock remained. An average mortality of 50–60 per cent is generally experienced in rearing the fry of the large mouth black bass (*Huro salmoides*) to the fingerling stage (Smith and Swingle, 1943). In the cultivation of *Chanos* in the Philippines an estimated mortality of fry 70 per cent from the fry stage to marketable size and 10–40 per cent mortality of fry during the first 4 or 5 weeks in nursery ponds have been reported (Carbine, 1948). In Indonesia the average survival of *Chanos* fry in the tambaks is not more than 30 per cent, though some expert Chinese fish growers obtain a survival of 60–80 per cent by adopting special methods of rearing (Schuster, 1952). In the culture of common carp (*Cyprinus carpio*) in Indonesia a mortality of about 60 per cent of the fry stocked has been estimated (Hofstede, Ardiwinata and Botke, 1953). Though carp culture is prevalent in most of the South-east Asian countries very little published information is available regarding the rates of survival of fry in nursery ponds. Lin (1949) in his account of the fish fry industry of China does not give exact figures of the percentage of survival of carp fry but his statement "If only 5 per cent of the fry collected should survive and grow to attain an average weight of one catty each...." gives a clear idea of the state of affairs. Lin (1950) has, however, stated that the newly hatched fry of the common Chinese carps released in half hectare nursery ponds at the rate of about 4 millions survive only to the extent of 12–30 per cent during a period 2 weeks to a month.

This heavy loss of fish seed is, no doubt, of vital significance in successful fish culture, and elaboration of dependable methods for overcoming this loss will result in enhanced fish production and profit to the fish farmer besides appreciable savings in collection expenditure.

II. Existing Practices and Possible Causes of Mortality

The causes of mortality of carp fry in the nursery ponds are, no doubt, several and some of these possibly originate even at the time of collection from the river. The existing practices of collection, conditioning, transport, stocking and rearing of carp fry as followed by the departmental staff at Cuttack during the 1949–50 seasons were therefore studied critically, with particular reference to the Taldanda canal fry collection centre, so as to ascertain the possible sources of injury to and causes of mortality of the young fry during different stages of the operations. Over a score of factors were found to contribute to keep down the rate of survival of fry. Some of the important factors are listed below:—

(i) *During collection from natural habitats*:—

(*a*) *Obstruction in the flow of water caused by the fry net, particularly when the current is fast*.—It is generally observed that excessive mortality results in fry collected from quick flowing water.

(*b*) *Choking in the 'gamcha'* due to accumulation of debris and silt*.—Large quantities of debris are often washed down and caught in the net; these accumulating in the small 'gamcha', physically choke and injure the fry.

(*c*) *Long, irregular intervals at which fry are cleared from the 'gamcha' and the consequent overcrowding*.—When collection is heavy there will be considerable overcrowding in the 'gamcha' if the fry are not cleared regularly at short intervals. Choking due to accumulation of debris also will be enhanced under such conditions.

(*d*) *Defective methods of transfer of fry from the 'gamcha'*.—Usually water from the 'gamcha' is drained fully and the debris and fry are transferred *en masse* to a bucket of water. This is obviously injurious to the fry as several of them are likely to be crushed in between the debris when the water is drained.

* 'Gamcha' is the tail cloth of fry collection net.

(*e*) *Strain during segregation of fry from debris by sieving.*—To separate the debris from the fry the entire collection is sieved through a fine meshed sieve, placed at the mouth of the 'hundi'.† The debris are caught on the sieve while the fry pass through the meshes into the 'hundi'. Generally the sieve is not kept immersed in water and hence when the collection is poured over it a number of fry get caught within the debris and are injured. Even when the sieve is kept submerged in water several of the fry get injured when they pass through the meshes. A number of the smaller cat fish fry also escape through the sieve into the 'hundi' and prey upon the carp fry.

(*f*) *Overcrowding in the container in which fry are temporarily kept and consequent adverse changes in the hydrology.*—Depletion of dissolved oxygen and accumulation of free carbon dioxide are common.

(*g*) *Weaklings with congenital defects and their lower capacity for resistance.*—These naturally succumb easily to the strain during the different stages of collection.

(ii) *During conditioning in tins, hundies or hapas*:—

(*a*) *Possible differences in the hydrological conditions at the collection spot and in the conditioning pit or container.*—When there are significant differences in the conditions and when the fry are suddenly transferred from one to the other medium, they may be adversely affected.

(*b*) *Changes in temperature of water.*—Shallow pits and containers when exposed are likely to get heated up on bright sunny days and this leads to large-scale mortality.

(*c*) Overcrowding in the 'hapa'* or container and consequent adverse changes in water conditions.

(*d*) Stagnant conditions and consequent facility for easy infection, fungal and bacterial, of weaklings and the injured.

(*e*) Starvation, particularly when conditioning is prolonged, leading to lower capacity for survival.

(*f*) Destruction by predatory fish fry, insects, etc. that escape through the sieve and which are not subsequently removed.

(*g*) Strain during collection from 'hapa' or container for estimation of number by measuring prior to stocking.

(iii) *During stocking and rearing in nursery ponds*:—

(*a*) Appreciable differences if any, in the physico-chemical conditions of water in the nursery pond and those in the 'hapa' or container in which fry are temporarily

† 'Hundi' is a narrow necked earthen or tin pot for carrying fry.

* 'Hapa' is a trough shaped device made of cloth, supported on poles in water, or shallow pit with or without arrangement for water circulation, in which fry are temporarily kept.

kept before stocking might prove harmful. While this could be largely obviated by keeping the container with fry floating in the pond for some time and gradual mixing of waters, in actual practice the fry are very often suddenly released in the pond without consideration of any possible harm.

(*b*) *Lack of adequate quantities of the requisite kind of food in water.*—The nursery ponds are generally stocked heavily and large quantities of natural food have to be provided if the fry are to find the conditions suitable for satisfactory survival and growth. Ponds being inadequately prepared for stocking, available food in water is often very low at the time of stocking and this would, no doubt, contribute largely to the poor rate of survival of fry.

(*c*) *Voracity of predatory fish fry that are inadvertently introduced in the pond along with carp fry.*—The former which are often somewhat larger than the carp fry take a heavy toll of the latter and grow quickly.

(*d*) *Predatory leanings of aquatic insects that abound in all pieces of fresh water.*—These are most numerous during the rainy season and infest all ponds, in certain cases in enormous numbers. Notonectids (*Anisops* spp.) are probably the most abundant, though *Laccotrephes*, *Ranatra*, *Cybister*, dragonfly nymphs and other beetles and bugs are also common.

(*e*) Predatory tendency of minnows and other unwanted fishes which are usually present in most of the nursery ponds.

(*f*) Cannibalism among carp fry, particularly when fry of different sizes are stocked together.

(*g*) Sudden rise in temperature of water particularly when the water level is low.

(*h*) Overgrowth of phytoplankton and possible depletion of dissolved oxygen during night and supersaturation during daytime.

(*i*) Overgrowth of macrovegetation and benthic algæ which is generally associated with a marked paucity of plankton in the water.

It is obvious from the above that the high rate of mortality of carp fry is attributable to the cumulative effect of the several factors listed. In some cases the mortality during the first 24 hours after collection has been quite appreciable (sometimes as high as 60–70 per cent) and this must largely be attributed to the defective methods of collection and handling of the fry before conditioning. As soon as the fry are released in the nursery pond they are voraciously preyed upon by aquatic insects, particularly the back swimmers (*Anisops* spp.). Careful watch near the water edge immediately after planting the tender fry will reveal the astounding sight of almost every notonectid in the marginal waters catching and eating them. In other words, within a few minutes of stocking thousands of fry are killed by aquatic insects. The lack of suitable food in abundance commensurate with the number of fry introduced in the pond is one of the major factors that has to be reckoned with always.

In the light of these preliminary observations large-scale experiments in the laboratory and in the field were undertaken on almost every aspect of the problem and the results of some of the experiments are set forth briefly in the following pages.

III. Lay-out of Experimental Ponds

The Cuttack experimental ponds are in two sets, one of 23 ponds at Zobra, and the other of 48 ponds at Killa, at a distance of about two miles from the former. The Zobra ponds are situated at a distance of about half a mile from the river Mahanadi and has the Taldanda Canal—an irrigation-*cum*-navigation canal—leading from the Mahanadi at the Cuttack anicut, passing by their side (Fig. 1). This canal at Zobra is a useful carp fry collection centre. The Zobra ponds have been in existence for over ten years. They are all of almost uniform size, square in shape and range in area from 0·06–0·08 acres at the top of the bundhs.* Rain and subsoil seepage are the sources of water. Depth of water during monsoon months goes up to over 6′. Some of the ponds, particularly those nearer the Taldanda Canal, dry up during May–June every year, while the others retain only about one foot of water. The bottom soil is clayey silt.

The Killa nursery ponds, 48 in number, were constructed in 1950 by embanking a portion of the Barbati Killa (Fig. 1). The bottom soil is rather hard with appreciable admixture of laterite stones. All the ponds are more or less of uniform size, ranging from 0·088–0·115 acres at bundh-top level. The entire series divided in three sections occupies an area of 5·04 acres. Rain is the source of water for the ponds, though from the Mahanadi which flows close by, water could be drawn into the Killa channel through a protected inlet and thence into the nursery ponds by pumping. Percolation of water from the channel into the ponds is very limited. The ponds are perennial and the depth ranges from 2 to 2½ feet in summer (May–June) to 5½ to 6½ feet in the rainy season (August–September).

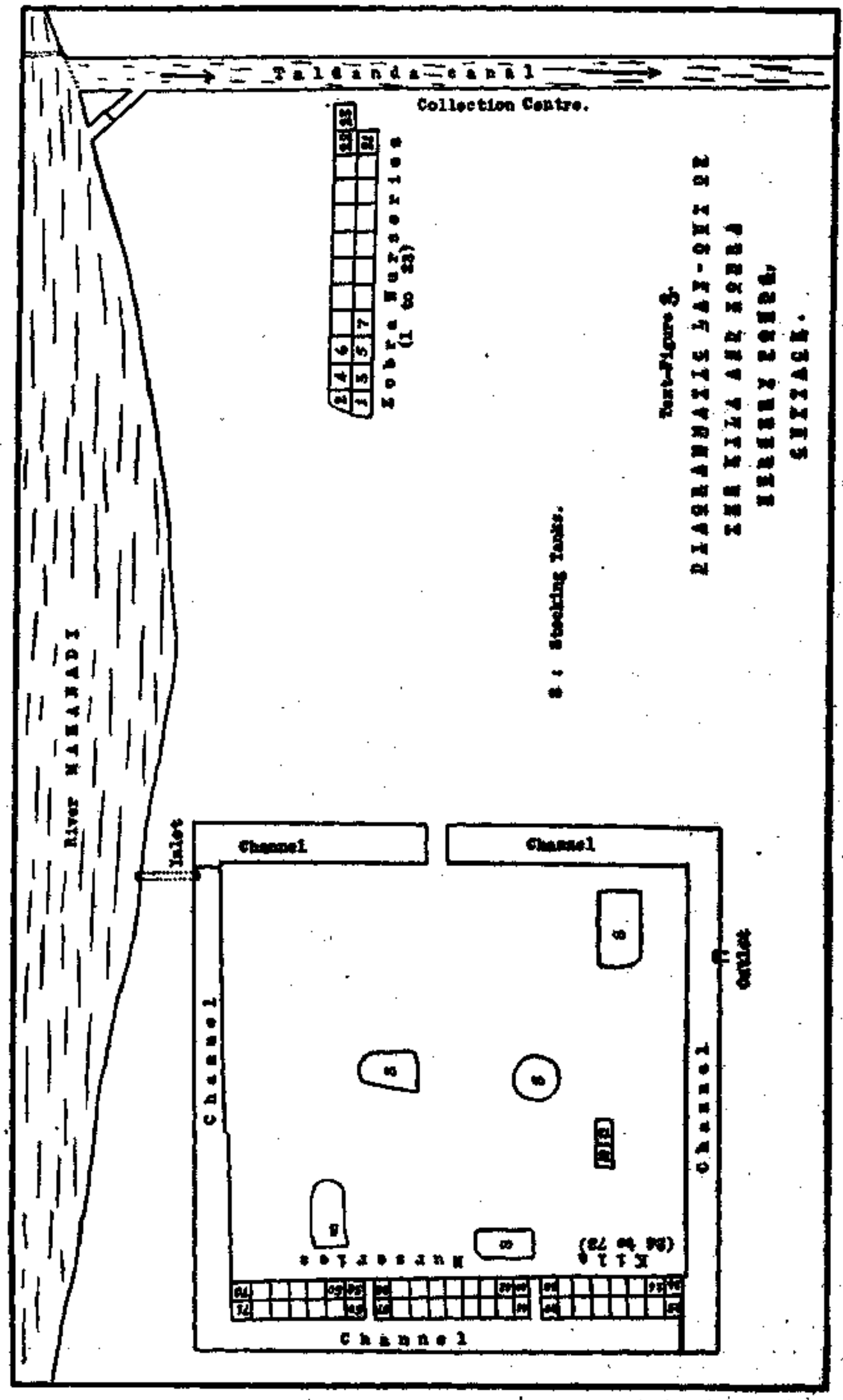
IV. Methods

Methods of actual nursery preparations are detailed in a separate section.

The fry are measured for stocking, in specially made fine-meshed wire net cups so as to allow as much water as possible to drain out during measuring and to ensure that the error, if any, due to the water content, will be uniform as far as practicable without injuring the fry. The capacity of the cups was determined beforehand by repeated sampling and counts.

Physico-chemical conditions were determined at weekly intervals. The water temperature was recorded at the spot at the time of collecting the sample for

* 'Bundh' is the earthen embankment of a pond.



Taldanda canal
Collection Centre.
Zobra Nurseries (1 to 23)
S : Stocking Tanks.
River MAHANADI
Inlet
Channel
Channel
Channel
Channel
Channel
Outlet
Kila Nurseries (24 to 72)

TEXT-FIG. 1

analysis. pH, dissolved oxygen, free carbon dioxide and alkalinities were also estimated in the field within an hour after collection of samples. The rest of the sample was then preserved with chloroform for estimating the nitrate and phosphate contents which was done within a week or two.

pH was determined colorimetrically with a Lovibond colour comparator using B.D.H. indicators. Dissolved oxygen was estimated by the Winkler method and free carbon dioxide by titration with N/50 or N/44 sodium carbonate using phenolphthalein as indicator. The alkalinities were estimated by titration with N/50 sulphuric acid. Estimations of nitrate were done by the phenol disulphonic acid method and of phosphate by Denige's cerulomolybdic method. The colours were compared in Nessler tubes.

Plankton.—Collections were ordinarily made at weekly intervals, but extra collections were taken one day after stocking and four days thereafter. A standard No. 21 bolting silk townet was used and each time 45 litres of water taken from 12–14 representative spots all over the pond were slowly filtered through the net. The collections were fixed on the spot in formalin and within 2–3 days when the organisms settled to the bottom of tube, the clear supernatant water was carefully decanted and the entire collection transferred to a graduated tube. When the organisms again settled down the volume of plankton sediment at the bottom of tube was noted. This was found to be a very useful means of rough assessment of the fluctuations in the bulk of plankton in the water. Zooplankters settled down very quickly after fixation while some of the phytoplankters like *Botryococcus*, *Microcystis*, etc., took quite a long time to settle down. In some cases they float near the surface forming a concentration at the top.

Representative samples of plankton were repeatedly examined under the microscope and the proportion of phyto- and zoo-plankton in the sample determined on the basis of number and relative bulk of the different constituents. A rough qualitative study of the sample was also made and the dominant plankters noted. Detailed systematic study of the different groups being beyond the scope of the present paper is not included.

The entire collection was thereafter diluted to a known volume, shaken thoroughly to ensure uniform distribution of the plankters and then three drops were taken on three slides. The volume of the drop was noted afresh for every sample of plankton and often ranged from 0·07–0·1 c.c. After carefully placing a square cover slip on the drop of plankton a complete count of the organisms in it was made under the microscope. The counts of three drops were averaged and the total number of each plankter in the entire collection was calculated and from this the number per litre of water was also found out.

The volume of sediment in selected collections was accurately measured and the dry weight of the same was determined by evaporating in porcelain basins to constant weight over a water-bath.

Fish population.—The ponds were first drag-netted repeatedly and the catch, in some cases, was individually counted species-wise; while in others representative samples were preserved for subsequent study of the size and weight. The ponds were then dewatered by a pump when the remaining fishes were also collected and studied. The preserved samples were analysed species-wise in the laboratory, measured and weighed and the total yield of fish from each pond calculated.

The relative abundance of macrofauna including tadpoles, insects, snails, etc., was noted at the time of fishing for possible correlation with the survival of fry in the different ponds.

V. PREPARATION OF NURSERIES

As the entire section of the Killa channel from which the ponds were embanked was completely dewatered, fished and subsequently excavated, all predatory fish as well as minnows were naturally eradicated from the new ponds. During subsequent years the ponds were dewatered by pumps in May or early June so as to remove any predatory fish that might have strayed into the ponds from the adjoining waters as also any residual non-predatory fish present in the pond, besides the bulk of the predatory insect population. Removal of all minnows and other fish from the nursery ponds is of utmost significance, as they usually feed heavily on the tender carp fry released in them (Alikunhi *et al.*, 1952).

The area of each pond and the cubic content of water in each at different depths were calculated so as to facilitate assessment of total plankton from the quantitative (numerical) counts of the latter.

All the ponds were manured, mainly with cowdung, after application of a low dose of lime with the aim of killing at least some of the predatory insects and of toning up the condition of the bottom soil. Details of the manures applied are given in Table I. The dose of cowdung ranged from 10,000 to 20,000 lbs. per acre/bottom. Though the ponds are all contiguous and received similar treatment, their behaviour, so far as plankton production was concerned, was vastly different (*vide* plankton). A period of about 3 weeks to a month intervenes between manuring and stocking the ponds with fry. During this period, due probably to the rich organic matter present in water the predatory aquatic insects multiply in large numbers. As a precautionary measure before stocking, it was, therefore, essential to remove as many of these predators as possible without in any way affecting the water conditions and the growth of plankton. In the absence of any suitable method of control by chemicals, the ponds were dragged very carefully with a cloth net and without unnecessarily disturbing the water, the majority of insects, particularly notonectids, were removed.

Table I

Details of the dose and quantity of different manures applied in 30 *selected nursery ponds at Cuttack during June–July,* 1950

Pond No.	Approximate dose (lb.) per acre/bottom of								Total quantity introduced (lb.)
	Cowdung	Compost	Paddy straw	'Puin'*	Mustard oilcake	Ammonium sulphate	Sodium nitrate	Lime	
1	10,000	3,750	100	..	..	..	..	100	251·1
3	10,000	3,750	100	..	..	..	..	100	348·5
4	10,000	3,750	100	..	..	..	..	100	306·9
6	10,000	3,750	100	..	..	..	..	100	474·3
13	10,000	3,750	100	..	..	..	..	100	488·0
20	10,000	3,750	100	..	..	..	..	100	251·1
35	10,000	..	100	25	25	..	..	100	471·6
36	10,000	..	100	25	25	25	25	100	474·0
37	10.000	..	100	..	..	..	..	100	469·2
40	10,000	2,000	100	25	25	25	25	100	566·0
41	15,000	..	100	25	25	25	25	150	706·3
43	15,000	..	100	..	..	..	..	150	701·5
44	15,000	..	100	25	25	25	25	..	699·4
45	15,000	..	100	25	25	25	25	200	708·6
47	15,000	..	100	..	..	..	..	200	703·8
50	15,000	2,000	100	..	..	..	..	200	795·8
52	10,000	..	100	25	25	25	25	100	474·0
53	10,000	..	100	25	25	25	25	150	476·3
54	10,000	..	100	25	25	25	25	100	474·0
56	10,000	..	100	300	..	..	..	100	483·0
57	10,000	..	100	300	..	..	..	100	483·0
58	20,000	..	100	25	25	25	25	300	943·2
61	20,000	2,000	100	..	..	..	..	200	1,025·8
62	2,000	20,000	100	25	25	25	25	200	1,030·6
63	15,000	5,000	100	..	..	..	..	200	933·8
67	15,000	5,000	100	..	..	..	..	200	933·8
68	15,000	5,000	100	..	..	..	..	200	933·8
69	15,000	5,000	100	..	..	..	..	200	933·8
70	15,000	5,000	100	..	..	..	..	200	933·8
71	15,000	5,000	100	..	..	..	..	200	933·8

* The Common Creeper *Basella alba* Linn.

This has necessarily to be carried out a day or two before stocking fry, for, if the interval between this netting and stocking is longer, insects from adjoining waters are likely to come into the pond again.

VI. Stocking

It has been demonstrated that the 'main food' of the tender carp fry in the first few days from the commencement of their feeding in the environment is zooplankton and that the planktonic algæ are consumed only as 'emergency food' which is hardly digested and on which the fry do not thrive (Alikunhi, 1952).

Cement cisterns, manured heavily with cowdung and partly protected from aquatic insects by wire-net screens, when stocked with fry at the time of maximum zooplankton production, gave high rates of survival of fry during the first 7 to 10 days of rearing.

It was therefore necessary to stock the ponds also on the basis of their zooplankton density. A minimum of 1·5–2·0 c.c. zooplankton sediment in 45 litres of water was considered essential for satisfactory stocking of the pond. As in actual experience only a few ponds at a time were found to have sufficient plankton for stocking, all the ponds could not be got ready for stocking, when fry were available. In the first year, however, the ponds were uniformly stocked irrespective of plankton density and without removing predatory insects prior to stocking. Supplementary manuring to induce increased growth of plankton was, however, resorted to in some ponds which had very low plankton content. Next year the ponds were stocked on the basis of zooplankton density and after removal of aquatic insects by netting a couple of days prior to stocking. The density of stocking ranged from approximately 1,00,000 to 5,00,000 spawn fry per acre. As a certain number of fry would invariably be dead at the time of stocking and as the number of these varied with each collection or lot, representative samples were carefully examined to ascertain the percentage of dead fry in the stock introduced.

VII. Physico-Chemical Conditions

The range and average of physico-chemical conditions from 18 selected ponds representing the three groups (*cf.*, survival of fry) are given in Table II. The depth of water in all the ponds steadily increased from July to September. In several of the ponds the water level in the second week of July was only about 1½′ while in a few it was as low as 1′ only. The rise in level of water was mainly due to direct rainfall, but in one row of ponds (even numbered) in the Killa series the influx of flood water due to rain on the adjacent gradually sloping meadow land also contributed to the rise in the water level. This was not possible in the other set of ponds (odd numbered) owing to the configuration of the land near them.

Killa Ponds.—(50, 57, 58 under A, 35, 37, 40, 41, 45, 47, 53 and 67 under B and 43–44 under C.).

The turbidity of water was almost always below 100 and did not exceed 105. When turbidity was over 100 the colour of the water was generally turbid brown. Depending on the time of collection, water temperature ranged from about 30° to 37·2° C. The waters are all alkaline. The

TABLE

Range and average of physico-chemical conditions of water in selected

(Values expressed as parts per

Nursery ponds		No. of samples analysed	Dates of collection	Time of collection (Hrs.)	Colour of water	Depth of water		Turbidity		Temperature °C.			
										Air		Water	
Group	Sl. No.					Range	Aver.	Range	Aver.	Range	Aver.	Range	Aver.
A	3	6	6-7-50 to 29-9-50	14·30-16·20	Turbid brown to dark green	1′ 6″-4′ 10″	3′ 6″	100-150	110	30·1-33·0	31·6	28·4-36·0	32·6
,,	6	6	do	14·30-16·20	Brownish green to green	2′ 9″-5′ 6″	4′ 0″	100	100	29·9-33·0	31·6	30·0-36·5	33·05
,,	50	10	8-7-50 to 18-9-50	10·40-15-30	Brownish to greenish	1′ 0″-5′ 0″	3′ 8″	100	100	27·5-34·5	31·08	29·8-37·0	33·2
,,	57	9	21-7-50 to 18-9-50	11·20-14·40	Reddish to green	3′ 0″-5′ 5″	4′ 2″	100	100	26·7-35·1	31·9	29·0-37·0	33·7
,,	58	10	8-7-50 to 18-9-50	11·20-16·00	Dark gray to greenish	1′ 6″-5′ 2″	3′ 11″	100	100	26·7-35·1	31·22	29·7-36·5	33·46
B	35	10	8-7-50 to 18-9-50	8·45-11·35	Slight brown to thick green	1′ 6″-5′ 6″	3′ 6″	100	100	29·2-33·0	30·89	30·1-35·0	32·3
,,	37	10	do	9·25-12·00	Brownish to green	1′ 6″-6′ 0°	4′ 2″	100	100	29·2-33·5	31·64	30·2-34·2	32·3
,,	40	10	do	9·25-12·35	Brownish to greenish	1′ 6″-5′ 2″	3′ 9″	100	100	29·2-33·5	31·56	30·1-36·4	32·7
,,	41	10	do	9·25-12·40	Brownish to dark green	1′ 6″-5′ 1″	3′ 7″	100	100	26·4-33·5	31·29	30·1-35·1	32·8
,,	45	10	do	10·00-13·50	Brownish to thick green	1′ 6″-5′ 4″	3′ 9°	100	100	26·4-34·6	31·0	30·2-36·5	32·86
,,	47	9	do	10·40-14·25	Brownish to green	1′ 6″-5′ 3″	3′ 8″	100	100	29·0-34·5	31·5	30·0-37·0	33·4
,,	53	9	21-7-50 to 18-9-50	10·40-14·30	Reddish to dark green	3′ 9″-5′ 6″	4′ 7″	100	100	27·5-34·5	31·3	30·0-37·0	33·3
,,	67	10	8-7-50 to 18-9-50	12·00-16·20	Brownish to green	1′ 0″-5′ 8″	3′ 10″	100-105	100·5	26·7-35·6	31·99	29·7-36·5	33·37
C	1	6	6-7-50 to 29-9-50	14·30-16·15	Pale green to greenish	2′ 7″-5′ 10″	4′ 4″	100-105	101	29·8-33·0	31·3	29·4-35·0	31·9
,,	4	6	do	14·30-16·20	Brown, turbid to greenish	2′ 7″-5′ 10″	4′ 4″	100-180	116	29·8-32·3	31·2	29·8-34·0	32·15
,,	20	4	26-7-50 to 30-9-50	15·30-16·10	Light brown to pale greenish	4′ 3″-5′ 6″	4′ 11″	100	100	29·8-32·2	30·9	28·6-35·6	32·3
,,	43	10	8-7-50 to 18-9-50	10·00-13·00	Yellowish to green	1′ 6″-5′ 1″	3′ 7″	100	100	26·4-34·6	31·35	30·0-37·2	33·31
,,	44	10	do	10·00-13·45	Brown to greenish	0′ 9″-5′ 10″	4′ 2″	100	100	26·4-34·6	31·2	29·8-37·2	33·14

II

nursery ponds in the Killa, Cuttack, during July–September, 1950

million, unless otherwise stated)

pH		Dissolved Oxygen		Free Carbon dioxide		Carbonate		Bicarbonate		Total Alkalinity		Nitrate (N)		Phosphate (PO_4)	
Range	Aver.	Range	Aver.	Range	Aver.	Range	Aver.	Range	Aver.	Range	Aver.	Range	Aver.	Range	Aver.
7·5–9·3	8·4	3·2–24·3	11·5	nil–0·88	0·15	nil–48·0	17·1	58·0–124·0	96·1	101·4–144·0	113·2	·07–·25	·131	Trace–4·6	1·7
7·0–8·9	8·1	4·0–14·5	9·38	nil–7·7	1·3	nil–8·0	3·6	85·0–122·0	100·2	90·0–134·0	107·4	·058–·16	·087	Trace–1·04	0·2
7·5–8·7	8·1	4·0–8·8	6·34	nil–0·88	0·088	Trace–18·0	6·65	63·0–146·0	92·8	67·0–162·0	99·5	·06–·10	·071	0·62–6·8	2·76
7·4–9·6	8·1	3·6–17·2	6·8	nil–4·4	0·5	Trace–60·0	8·0	42·0–120·0	111·5	90·0–120·0	107·0	·05–·08	·059	0·33–1·72	0·82
7·5–8·5	8·01	4·0–6·4	5·63	nil	..	Trace–16·0	3·2	112·0–176·0	137·1	112·0–184·0	140·0	·05–·09	·072	0·43–4·16	1·28
7·3–8·9	7·87	3·6–11·8	6·79	nil–3·5	0·35	nil–30·0	6·2	72·0–152·0	103·4	74·0–160·0	109·6	·058–·53	·127	0·53–4·1	1·78
7·3–9·1	8·13	3·6–14·9	7·32	nil–7·04	0·924	nil–60·0	12·4	92·0–184·0	120·8	92·0–184·0	133·2	·056–1·1	·175	0·45–2·88	1·0
7·5–8·6	8·1	4·2–8·0	6·16	nil–0·88	0·088	nil–12·0	2·8	110·0–208·0	148·0	116·0–208·0	150·7	·06–·10	·075	0·3–3·12	0·934
7·6–8·7	8·2	4·8–13·0	7·76	nil	..	Trace–36·0	12·7	128·0–250·0	192·7	128·0–276·0	211·4	·06–·09	·074	0·44–4·0	1·35
7·9–11·0	8·63	3·9–20·8	8·87	nil	..	Trace–124·0	26·0	40·0–184·0	137·8	136·0–184·0	145·6	·06–·26	·10	0·8–2·0	1·51
7·8–11·0	8·8	4·0–13·5	8·45	nil	..	8·0–100·0	32·0	4·0–170·0	125·0	104·0–178·0	141·4	·06–·37	·106	0·86–2·4	1·71
7·6–9·6	6·3	4·3–13·1	7·64	nil	..	Trace–52·0	17·0	70·0–149·0	112·3	114·0–165·0	129·0	·05–·08	·064	0·4–1·52	0·85
7·3–9·6	8·58	2·4–20·9	8·64	nil–2·64	0·26	Trace–88·0	26·4	80·0–180·0	142·8	80·0–192·0	169·2	·06–·35	·13	1·2–7·2	3·054
7·3–8·7	8·1	6·8–18·23	11·29	nil–Trace	..	nil–20·0	9·3	70·0–110·0	86·4	70·2–118·0	95·7	·068–·15	·109	Trace–1·4	0·275
7·3–8·9	8·0	2·8–14·11	9·8	nil–6·16	1·03	nil–40·0	9·3	70·0–114·0	90·6	88·4–116·0	99·9	·08–1·3	·378	Trace–1·9	0·39
7·3–8·7	8·2	4·8–8·4	7·15	nil–1·76	0·44	nil–10·0	6·5	49·4–66·0	58·9	59·4–68·0	65·4	·06–·38	·16	Trace–0·05	0·02
7·9–11·0	8·83	6·0–24·0	11·6	nil	..	Trace–120·0	34·5	nil–218·0	140·4	120·0–248·0	188·1	·07–·60	·185	0·43–3·99	1·17
7·8–8·65	8·25	4·8–9·2	6·74	nil	..	Trace–20·0	26·7	88·0–172·0	118·9	88·0–180·0	125·6	·06–·13	·083	0·53–7·0	2·24

variations in pH did not show any regularity. If the pond had an abundance of phytoplankton or submerged weeds the pH was generally high, often reaching 11·0 when very dense algal blooms occurred. The minimum pH observed was 7·3. Dissolved oxygen in water also did not show any regularity in fluctuations. High dissolved oxygen generally accompanied high pH and *vice versa*. In ponds (Nos. 43, 45, 67) which had dense algal blooms the dissolved oxygen was over 20 ppm., resulting in supersaturation exceeding 300%. It has already been shown that such conditions are fatal to the fry owing to gas accumulation in the stomach, gut, sub-cutaneous spaces, etc. (Alikunhi *et al.*, 1951). Free carbon dioxide did not exceed the 10 ppm. level in any of the ponds.

Total alkalinity of water has also shown wide though irregular fluctuations from 67 to 276 ppm. However, from the middle of July up to September the alkalinity tends to decrease owing probably to dilution by rain water.

Nitrates are ordinarily low but go up in certain cases to even over 1·0 ppm. It is difficult to find any correlation of the nitrate fluctuations either with the other physico-chemical factors or even with the fluctuations in the phytoplankton density. Phosphates show more regular fluctuations. Within a few days of manuring, the phosphate content in all the ponds was very high, ranging from about 1·0 ppm. to as much as 7·0 ppm. In months following manuring the phosphate content gradually falls until by the middle of September it has been reduced to 0·4–1·0 ppm. in most of the ponds.

Zobra Ponds.—(3 and 6 under A; 1, 4 and 20 under C.)

The trend of fluctuations of the different factors is almost the same as in the Killa ponds, but the noticeable differences from the latter are as follows:—

(i) The reduction of the phosphate content of water in the Zobra ponds to mere traces within a month after manuring is much quicker than in the Killa ponds.

(ii) The Zobra ponds have on the whole a lower total alkalinity than the Killa ponds. Among the Zobra ponds those nearer to the Taldanda Canal (Nos. 19 to 23) have decidedly lower total alkalinity than those farther away from the canal.

(iii) Chloride content of the Zobra waters is much lower than that of the Killa waters (data not included in the table).

(iv) The slightly lower pH in the Zobra ponds is not clearly demonstrable.

VIII. Plankton

From laboratory experiments the role of zooplankton in the survival and growth of carp fry has already been indicated (Alikunhi, 1952). A detailed study of the fluctuations, quality and quantity of plankton in the nursery ponds stocked with carp fry was therefore made with a view to correlating the same with survival and growth of fry.

(*a*) *Manuring and production*

Though manuring with cowdung did not result in any significant increase in the nitrate content of the pond waters, there was invariably a marked increase in the phosphate content. The organic nitrogen, no doubt, present in the cowdung, is probably not converted into nitrates, or is probably utilised before it could be converted into nitrates. Heavy manuring with cowdung in experimental pots or cement cisterns discolours water to a dark brown shade and during the first 8–10 days after manuring the phytoplankton content (net plankton) of the water is remarkably poor. From the 9th or 10th day onwards, however, the water begins to teem with zooplankton, particularly rotifers, cladocerans (dominant) and copepods, a crop that continues to flourish for about a week or 10 days, during which the townet collections show almost 100 per cent zooplankton. There are two possible explanations for this phenomenon; either the algal chain of the cycle has not begun to establish itself during the period when the zooplankters are probably utilising the rich organic nutrient matter in the cowdung, or the algal flora is being consumed by the zooplankters. After the initial crop of zooplankton has been consumed by the fry, the phytoplankton becomes rich.

In cement cisterns, particularly without a mud or sand substratum heavy manuring with cowdung, raw or dry, almost invariably results at first in the production of swarms of zooplankters, after which only are appreciable number of phytoplankters observed. The conditions in the natural ponds are, however, different.

No two nursery ponds behave similarly at any given time even though similarly treated. Some have initially an enhanced production of zooplankton, while the others have algal blooms first. In still others the effect of manuring is considerably delayed. An assessment of the time taken for enhanced production of plankton (zoo- and phyto-) and the period during which high production was maintained, considered in relation to the dose of manure applied is given in the Table III.

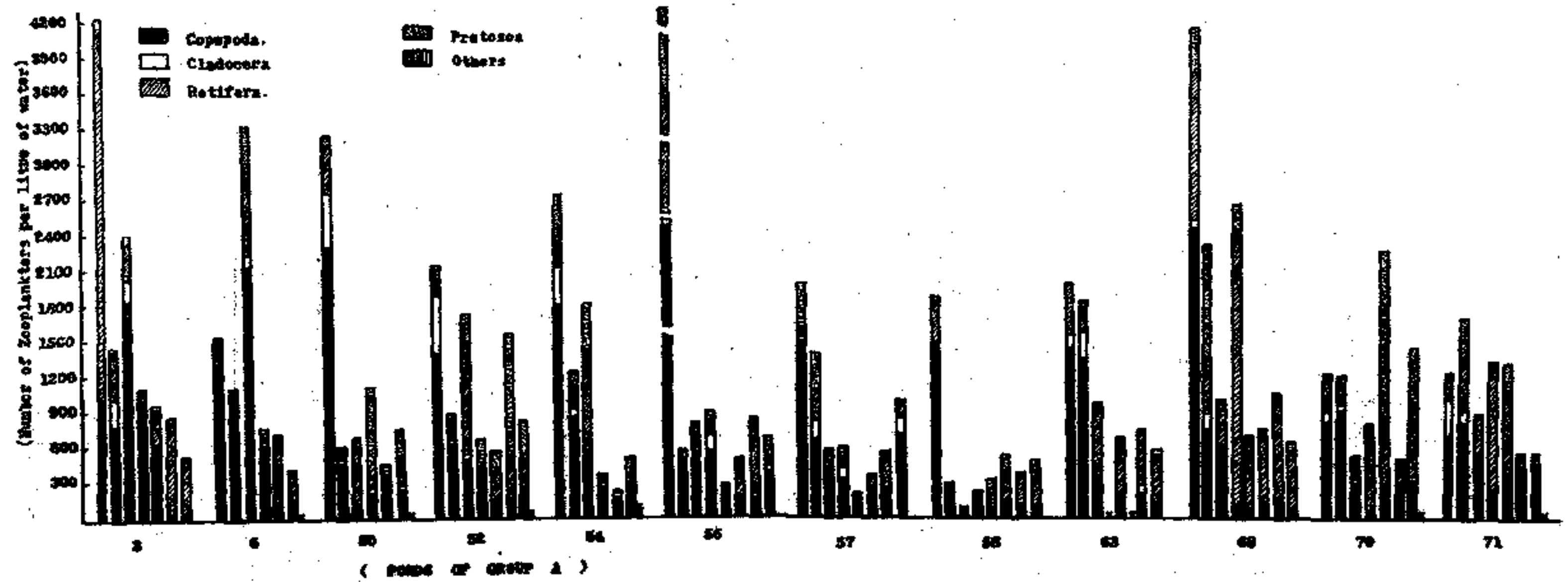
TABLE III

Rate of manuring and the time for maximum production of plankton in selected nursery ponds at Cuttack during June, 1950

Chief manure applied	Dose per acre (lb.)	No. of ponds manured	No. of days taken for maximum production of plankton		No. of days during which high production was maintained	
			Range	Average	Range	Average
Cowdung ..	10,000	15	12–33	24	7–38	16·5
Cowdung ..	15,000	12	14–42	22	7–35	17
Cowdung ..	20,000	2	15–27	21	12–34	23
Compost ..	20,000	1	44	..	..	..

Whether the production of plankton is proportionate to the quantity of manure put in is not yet known, though the relatively longer duration of the period of high production resulting from increased dose of manure indicates that there is some relation between the two. The quantity of plankton produced also does not show any consistent relation with the quantity of manure put in. The maximum quantity of plankton produced was in pond 43 which was manured at 15,000 lb. of cowdung per acre. Phytoplankton dominated in this pond throughout the period of rearing. Average production of plankton in ponds manured at 10,000 lb./acre was more than that in ponds manured at 15,000 lb./acre, probably because phytoplankton blooms appeared in more ponds of the former group than in the latter, in which, excepting pond 43, the blooms were also not so dense or sustained as in the former. As the period of rearing differed in the different ponds the weight of fish produced in them cannot strictly be compared; it is, however, seen that the average production of fish flesh per day per pond when manured with cowdung at the rate of 10,000 lb./acre amounted to about 237 gm.; while in those manured at 15,000 lb./acre the daily production averaged about 459 gm. Curiously enough, the two ponds which received 20,000 lb. of cowdung per acre compare only with those manured at half that dose, both in the quantity of plankton produced and in the average fish production (Table XIV). Elaborate experiments, however, have to be carried out to arrive at some definite and useful correlation between the survival of fry or the production of fish flesh and the quantity of manure applied.

The fluctuations in the standing crop of net plankton in the 30 ponds during the period of rearing carp fry are shown in Table IV, expressed as



TEXT-FIG. 2. Bar graphs showing zooplankton fluctuations in nursery ponds of Group A. (Pond No. 3, 6, 50, 52, 54, 56, 57, 58, 63, 68, 70 and 71.) Breaks in the bars indicate swarms. Each bar represents a day's collection. Dates of collections are 6/7, 20/7, 24/7, 31/7, 7/8, 16/8 and 25/8/1950 for ponds 3 and 6; and 9/7, 18/7, 22/7, 31/7, 8/8, 14/8, 21/8, 29/8 and 6/9/1950 for the other ponds. × between bars indicates missing collections.

TABLE IV

Fluctuations in the quantity of plankton in 30 selected nursery ponds at Cuttack during July–September, 1950

Group	Pond No.	Plankton (sediment) expressed in c.c. per litre of pond water								Remarks
		Before stocking	1 day after stocking	5 days after stocking	14 days after stocking	21 days after stocking	28 days after stocking	35 days after stocking	42 days after stocking	
A	3	0·026	0·036	0·034	0·019	0·016	0·012	..	..	
	6	0·031	0·025	0·036	0·027	0·013	..	..	..	Fished on 27th day
	50	0·068	0·054	0·033	..	0·008	0·015	0·006	0·015	
	52	0·031	0·046	0·024	0·016	0·017	0·012	0·006	0·011	
	54	0·320	0·067	0·014	0·097	0·013	0·017	0·011	0·010	
	56	0·054	0·370	1·600	0·013	0·017	0·013	0·011	0·013	
	57	0·051	0·422	0·250	0·015	0·017	0·005	0·008	0·013	
	58	0·053	0·022	0·013	0·005	0·010	0·006	0·009	0·015	
	63	0·031	0·018	0·023	0·018	0·018	0·013	0·004	0·013	
	68	0·024	0·016	0·027	0·022	0·022	0·006	0·009	0·018	
	70	0·026	0·036	0·018	0·020	0·012	..	..	..	Dewatered on 22nd day
	71	0·028	0·028	0·033	0·018	0·009	..	..	..	do

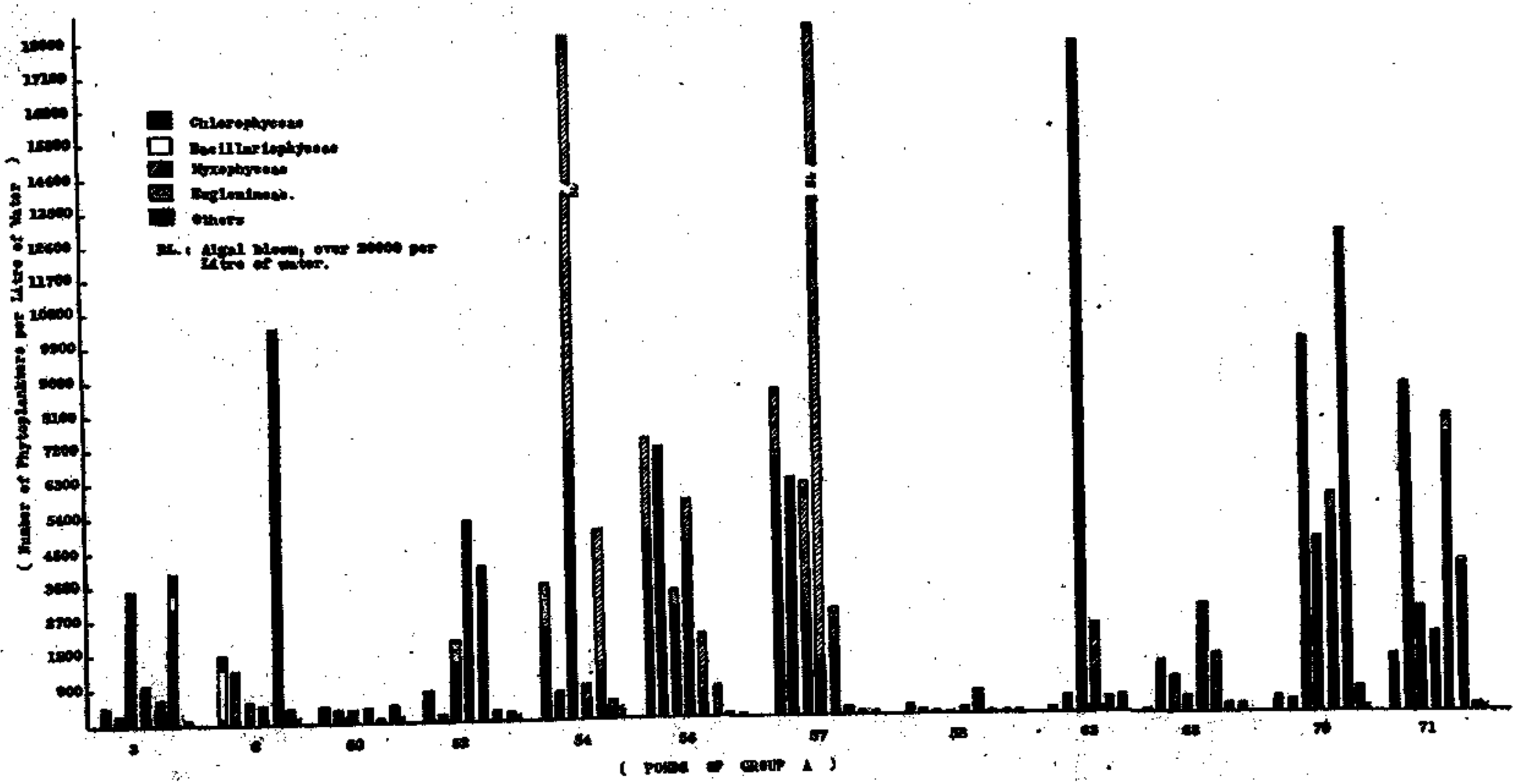
	13	..	3·981	0·433	..	..	..	..	..	
	35	0·382	0·036	0·075	0·423	..	..	..	..	Dewatered on 19th day
	36	1·977	1·042	0·014	0·021	0·023	0·011	0·013	0·048	
	37	0·091	0·402	0·380	0·670	..	..	..	..	Dewatered on 17th day.
	40	0·053	0·029	0·006	0·018	0·011	0·008	0·015	0·024	
	41	0·068	0·030	0·016	0·022	0·012	0·014	0·010	0·016	
	45	0·032	0·024	0·015	0·031	0·017	0·017	0·013	0·050	
	47	0·033	0·020	0·010	0·248	0·013	0·010	0·008	..	
	53	0·027	0·052	0·024	0·022	0·026	0·037	0·011	0·015	
	61	0·055	0·023	0·064	0·040	0·040	0·021	0·005	0·016	
	67	0·031	0·185	0·096	0·017	0·026	0·038	0·044	0·017	
	69	0·031	0·036	0·021	0·015	0·011				Dewatered on 21st day
C	1	0·022	0·025	0·024	0·017	0·031	0·024	..	..	
	4	0·013	0·040	0·028	0·037	0·022	..	..	..	
	20	0·048	0·026	0·041	0·023	0·027	..	..		
	43	0·042	0·024	0·137	1·660	5·35	2·87	1·600	0·085	
	44	0·028	0·044	0·017	0·027	0·020	0·015	0·011	0·023	
	62	0·020	0·013	0·015	0·024	0·037	0·009	0·013	0·020	

volume (c.c.) of plankton sediment per litre of water. In certain ponds which developed algal blooms the production of plankton has been enormous and a maximum of 5·35 c.c. of sediment per litre of water was observed in pond 43.

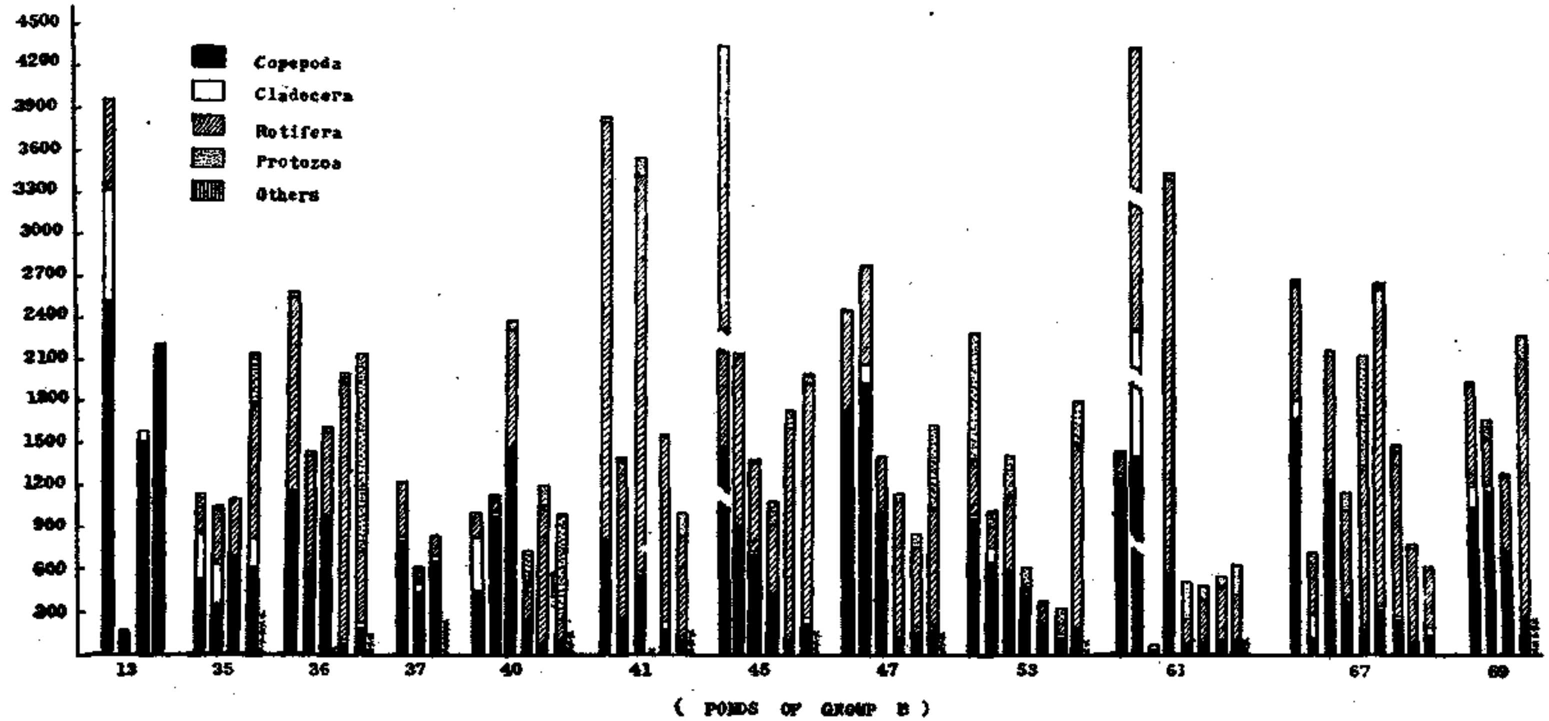
The enhanced production of plankton, resulting from manuring, is maintained only for a relatively short period after which the concentration of plankton in the pond water is rather low. Under the present state of our knowledge, it is extremely difficult to maintain in nursery ponds this enhanced production for a longer duration or to induce a fresh heavy growth of plankton even with supplementary manuring. This is still more difficult with an appreciable population of carp fry stocked in the pond. A perusal of the plankton analysis data illustrated in Text-Figs. 2, 4 and 6 shows that almost invariably the zooplankton density in the water is much less towards the latter half of the rearing period than in the first half. This, however, does not apply fully when phytoplankton is taken into consideration (Figs. 3, 5 and 7).

(*b*) *Quantitative Analysis*

As carp fry are known to show preference for certain items of plankton it was necessary to have a detailed picture of the composition of plankton in the different ponds during the period of rearing in order to attempt correlation of the same with the survival of fry. In the absence of a satisfactory method for arriving at the exact proportion of the different constituents according to their bulk, the collections were analysed by counting the different items and calculating the number of each in a litre of water. A total number of 211 collections were examined from the 30 selected ponds, averaging seven collections per pond for the average rearing period of 46 days. Though the different phyto- and zooplankters were identified up to the genera and were counted separately, only the counts for the different groups are represented in Text-Figs. 2 to 7 with a view to bring out clearly the relative abundance of phyto- and zooplankton and the predominant groups in either. A critical study of these figures side by side with Table IV will give some idea of the total number of plankters and their total volume. A comparison of the quality of plankton and the number of individuals of the different groups in it with the total volume of the sample will give some general idea of the relative bulk of phyto- and zooplankters also. Numbers alone will give an erroneous picture as some of the phytoplankters which often occur in blooms are extremely small when compared to the common zooplankters like *Diaptomus* or *Moina*.



TEXT-FIG. 3. Bar graphs showing phytoplankton fluctuations in nursery ponds of Group A. Details same as in Fig. 1.



TEXT-FIG. 4. Bar graphs showing zooplankton fluctuations in nursery ponds of Group B. (Pond No. 13, 35, 36, 37, 40, 41, 45, 47, 53, 61, 67 and 69.) Breaks in the bars indicate swarms. Each bar represents a day's collection. ×between bars indicates missing collections. Dates of collections are 20/7, 1/8, 4/8 and 11/8/1950 for ponds 13 and 8/7, 17/7, 21/7, 30/7, 6/8, 13/8, 20/8, 29/8, 6/9 and 13/9/1950 for the other ponds.

Since the digestibility and thereby the relative nutrient value of phyto- and zooplankters are reported to differ and since the volume measurements of the different samples as detailed can only be a very rough means of noting the gross fluctuations of plankton, a preliminary study of the dry weight of selected samples was also made. Even in almost pure collections of phytoplankton there were considerable differences in dry weight depending on the species of algæ. Zooplankton also showed similar fluctuations, but a much larger number of samples are required to be studied before any generalisation, taking into consideration the environmental conditions and the stage in the life-history of the organisms, could be made. The dry weight data for a selected number of collections are given in Table V. When the weight

TABLE V

Data showing the nature of plankton and their dry weight per unit volume (c.c.) of sediment

Sl. No.	Nature of Plankton (%)		Dry weight (gm.) per c.c. of sediment	Predominant organisms
	Phyto-plankton	Zoo-plankton		
1	100·0	0·0	0·01904	Volvox
2	99·8	0·2	0·01674	Microcystis
3	99·5	0·5	0·01764	,,
4	99·5	0·5	0·0254	Volvox
5	97·0	3·0	0·01135	,,
6	96·0	4·0	0·0096	Microcystis
7	95·0	5·0	0·02456	Volvox
8	90·0	10·0	0·01239	Microcystis
9	80·0	20·0	0·01883	,,
10	40·0	60·0	0·02885	Microcystis and Diaptomus
11	7·0	93·0	0·04103	Diaptomus
12	5·0	95·0	0·06017	,,
13	5·0	95·0	0·0265	,,
14	3·0	97·0	0·04600	,,
15	2·0	98·0	0·06032	,,
16	1·0	99·0	0·03156	,,
17	1·0	99·0	0·02243	Cladocerans
18	1·0	99·0	0·03310	Diaptomus
19	0·5	99·5	0·01529	Cladocerans
20	0·5	99·5	0·01294	,,

per unit volume of sediment of zooplankton and phytoplankton is compared it is seen that the majority of the latter weigh appreciably less than the former. The decidedly lower digestibility of the phytoplankters,

TABLE

Nature of algal blooms that appeared in manured nursery ponds

Pond No.	Alga forming bloom	Nature of					
		Total duration (days)	Commenced on (date)	Peak attained		Peak markedly declined	
				on (date)	in (days)	on (date)	in (days)
3	*Closterium*	9	20-7-50	25-7-50	6	29-7-50	4
1	do	15	27-7-50	3-8-50	8	10-8-50	7
43	*Crucigenia*	About 10	17-7-50	21-7-50	5	30-7-50*	..
43	*Pediastrum*	About 15	..	9-7-50	..	17-7-50	9
54	do	15	25-7-50	31-7-50	7	8-8-50	8
41	do	20	30-7-50	13-8-50	14	20-8-50	7
53	do	About 40	9-7-50*	31-7-50	23	14-8-50	14
43	*Scenedesmus*	..	..	9-7-50*	..	..	..
1	*Eudorina*	About 20	23-7-50	10-8-50	18	..	..
6	do	16	31-7-50*	7-8-50	7	16-8-50	9
13	do	14	20-7-50	1-8-50	11	4-8-50	3
20	do	About 24	..	7-7-50	..	26-7-50	19
35	do	About 20	21-7-50	30-7-50	9	6-8-50*	7
36	do	About 14	..	13-8-50	..	20-8-50	7
37	do	13	..	17-7-50	9	21-7-50	4
43	do	13	17-7-50	21-7-50	4	30-7-50	9
45	do	13	17-7-50	21-7-50	4	31-7-50	10
47	do	22	9-7-50	21-7-50	12	31-7-50	10
52	do	14	31-7-50	8-8-50	8	14-8-50	6
56	do	14	31-7-50	8-8-50	8	14-8-50	6
61	do	About 14	31-7-50	8-8-50	8	14-8-50	6
62	do	About 14	31-7-50	8-8-50	8	14-8-50	6
63	do	About 14	25-7-50	31-7-50	6	8-8-50	7

VI

stocked with carp fry during July–September 1950

Bloom		Other algæ simultaneously in bloom	Nature of zooplankton at peak of bloom	Remarks
Maximum concentration per litre of water	Relative intensity			
3,400	thin	nil	fairly rich	
15,494	fairly thick	*Eudorina*	rich	Present as light bloom from 17–7–50
12,380	thin	*Pediastrum, Eudorina, Microcystis, Oscillatoria*	very rich	* Disappeared from plankton
38,857	fairly thick	*Scenedesmus, Crucigenia, Oscillatoria, Microcystis*	rich	Increased again by 21–7–50
5,761	thin	*Microcystis, Anabæna*	fairly rich	
5,232	thin	nil	do	
1,27,841	thick	*Anabæna, Microcystis*	moderate	* Already as bloom
38,857	thin	*Pediastrum*	rich	* No previous collection; disappeared in 8 days
51,505	fairly thick	*Closterium*	poor	
10,029	thin	nil	poor	* Very few in water
38,607	fairly thick	*Volvox, Microcystis*	very poor	Thin bloom by 11–8–50
26,865	do	nil	fairly rich	
1,18,258	thick	*Volvox, Microcystis*	moderate	* Still fairly thick bloom
7,513	thin	nil	fairly rich	
5,284	thin	*Volvox, Microcystis*	moderate	
38,104	fairly thick	*Pediastrum, Crucigenia, Microcystis, Oscillatoria*	very rich	
11,762	thin	nil	fairly rich	
5,651	thin	*Microcystis*	fairly rich	
5,191	thin	nil	poor	
4,280	thin	nil	poor	
5,886	thin	nil	rich	
18,671	thin	nil	fairly rich	
16,794	thin	nil	poor	

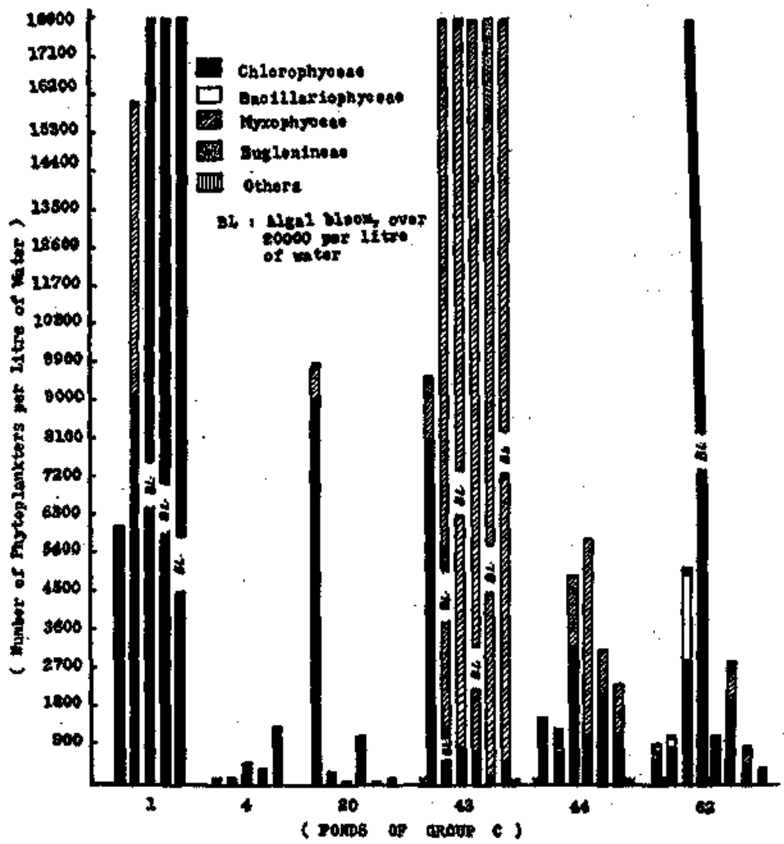
TABLE

Pond No.	Alga forming bloom	Nature of					
		Total duration (days)	Commenced on (date)	Peak attained		Peak markedly declined	
				on (date)	in (days)	on (date)	in (days)
67	*Eudrina*	About 10	10-8-50	14-8-50	4	18-8-50	4
69	do	About 19	12-7-50	18-7-50	6	31-7-50	13
70	do	About 20	25-7-50	31-7-50	6	14-8-60	14
71	do	13	18-7-50	22-7-50	4	31-9-50	9
13	*Volvox*	13	20-7-50	1-8-50	10	4-8-50*	3
35	do	..	..	8-7-50	..	17-7-50*	9
35	do	..	21-7-50	6-8-50	15	..	..
37	do	16	12-7-50	21-7-50	9	28-7-50	7
54	do	..	..	9-7-50	9	18-7-50	..
56	do	13	15-7-50	22-7-50	7	28-7-50	6
57	do	..	..	18-7-50	..	25-7-50	7
13	*Microcystis*	14	20-7-50	1-8-50	11	4-8-50	3
35	do	..	21-7-50	6-8-50	16	..	..
36	do	..	..	8-7-50	..	17-7-50	9
37	do	..	17-7-50	30-7-50	13	..	..
43	do	34	17-7-50	6-8-50	20	20-8-50	14
47	do	20	19-7-50	31-7-50	12	8-8-50	8
53	do	21	31-7-50	14-8-50	14	21-8-50	7
61	do	20	19-7-50	22-7-50	3	8-8-50	17
45	*Anabæna*	..	..	9-7-50	..	17-7-50*	8
53	do	20	25-7-50	8-8-50	14	14-8-50	6
54	do	14	25-7-50	31-7-50	6	8-8-50	8
57	do	14	31-7-50	8-8-50	8	14-8-50	6
43	*Oscillatoria*	13	17-7-50	21-7-50	4	30-7-50	9
62	*Melosira*	14	31-7-50	8-8-50	8	14-8-50	6

VI—(*Contd.*)

Bloom		Other algæ simultaneously in bloom	Nature of zooplankton at peak of bloom	Remarks
Maximum concentration per litre of water	Relative intensity			
97,381	thick	nil	fairly rich	
13,391	thin	nil	moderate	* Thin bloom up to 8-8-50
9,786	thin	nil	poor	
8,292	thin	nil	moderate	
9,084	fairly thick	*Eudorina*, *Microcystis*	very poor	* Very few in water
22,290	thick	*Eudorina*	rich	* Very few in water
25,678	thick	*Eudorina*, *Microcystis*	moderate	
44,992	thick	*Eudorina*	poor	
5,752	thin	nil	moderate	
7,023	thin	nil	poor	
6,563	thin	il	moderate	
7,31,266	thick	*Volvox*, *Eudorina*	very poor	Another peak 7 days after
18,460	thin	*Volvox*, *Eudorina*	fairly rich	
15,82,482	thick	nil	very rich	
23,091	thin	nil	poor	
19,92,064	thick	nil	very poor	Thick bloom all through
83,571	fairly thick	*Eudorina*, *Pediastrum*	moderate	
10,889	thin	*Pediastrum*, *Anabæna*	poor	
93,206	fairly thick	nil	rich	
54,127	thin	nil	rich	* Disappeared from water
93,575	thin	*Microcystis*, *Pediastrum*	poor	
10,204	thin	do	moderate	
25,638	thin	nil	poor	
11,748	thin	*Microcystis*, *Crucigenia*, *Eudorina*, *Pediastrum*	very rich	
15,533	thin	*Eudorina*	fairly rich	

Desmids are also poorly represented in the collections, the most common genera encountered being *Closterium*, *Cosmarium* and *Staurastrum*. Volvocales and chlorococcales among the green algæ predominated in the phytoplankton and were represented by such common genera as *Eudorina*, *Volvox*, *Chlamydomonas*, *Westella*, *Cœlastrum*, *Pediastrum*, *Ankistrodesmus*. *Scenedesmus*, *Crucigenia*, *Kirchneriella*, *Gonium*, *Actinastrum*, *Dictyosphærium*, *Ophiocytium* and *Tetrædron*, among others.



TEXT-FIG. 7. Bar graphs showing phytoplankton fluctuations in nursery ponds of Group C. Details same as in Fig. 6.

The common blue green algæ, *Microcystis*, *Anabæna*, *Oscillatoria*, *Merismopedia* and *Aphanocapsa*, were also almost equally abundant as the green algæ. Yellow green algæ (Xanthophyceæ) were represented by *Botryococcus* and occurred in a few ponds only. *Euglenineæ*, commonly represented by *Euglena*, *Phacus* and *Trachelomonas* was also an important constituent of the phytoplankton in these experimental ponds.

Among the phytoplankters *Eudorina* was the commonest and the most abundant alga, having been encountered in practically all the collections from all the 30 ponds. *Microcystis* forms a close second in this respect, while others like *Volvox*, *Pediastrum*, *Anabæna*, etc. though very common are not so universal in occurrence.

The most important zooplankters were *Difflugia*, *Centropyxis*, *Vorticella*, *Loxodes* and certain other ciliates among Protozoa; the rotifers *Brachionus*, *Keratella*, *Noteus*, *Lecane*, *Salpina*, *Asplanchna*, *Pedalia*, *Polyarthra*, *Filinia*, *Tetramastix*, and *Conochilus*; the copepods *Diaptomus* and *Cyclops* with their nauplii; the cladocerans *Moina*, *Diaphanosoma* and *Ceriodaphnia* and occasionally some ostracods also. Of these the protozoans were relatively of much less importance than others as food for carp fry. The rotifers, though often occurring in large numbers, were available for limited number of days only and hence the bulk of sustenance for fry was supplied, in this case, largely by nauplii, cladocerans and the small *Cyclops*. Like *Eudorina* among phytoplankters, nauplii were also of universal occurrence among zooplankters.

From the foregoing brief account it is clear that the plankton in these ponds is of the typical Baltic type characterised by the limited number of species but large number of individuals of the species represented; paucity of desmids; and predominance of chlorococcales and myxophyceæ (Welch, 1952).

(*d*) *Blooms and Swarms*

As already stated the production of algæ is enormous in some of the ponds and out of the 30 ponds under consideration in this paper at least 20 had developed algal blooms at some time or other during the fry rearing period. The common algæ that developed blooms in these ponds during the rainy months, July–September, were the green algæ *Eudorina*, *Volvox*, *Pediastrum*, *Crucigenia*, *Scenedesmus* and *Closterium*; the diatom *Melosira* and the blue greens *Microcystis*, *Anabæna* and *Oscillatoria*. From the detailed analysis of plankton certain facts relating to the nature of algal blooms, their duration, attainment of peaks, associations with other algæ, etc., could be gleaned and these are furnished in Table VI.

A concentration of about 5,000 specimens of any particular species in a litre of water was considered to be of the nature of a thin bloom of that species. On this basis, *Eudorina* which is the commonest alga in the plankton appeared in bloom in at least 19 of the 30 ponds; the highest concentration observed being 1,18,258 specimens per litre of water in pond 35. The

TABLE

Nature of zooplankton swarms that appeared during July-September,

Pond No.	Zooplankters forming swarms	Nature of Swarms					
		Total duration (days)	Commenced on (date)	Peak attained		Peak markedly declined	
				on (date)	in (days)	on (date)	in (days)
36	*Difflugia*	..	13-8-50	20-8-50	7	..	..
44	do	14	31-7-50	8-8-50	8	14-8-50	6
52	do	15	14-8-50	21-8-50	7	29-8-50	8
56	do	12	10-7-50	18-7-50	8	22-7-50	4
70	do	13	8-8-50	14-8-50	6	21-8-50	7
36	*Brachionus*	..	..	8-7-50	..	17-7-50*	9
36	do	14	6-8-50	13-8-50	7	20-8-50	7
41	do	16	21-7-50	30-7-50	9	6-8-50	7
43	do	..	13-8-50*	20-8-50	7	..	..
45	do	..	14-8-50	21-8-50	7	.	..
50	do	..	..	9-7-50	..	18-7-50	8
61	do	13	18-7-50	22-7-50	4	31-7-50	9
67	do	15	14-8-50	21-8-50	7	29-8-50	8
1	*Keratella*	18	23-7-50	3-8-50	11	10-8-50	7
62	do	14	31-7-50*	8-8-50	8	14-8-50	6
43	*Filinia*	13	17-7-50	21-7-50	4	30-7-50	9
45	do	12	9-7-50*	17-7-50	8	21-7-50	4
50	do	..	..	9-7-50	..	18-7-50*	9
61	do	14	31-7-50*	8-8-50	8	14-8-50	6
68	do	14	31-7-50	8-8-50	8	14-8-50	6
68	*Polyarthra*	..	..	10-7-50	..	18-7-50	8
43	do	13	17-7-50	21-7-50	4	30-7-50	9
40	*Pedalia*	..	..	9-7-50	..	17-7-50	8

VII

1950 *in selected manured nursery ponds at Cuttack, Orissa*

Maximum number per litre of water	Other zooplankters simultaneously in swarm	Phytoplankters at peak of swarms	Remarks
1,413	nil	moderate	
2,211	*Nauplii*	moderate	
1,027	nil	poor	
1,667	*Pedalia*, *Diaptomus*, *Nauplii*	moderate	
1,424	nil	moderate	
6,875	*Polyarthra*, *Filinia*, *Pedalia*, *Cyclops*, *Nauplii*, *Moina*	rich	* Disappeared from water
1,871	nil	moderate	
2,198	nil	moderate	
3,651	nil	rich	* Practically absent in water
1,410	nil	poor	
1,611	*Filiuia*, *Nauplii*	poor	
1,523	*Moina*	rich	
1,068	nil	poor	
1,761	nil	rich	
1,254	*Nauplii*	rich	* Very few present
2,540	*Pedalia*, *Polyarthra*, *Nauplii*	rich	
2,984	*Pedalia*, *Nauplii*	poor	* Absent in water
11,815	*Nauplii*	poor	* Rare
1,086	nil	fair	* Absent in water
1,196	nil	poor	
1,265	*Brachionus*, *Nauplii*	very poor	
3,808	*Filinia*, *Pedalia*, *Nauplii*	rich	
2,205	*Nauplii*	poor	

TABLE

Pond No.	Zooplankters forming swarms	Nature of Swarms					
		Total duration (days)	Commenced on (date)	Peak attained		Peak markedly declined	
				on (date)	in (days)	on (date)	in (days)
41	*Pedalia*	12	9-7-50	17-7-50	8	21-7-50	4
43	do	13	17-7-50	21-7-50	4	30-7-50	9
45	do	..	..	9-7-50	..	21-7-50	12
53	do	..	..	9-7-50	..	18-7-50	9
56	do	12	10-7-50*	18-7-50	8	22-7-50	4
36	*Cyclops*	..	..	8-7-50	..	17-7-50	9
43	do	13	17-7-50	21-7-50	4	30-7-50	9
13	*Diaptomus*	..	1-8-50	11-8-50	7	..	..
20	do	19	7-7-50	20-7-50	13	26-7-50	6
56	do	12	10-7-50	18-7-50	8	22-7-50	4
1	*Nauplii*	11	23-7-50	27-7-50	4	3-8-50	7
3	do	9	20-7-50	25-7-50	5	29-7-50	4
6	do	11	20-7-50	24-7-50	4	31-7-50	7
36	do	..	..	8-7-50	..	17-7-50	9
43	do	..	..	9-7-50	..	30-7-50*	21
45	do	12	9-7-50	17-7-50	8	21-7-50	4
47	do	22	9-7-50	21-7-50	12	31-7-50	10
50	do	13	9-7-50	18-7-50	9	22-7-50	4
56	do	12	10-7-50	18-7-50	8	22-7-50	4
63	do	..	..	10-7-50	..	22-7-50*	12
66	do	..	..	10-7-50	..	22-7-50	12
36	*Moina*	..	..	8-7-50	..	17-7-50*	9
61	do	13	18-7-50*	22-7-50	4	31-7-50	9

VII—(*Contd.*)

Maximum number per litre of water	Other zooplankters simultaneously in swarm	Phytoplankters at peak of swarms	Remarks
2,273	nil	poor	
1,904	*Polyarthra, Filinia, Nauplii*	rich	
1,397	*Nauplii*	rich	
1,467	*Nauplii*	rich	
2,301	*Diaptomus, Nauplii*	moderate	* Very few in water
3,820	*Nauplii, Brachionus, Moina*	rich	
952	*Polyarthra, Filinia, Pedalia, Nauplii*	rich	
1,269	nil	rich	
1,079	*Nauplii*	moderate	
1,508	*Pedalia, Nauplii*	moderate	
1,936	*Keratella*	rich	
1,596	nil	fair	
1,461	nil	poor	
36,672	*Moina, Brachionus*	rich	
2,651	*Polyarthra, Pedalia, Filinia*	rich	* Swarms continue
2,079	*Filinia, Pedalia*	poor	
1,810	nil	rich	
2,081	nil	poor	
3,333	*Diaptomus, Pedalia*	moderate	
1,841	nil	very poor	*Swarm continues
3,630	*Brachionus, Polyarthra*	very poor	
12,988	*Cyclops, Nauplii, Brachionus*	rich	* Disappeared from water
1,270	*Brachionus*	rich	* Very few in water

blooms appear and disappear or markedly decline in a relatively short period. In the case of *Eudorina* this period ranged from 10 to 24 days, with the average at 16. The duration of the bloom and the concentration of algæ in water do not appear to show any consistent relationship. *Volvox* and *Microcystis* are the commonest algæ occurring with *Eudorina* simultaneously in bloom; *Closterium*, *Pediastrum*, *Crucigenia* and *Oscillatoria* are only occasionally found in bloom along with *Eudorina*. Blooms of *Volvox* occurred only in 6 out of the 30 ponds and the maximum concentration observed was 44,992 per litre of water. The duration of the blooms is similar to that in *Eudorina*. The only diatom that was observed in bloom was *Melosira*, and likewise, amongst the desmids blooms of *Closterium* also appeared in two ponds. *Pediastrum* appears to remain in bloom for slightly longer duration than *Eudorina* or *Volvox*. The densest blooms observed were those of *Microcystis* (19,92,064 per litre of water). The duration of these blooms appears to be somewhat longer than in *Eudorina* or *Volvox*. It is interesting to observe that in the 4 ponds in which *Anabæna* occurred in bloom, *Eudorina* and *Volvox* were not present simultaneously in bloom. It often happens that when two or three species of algæ occur simultaneously in blooms in a pond, irrespective of the groups to which they belong, all of them attain their peak also simultaneously. In pond 13 *Microcystis* (Myxophyceæ), *Eudorina* and *Volvox* (Chlorophyceæ) had their peaks on 1–8–1950; similarly, *Microcystis*, *Anabæna* and *Pediastrum* have also been observed simultaneously in peak in the same water. They do not therefore appear to occur to the exclusion of the rest, though they belong to different groups. The density of zooplankton at the peak period of algal blooms also does not indicate any consistent relation with the latter.

Among zooplankters also some of the organisms occasionally occur in appreciable numbers forming what may be called 'swarms'. A concentration of about 1,000 individuals of a species in a litre of water was considered to be of the nature of a moderate swarm of that species. The rhizopod protozoan *Difflugia*, the rotifers *Brachionus*, *Keratella*, *Filinia*, *Polyarthra* and *Pedalia*, the copepods *Cyclops* and *Diaptomus* and their nauplii and the cladoceran *Moina* are some of the zooplankters encountered in swarms. Available data on their occurrence in the different ponds are given in Table VII.

The zooplankters multiply very rapidly and some of the rotifers particularly, starting from stray specimens, appear in swarms within 4–6 days, but during the succeeding 7–8 days the species might even altogether disappear from the collections. The total duration of the swarms of the different zooplankters is not unlike that of the phytoplankters; the swarm appearing and disappearing in the course of 12–22 days. More than one species often occur in the same water simultaneously in swarms. Among the rotifers *Brachionus, Filinia, Polyarthra* and *Pedalia* have been observed in swarms simultaneously together with *Cyclops,* copepod nauplii and also *Moina.* Nauplii are very often found in swarms and occur with most other zooplankters which, therefore, do not appear to exclude each other. The concentration of phytoplankton does not seem to show any consistent relation to the zooplankton swarms, the former ranging from 'very poor' to 'rich' when the swarms are at their peak.

IX. Survival of Fry

(a) In Laboratory Aquaria

Given ideal conditions like abundance of desired food and absence of all enemies, even a hundred per cent survival of fry has been obtained in aquaria during the first week of rearing (Alikunhi, 1952). Subsequent experiments have not only confirmed this observation but have further indicated that, if completely protected from enemies, small fluctuations in the availability of food not only do not affect the rate of survival very much but lead to the survival of 70–90 per cent of the fry. It is therefore obvious that, if the favourable conditions in laboratory aquaria could be reproduced in nursery ponds, the fry stocked in them should largely survive. In other words, when the numerous fish enemies in the pond are effectively controlled and sufficient zooplankton is produced in the water, the favourable conditions will largely approximate to those of the aquaria and a satisfactory harvest could reasonably be expected.

(b) In Cement Cisterns

An attempt was made to repeat the laboratory findings on a larger scale in cement cisterns. Four cisterns ($12' \times 6' \times 3'$ in diamensions), each with a 3" thick bottom layer of pond mud, were heavily manured with cowdung, the depth of water in each being maintained at $2\frac{1}{2}'$. The cisterns were kept covered with medium-meshed wire-net screens to prevent, as far as possible, the entry of predatory insects. Owing to the heavy manuring the water turned deep brown in colour, but within a few days it was teeming with zooplankton, particularly cladocerans. Fry were introduced when zooplankton was extremely rich. Dissolved oxygen in water at the time of stocking was very low, ranging from 0·8–1·4 ppm. only. Details of stocking and the rate of survival of fry are given below.

The observations in the laboratory aquaria are thus fully confirmed by the results obtained in the cement cisterns and there are indications that,

TABLE VIII

Details of fry stocked and survived in 4 cement cisterns at Cuttack during July–September 1951

Cistern No.	Area (acres)	No. of fry stocked	Date of stocking	Date of fishing	Total No. recovered	Percentage of survival
8	0·0016	6,000	28-7-51	(1) 6-8-51 (2) 23-8-51 (3) 8-9-51	5905	98·41
9	do	do	do	do	5865	97·75
10	do	do	do	do	5443	90·71
11	do	3,500	do	do	3474	99·25

when predators are eliminated, food probably becomes an overriding factor over all else, as quite a number of fry survived even when dissolved oxygen content of water was dangerously low, at least during the first 2–3 days after stocking. In the present case a plentiful supply of the 'main food' was available for several days after stocking, and when that was depleted the stock was largely thinned out.

(c) In Nursery Ponds

In spite of the very clear indications that control of aquatic insect predators and supply of desired food ensure satisfactory survival of fry, it is practically impossible under field conditions, at least at this stage, to effectively control aquatic insects. Systematic heavy manuring, as already detailed, will, however, provide ample food at least in some cases. Even if the ponds are stocked when zooplankton is rich, if insects are not properly controlled the rate of survival of fry would naturally depend largely on the number of insects present in the pond.

Full details of the fry stocked and the number survived, analysed species-wise, in 30 selected nursery ponds at Cuttack during 1950 are given in Table IX.

Excepting complete dewatering and elimination of all fish predators and also insects then present, no attempt was made to remove the insects that had populated the ponds during the interval between manuring and stocking. Though the survival of fry in some ponds was rather poor, it was quite satisfactory in several and exceedingly good in a few. The rate of survival of fry in the 30 ponds ranges from 11·7 to 88·2 per cent with the average at 46 per cent. The average production of early fingerlings per pond is just over 7,000.

During the 1952 stocking season an attempt was made to remove as many of the aquatic insects as possible by drag-netting the manured nurseries with a fine-meshed net a few days before stocking and to destory the insects so caught. Ponds were stocked when the water in them was rich in zooplankton. The production of early fingerlings per pond exceeded 10,000 and, generally speaking, when zooplankton was rich at the time of stocking the rate of survival was high.

Deliberate understocking of two ponds with 500 selected fry clearly demonstrated that, even though food was always plentiful for them and the rate of stocking was extremely low, the insect predators could destory almost 75 per cent. of them. Ponds which were poor in plankton at the time of stocking and which had submerged weeds in abundance generally gave poor returns.

On the basis of the percentage of survival of fry the ponds have been arranged into three groups as follows:—

Group	Percentage of survival of fry	Pond number
A. (good) ..	over 50	3, 6, 50, 52, 54, 56, 57, 58, 63, 68, 70 and 71
B. (fair) ..	30–50	13, 35, 36, 37, 40, 41, 45, 47, 53, 61, 67 and 69
C. (poor) ..	below 30	1, 4, 20, 43, 44, 62

If the tender fry released in the pond are able to survive the first 3–4 days after stocking they grow rapidly and attain a size at which they would be capable of escaping at least some of the common predatory insects. If the zooplankton in the water at the time of stocking and a few days thereafter is found to be sufficient for the sustenance of the fry stocked the marked differences in the survival of fry in the different ponds could largely be ascribed to the havoc caused by aquatic insects which more or less abound in all the ponds. An attempt was therefore made to correlate the zooplankton content in the different ponds during the first week after stocking with the rate of survival of fry, and the relevant data are given in Table X.

The number of zooplankters in the total volume of water was calculated from the counts per litre and the number per fry was calculated taking the total number stocked in the pond into consideration. It is seen from this that the average number of zooplankters available per fry in the three groups

TABLE IX

Percentage and species composition of fry survived in 30 selected nursery ponds at Cuttack during July–September, 1950 (Ponds grouped on the basis of Survival of Fry)

Group	Pond No.	No. of fry stocked	Period of rearing (days)	Number survived	Percentage of survival	Species Composition								Remarks
						Percentage				Number				
						Catla	Rohu	Mrigal	Others	Catla	Rohu	Mrigal	Others	
A	3	10600	67	8270	78·0	10·16	8·72	55·15	25·97	841	722	4567	2150	
	6	21200	27	18691	88·2	9·45	10·06	49·88	30·61	1766	1881	9323	5721	
	50	10600	44	8829	83·3	16·42	4·87	68·41	10·30	1450	430	6040	909	
	52	10600	45	3770	73·25	24·72	8·73	40·59	25·96	932	329	1530	979	The two ponds merged
	54	10600	45	11760		10·82	6·34	75·29	7·55	1272	746	8854	888	
	56	10600	46	5661	53·4	11·72	4·40	66·74	17·14	664	249	3778	970	
	57	10600	46	6318	59·6	8·31	3·58	77·33	10·78	525	226	4886	681	
	58	10600	49	5657	53·4	10·94	4·89	74·19	9·98	619	276	4197	565	
	63	31800	53	18135	57·0	21·64	23·92	45·13	9·31	3924	4338	8185	1688	
	68	21200	53	11977	56·5	18·37	6·78	64·95	9·90	2200	812	7779	1186	
	70	21200	22	17429	82·2	26·46	10·96	53·32	9·26	4611	1910	9294	1614	
	71	21200	22	11080	52·3	4·11	7·65	83·52	4·72	455	848	9254	523	

	13	21200	58	8741	41·2	37·99	4·11	52·91	4·99	3321	359	4625	436
	35	10600	19	4754	44·8	61·51	11·11	25·40	1·98	2924	528	1208	94
	36	10600	33	4574	43·1	26·10	14·39	44·75	14·76	1194	658	2047	675
	37	10 600	17	4359	41·4	5·83	13·58	75·89	4·70	254	592	3308	205
	40	10600	31	4814	45·4	26·70	12·90	50·08	10·32	1285	621	2411	497
	41	10600	37	3552	33·8	21·08	4·86	62·34	11·72	755	174	2233	420
	45	10600	39	3809	36·0	11·89	3·10	79·92	5·09	453	118	3044	194
	47	10600	41	5246	49·5	17·82	5·80	57·51	18·87	935	304	3017	990
	53	10600	45	4379	41·3	5·14	2·81	68·96	23·09	225	123	3020	1011
	61	10600	51	4795	45·2	13·41	7·22	64·31	15·06	643	346	3084	722
	67	15900	55	6731	42·3	8·16	1·16	68·86	21·82	549	78	4635	1469
	69	42400	21	17291	40·8	21·02	11·36	55·90	11·72	3635	1965	9665	2026
C	1	21200	66	2992	14·1	23·96	6·52	58·86	10·66	717	195	1761	319
	4	21200	120	2572	12·1	23·02	15·43	35·11	26·44	592	397	903	680
	20	10600	99	1313	12·4	28·48	0·91	11·20	59·41	374	12	147	780
	43	10600	38	2547	24·0	15·98	2·12	75·97	5·93	407	54	1935	151
	44	10600	39	1238	11·7	6·06	3·87	76·98	13·09	75	48	953	16[illegible]
	62	5300	52	887	16·8	7·00	1·35	89·85	1·80	62	12	797	16

Table X

Data showing zooplankton content during the first week after stocking and the rate of survival of fry in 30 selected nursery ponds at Cuttack during July, 1950

Group	Pond No.	No. of zooplankters available per fry in total volume of water		Concentration of zooplankters in unit volume (1 litre) of water		No. of fry stocked	No. of fry survived	Percentage of survival	Remarks
		1 day after stocking	5 days after stocking	1 day after stocking	5 days after stocking				
A	3	7408	16994	1443	2403	10600	8270	78·0	No algal bloom
	6	5915	21324	1036	3323	21200	18691	88·2	do
	50	26013	6551	3221	590	10600	8829	83·3	do
	52	18475	9877	2128	876	10600	3770	73·25	do
	54	24761	14573	2727	1237	10600	11760		
	56	62865	4272	9603	566	10600	5661	53·4	Thin bloom of *Volvox*
	57	25786	22209	1980	1389	10600	6318	59·6	do
	58	18300	3261	1868	294	10600	5657	53·4	No algal bloom
	63	6548	7814	1977	1832	31800	18135	57·0	do
	68	17426	12253	4126	2296	21200	11977	56·5	No bloom
	70	6477	7796	1229	1202	21200	17429	82·2	No bloom
	71	7775	12962	1243	1687	21200	11080	52·3	Thin bloom of *Eudorina*

B	13	1446	11298	170	1586	21200	8741	41·2	Thick bloom of *Microcystis*
	35	12568	13300	1139	1051	10600	4754	44·8	
	36	31627	21832	2586	1453	10600	4574	43·1	
	37	15463	10046	1230	617	10600	4359	41·4	
	40	13920	17400	1016	1140	10600	4814	45·4	
	41	38497	16303	3835	1410	10600	3582	33·8	
	45	80285	31212	6355	2159	10600	3809	36·0	
	47	31770	41042	2476	2794	10600	5246	49·5	
	53	46619	27132	2300	1032	10600	4379	41·3	
	61	19711	99679	1471	6061	10600	4795	45·2	Bloom of *Microcystis*
	67	20067	6092	2668	706	15900	6731	42·3	Bloom of *Eudorina* developing
	69	5507	6115	1947	1673	42400	17291	40·8	Bloom of *Eudorina*
C	1	6844	9072	2780	2746	21200	2922	14·1	Algal bloom developing
	4	10582	6547	3607	1716	21200	2572	12·1	No algal bloom
	20	26349	17549	3048	1398	10600	1313	12·4	
	43	35341	163058	3173	12696	10600	2547	24·0	Very thick bloom
	44	12708	10054	1230	752	10600	1238	11·7	
	62	29991	20056	1975	823	5300	887	16·8	

TABLE XI

Data on early growth of carp fry in 30 selected nursery ponds at Cuttack During July–September, 1950

Group	Pond No.	Total population	Period of rearing	Average length in mm.				Average weight in gm.			
				Catla	Rohu	Mrigal	Others	Catla	Rohu	Mrigal	Others
A	3	8270	67	62·6	90·71	51·4	65·4	3·25	10·17	1·53	4·17
	6	18691	27	35·57	31·95	27·67	29·1	0·48	0·46	0·238	0·36
	50	8829	44	45·11	50·2	38·19	43·5	1·94	2·6	0·52	1·01
	52	3770	45	53·71	47·035	42·15	45·89	1·84	1·15	1·1	2·12
	54	11760	45	48·1	42·2	44·17	54·08	1·49	0·98	1·37	2·56
	56	5661	46	47·13	47·7	43·15	54·38	2·27	3·25	0·68	2·286
	57	6318	46	70·57	69·11	68·4	68·35	5·04	3·72	3·17	3·73
	58	5657	49	60·97	62·6	49·14	62·17	4·35	3·78	1·26	2·98
	63	18135	53	51·97	54·03	43·98	53·67	2·19	2·4	0·85	1·69
	68	11977	53	50·6	51·6	46·[illegible]	56·87	2·26	1·51	1·33	2·0
	70	17429	22	34·76	30·69	26·8	33·0	0·45	0·36	0·195	0·64
	71	11080	22	57·25	48·0	36·21	35·16	2·5	1·64	2·55	2·608

B	13	8741	58	54·92	60·64	57·5	71·2	2·45	3·61	2·16	4·25
	35	4754	19	43·82	30·63	29·65	31·6	1·17	0·32	0·26	0·25
	36	4574	33	40·82	35·0	45·97	43·31	1·13	0·565	0·99	0·86
	37	4359	17	32·5	27·85	29·17	31·0	0·355	0·285	0·155	0·325
	40	4814	31	49·35	42·24	49·03	45·3	1·43	0·97	1·06	0·89
	41	3552	37	81·31	77·5	63·28	60·53	7·71	5·89	2·99	2·47
	45	3809	39	80·73	92·8	60·1	75·6	8·77	10·96	2·51	5·74
	47	5248	41	77·0	72·75	55·5	52·14	6·7	4·99	1·92	2·245
	53	4379	45	122·93	107·5	82·05	53·8	24·44	17·58	6·17	2·85
				48·17	38·75	41·3	··	1·43	0·87	0·926	··
	61	4795	51	73·23	72·9	57·94	64·62	4·9	6·19	1·95	2·72
	67	6731	55	95·9	118·6	58·81	74·27	12·78	22·8	4·53	4·52
	69	17291	21	39·97	40·25	28·25	32·7	0·87	0·8	0·39	0·51
C	1	2992	66	60·8	88·38	61·23	68·37	4·34	7·94	2·39	3·82
	4	2572	120	62·77	95·76	55·81	74·4	4·61	3·67	1·58	3·95
	20	1313	99	61·8	107·4	44·25	51·69	4·5	17·5	1·1	1·58
	43	2547	38	96·83	100·16	64·65	60·92	13·27	14·12	3·01	2·66
	44	1236	39	149·42	103·75	84·05	77·69	57·38	15·9	7·29	5·46
	62	887	52	140·14	136·8	87·25	83·0	43·3	33·9	7·61	5·85

(Average length of fry at the time of stocking = 6·41 mm.)

TABLE XII

Data on the fish productivity of 30 selected nursery ponds at Cuttack, during July–September, 1950

Group	Pond No.	Period of rearing (days)	Number of fry survived	Actual weight (gm.) of fish produced					Actual average production per day (gm.)	Production (lb.) per acre	
				Catla	Rohu	Mrigal	Others	Total		During the period	Average per day
A	3	67	8270	2733·25	7342·74	6987·51	8965·50	26029·00	388·5	819·00	12·22
	6	27	18691	847·68	865·26	2418·87	2059·56	6191·37	229·3	170·37	6·31
	50	44	8829	2813·00	1118·00	3140·80	918·09	7989·89	181·6	179·5	4·08
	52	45	3770	1714·88	380·00	1683·00	2075·48	5853·36	254·3	271·06	6·02
	54	45	11760	1901·64	731·08	12229·98	2273·28	17035·98	..	..	..
	56	46	5661	1507·28	809·25	2569·04	2217·42	7102·99	154·4	177·78	3·86
	57	46	6318	2646·00	840·72	15488·62	2540·47	21515·47	467·7	464·61	10·10
	58	49	5657	2692·65	1044·66	5311·20	1683·70	10652·21	217·4	266·62	5·44
	63	53	18135	8593·56	10411·20	6998·17	2858·72	28855·65	544·4	567·48	10·70
	68	53	11977	4972·00	1226·12	10346·07	2372·00	18916·19	356·9	389·4	7·34
	70	22	17429	2074·95	687·60	1822·33	1039·42	5624·30	255·6	130·4	5·92
	71	22	11080	1137·50	1394·96	23597·70	1363·98	27494·14	1249·7	555·59	25·26

B	13	58	8741	7891·45	1295·99	9990·00	1853·00	21030·44	362·6	579·00	9·98
	35	19	4754	3421·06	168·96	314·08	23·50	3927·62	206·7	78·64	4·14
	36	33	4574	1349·22	371·77	2026·53	580·50	4328·02	131·1	91·66	2·78
	37	17	4359	90·17	133·20	512·74	66·62	802·73	47·2	15·37	0·904
	40	31	4814	1837·55	602·37	2555·66	442·33	5437·91	157·05	123·48	3·43
	41	37	3582	5821·05	1024·86	6676·67	1039·50	14562·08	393·5	305·47	8·25
	45	39	3809	3975·07	1293·28	7640·44	1113·56	14022·75	359·55	266·26	6·82
	47	41	5246	6264·50	1516·96	5792·64	2222·55	15796·65	385·28	302·55	7·37
	53	45	4379	4808·70	992·64	21371·14	859·35	28031·83	622·9	551·28	12·23
	61	51	4795	3150·70	2141·74	6013·80	1966·73	13272·97	260·25	261·03	5·12
	67	55	6731	7016·22	1778·40	20996·55	6639·88	36431·05	662·38	736·18	13·38
	69	21	17291	3162·45	1572·03	3769·35	1033·26	9537·06	454·14	187·56	8·93
C	1	66	2922	3111·78	1548·30	4208·79	1218·58	10087·45	152·84	370·16	5·61
	4	120	2572	2729·12	4037·49	1381·59	2835·60	10963·80	91·53	403·16	3·36
	20	99	1313	1683·00	210·00	161·70	1232·48	3277·18	33·1	112·8	1·14
	43	38	2547	5400·89	762·48	5824·35	401·66	12389·38	326·03	239·37	6·3
	44	39	1238	4303·50	763·20	6947·37	884·52	12898·59	330·7	275·83	7·07
	62	52	887	2684·60	406·80	6069·15	93·60	9254·15	177·9	199·83	3·84

of ponds (A, B, C) are 18,979, 26,458 and 20,302 respectively a day after stocking and 11,657, 25,121 and 37,722 respectively 5 days after stocking. Ponds in which a larger percentage of fry survived had lower plankton density than those in which the survival was lower. In the low survival ponds plankton has therefore been adequate and in spite of this the survival was low. The low survival itself could be one of the reasons for the higher plankton density, but there are no apparent reasons for the initial mortality of fry in these ponds as zooplankton was adequate at the time of stocking. The depredation by the aquatic insects and the differences in their population in the different ponds would therefore appear to be the major factor responsible for the low survival of fry in ponds of groups B and C. It should, however, be noted that algal blooms were remarkably poor in ponds of group A, while blooms were common and dense in ponds of groups B and C. Definite conclusions are, however, not permissible since all the relevant factors governing survival of fry were not under control.

X. Growth and Production

Table XI gives complete data on the average length and weight attained by the different species of fishes at the time of fishing, in relation to the total fish population in the pond. This and Table IX, if studied together, will give a clear idea of the relative growth of each species in relation to its own population in the pond. In most cases disparity in size in any particular species in comparable ponds could easily be attributed directly to its population; *e.g.*, in pond 6, in 27 days *Catla* attained an average length of 35·57 mm. The population of *Catla* in the pond was 1,766. In pond 71, within 22 days, *Catla* attained a much larger average length of 57·25 mm., but the number of *Catla* in that pond (455) was only about one-fourth that in pond 6. On the other hand, the 39·97 mm. length of *Catla* in 21 days in pond 69 is decidedly a much quicker growth than in pond 6 as the *Catla* population in the former was 3,635. A critical study of the growth of the different species in relation to the plankton content of the ponds is likely to yield interesting information on the natural food preference of the species.

In nursery ponds production of the maximum number of fingerlings being the main aim, the weight of fish produced is of little significance, at this stage. However, details of actual production in terms of weight of fingerlings survived in the different ponds are furnished in Table XII. The maximum production of 555·59 lb. per acre during 22 days in pond 71, representing a daily average production of 25·26 lb. per acre, is perhaps quite a high rate of production.

The average fish production per acre in the three groups of ponds is as follows:—

TABLE XIII

Average fish production per acre in ponds of groups A, B and C

Group of Ponds	Period of rearing (days)	Total production (lb.)	Production per day (lb.)
A. *Good*; survival of fry above 50%	43·00	362·9	8·44
B. *Fair*; survival of fry 30–50% ..	37·25	291·54	7·82
C. *Poor*; survival of fry below 30%	69·00	266·8	3·48

Though the average daily production is apparently higher in ponds of group A when the duration of the rearing period is also considered, there is hardly any difference between these and the ponds of group B. Production in ponds of group C is, however, decidedly low.

When the total production of fish flesh is considered it should be remembered that the productive capacity of the tender fry is very much less than that of advanced fry. In view of this and particularly since the ponds were not all fished on the same day the growth and weight figures given in Table XII for the different ponds are not strictly comparable. A useful general picture alone could be had from the averages given.

XI. DISCUSSION

Successful rearing of the young carp fry released in nursery ponds is the most important fundamental problem in carp culture in India. As already detailed, at every stage of the various cultural operations starting from their collection from rivers these fry are usually subject to unfavourable conditions. Extreme care at all stages of operation, fully bearing in mind that the nursery problems confronting the pisciculturist are more akin to those of child welfare, is essential to ensure successful results. The detailed review of the possible causes of mortality of fry has enabled us to get a precise idea of the magnitude of the problem, besides indicating the lines along which we have to tackle the same. Defective methods have, no doubt, to be corrected and certain preliminary experiments in improvements of fry collection tackle (to be reported separately) already carried out have clearly indicated that the causes of injury during collection are real. Rearing of fry under almost ideal conditions in the laboratory and in cement cisterns, and information that certain items of plankton organisms are preferred to others as food have very strongly indicated the steps to be taken under field conditions so as to ensure maximum survival of fry.

Regular manuring of the ponds is essential to produce the quantity of fish food required for the fry. The basic rate of manuring adopted in 1950 was 10,000 lb. of cowdung per acre; while certain ponds were manured at 15,000 and 20,000 lb. per acre also.

It has already been pointed out that the phosphate concentration in these ponds steadily decreases as the fry grow in them. The corresponding decrease in zooplankton density is apparently striking (*vide* Text-Figs. 2, 4 and 6) though the decrease in the concentration of phosphates may be caused by adsorption in the bottom substratum, utilization by phytoplankton and dilution resulting from a steadily increasing depth of water owing to rains. During manuring and for about 2 weeks thereafter the depth of water in most of the ponds was low and if the phosphate contents during this initial stage in the different ponds are compared taking into account the prevailing depth of water, it is seen that the average phosphate level in ponds manured at 15,000 lb. of cowdung per acre is almost the same as in those manured at 10,000 lb./acre, though with slight increase in the level of water more phosphates are available in ponds manured at a higher dose. It is also seen that with a higher dose of manure the fish production is also increased (Table XIV). At 15,000 lb. of cowdung per acre the average fish production per day is about a pound per pond, but with 10,000 lb. the production is only half that quantity. No doubt these observations are to be confirmed and further the maximum dose of manure to be applied for maximum production is also to be ascertained by repeated experimentation.

Though the present observations cover only a limited period of about 2 months in a limited number (only 18 for physico-chemical factors) of ponds and therefore do not justify any conclusions, certain trends are seen when an attempt is made to correlate the average daily production of fish in these ponds with the prevailing physico-chemical factors (Table XV).

If the ponds are arranged in the order of increasing total alkalinity it is seen that the average pH, phosphate content and fish production are lower when the total alkalinity is low, but generally increase as the alkalinity increases. Thus when the average total alkalinity is high the average phosphate content, pH and fish production are also usually high. These trends appear to be in accord with the observations of Moyle (1949) who groups the ponds according to their total alkalinity and phosphate content and finds fish production steadily increasing till these reach certain levels beyond

TABLE XIV

Showing the quantity of fish produced in relation to the dose of chief manure applied in 29 nursery ponds at Cuttack during June–September, 1950

Pond No.	Dose of cowdung (lb./acre)	Aver. wt. of fish produced per day (gm.)	Average
1	10,000	152·80	
3	,,	388·50	
4	,,	91·53	
6	,,	229·30	
13	,,	362·60	
20	,,	33·31	236·8
35	,,	206·70	
36	,,	131·10	
37	,,	47·20	
40	,,	157·05	
52	,,	254·30	
53	,,	622·90	
54	,,	254·30	
56	,,	154·40	
57	,,	467·70	
41	15,000	393·50	
43	,,	326·03	
44	,,	330·70	
45	,,	359·50	
47	,,	389·28	
50	,,	181·60	458·64
63	,,	544·40	
67	,,	662·38	
68	,,	356·90	
69	,,	454·14	
70	,,	255·60	
71	,,	1249·70	
58	20,000	217·40	
61	,,	260·25	238·82

TABLE XV

Showing the relationship of fish production to the phosphate content, the total alkalinity and the pH in 18 nursery ponds at Cuttack during June–September, 1950

Pond No.	Average Total alkalinity (ppm.)	Average phosphate content (ppm.)	Average pH	Average fish production per day (gm.)
20	65·4	0·020	8·2	33·31
1	95·7	0·275	8·1	152·80
4	99·0	0·390	8·0	91·53
50	99·5	2·760	8·1	181·60
Averages ..	89·9	0·861	8·10	114·81
57	107·0	0·82	8·1	467·7
6	107·4	0·20	8·1	229·3
35	109·6	1·78	7·87	206·7
3	113·2	1·17	8·4	113·2
44	125·6	2·24	8·25	330·7
53	129·0	0·85	8·3	622·9
37	133·2	1·90	8·13	47·2
Averages ..	117·8	1·28	8·16	288·2
58	140·0	1·28	8·01	217·4
47	141·2	1·71	8·80	389·28
45	145·4	1·51	8·63	359·50
40	150·7	0·934	8·10	157·05
67	169·2	3·054	8·58	662·38
43	181·1	1·17	8·83	326·03
41	211·4	1·35	8·20	393·50
Averages ..	162·7	1·573	8·45	357·88

which there is little difference in the production or it even decreases. In the present case the pH also shows a direct relation to productivity. The optimum levels of the different factors in our ponds, however, remain yet to be elucidated.

The total alkalinity and the pH show some direct relation to the dose of cowdung and lime applied in the pond and also to the fish production in them (Table XVI).

TABLE XVI

Showing the interrelationship of fish production, dose of manures, the pH and the total alkalinity in 16 nursery ponds at Cuttack during June–September, 1950

Pond No.	Dose of cowdung (lb./acre)	Dose of lime (lb./acre)	Average pH.	Average total alkalinity ppm.	Aver. fish production per day (gm.)
3	10,000	100	8·4	113·2	113·20
6	„	„	8·1	107·4	229·50
57	„	„	8·1	107·0	467·70
35	„	„	7·87	109·6	206·70
37	„	„	8·13	133·2	47·20
40	„	„	8·1	150·7	157·05
1	„	„	8·1	95·7	152·80
4	„	„	8·0	99·9	91·53
20	„	„	8·2	65·4	33·31
Averages ..	10,000	100	8·11	109·1	166·55
41	15,000	150	8·2	211·4	393·50
43	„	„	8·83	188·1	326·03
44	„	„	8·25	125·6	330·7
Averages ..	15,000	150	8·42	175·0	350·08
50	15,000	200	8·1	99·5	181·60
45	„	„	8·63	145·6	359·50
47	„	„	8·80	141·4	389·28
67	„	„	8·58	169·2	662·38
Averages ..	15,000	200	8·53	139·0	398·19

With 10,000 lb. of cowdung and 100 lb. of lime per acre, the average pH, total alkalinity and fish production remain comparatively low. At 15,000 lb. of cowdung and 150 lb. of lime the average fish production is more than double the former. The pH and the total alkalinity are also higher. The pH shows further increase when the dose of lime is increased to 200 lb./acre and the fish production is the highest, being about 400 gm. per day per pond. The average total alkalinity, however, remains lower than in ponds manured with 15,000 lb. cowdung and 150 lb. of lime.

In several of the ponds, though an abundance of zooplankton was available, the survival of fry stocked in them was low. While the algal blooms in ponds of groups B and C would, no doubt, have caused extreme fluctuations in the physico-chemical factors in water, perhaps to the detriment of the fry, the rather heavy rates of mortality cannot be fully accounted for by such fluctuations alone. The only other factor of importance which was not under control in these ponds is the harm done by aquatic insects.

Control of aquatic insects has thus become most important to ensure satisfactory survival of fry. Until this is achieved satisfactorily the survival of large number of fry in any pond should, to a large extent, be due to the coincidence of a minimum insect population in the pond with rich plankton at the time of stocking. The relatively low rate of survival in certain ponds which had an abundance of zooplankton at stocking has to be attributed to an abundance in insect population.

The strong indication from the laboratory and cistern observations about the important role of zooplankton has been partly substantiated by the fact that all the ponds which have given high rate of survival of fry had an abundance of zooplankton at the time of stocking and that their phytoplankton content was low not only at the time of stocking but practically throughout the whole period of rearing. Absence of algal blooms in these ponds is remarkable and significant.

Zooplankters are preferred by the tender fry and are easily digested (Alikunhi, 1952). Planktonic algæ are not only not utilized as food but they are difficult to digest also. Abundance (bloom) of algæ in water also often brings in fatal changes in the water conditions (Alikunhi *et al.*, 1951). It is now seen that when dry weight is considered, planktonic algæ weigh decidedly less than zooplankters. Weight for weight fresh phytoplankton, besides being less easily assimilable, might also be less nutritive than zooplankton. Available information on the chemical composition of certain phyto- and zooplankton organisms (Welch, 1952, pp. 273–275) also tends to show that the nutrient value of phytoplankters is generally less than that of zooplankters.

The average survival of 46 per cent. of the fry stocked in 1950 in the experimental ponds indicates approximately 500 per cent. increase over the previous year's figure.

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215	Line 5	Three pounds	5–4 pounds
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244	,, 20	212–33 mm.	212–330 mm.
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254	,, 24	*Badis buchanani* (Hamilton)	*Badis buchanani* Bleeker
254	,, 25	*Nandus marmoratus* (Cuvier & Valenciennes)	*Nandus marmoratus* Cuvier & Valenciennes
263	,, 10	*Chela labuca* Hamilton	*Chela laubaca* Hamilton
266	,, 1	*Family* Apogonidæ	*Family* Ambassidæ
266	,, 2	*Apogon gymnocehalus*	*Ambassis gymnocephalus*
297	,, 9	dehydraion	dehydration
307	,, 36	Panæids	Penæids
319	,, 14	si	is
324	,, 33	Plate VIII, Fig. 2	Plate VII, Fig. 2
331	Last line	hat	that

Growth of fry in the different ponds has been satisfactory. In ponds which had algal blooms, the relatively smaller number of fry which survived grew quicker probably because of the availability of large quantities of decaying algæ to feed on. Considered as a short term crop the production has been exceedingly high in certain ponds and should be attributed to the enhanced production of plankton consequent to systematic manuring.

In spite of systematic manuring, production of a swarm of zooplankters in the pond at the desired time is still a matter of chance only. The indication that application of cowdung in cisterns in heavy doses usually results in the early production of zooplankton swarms might well be worth trying in natural nursery ponds.

XII. Summary

1. A critical study of the existing practices of fry collection, conditioning, transport and stocking at Cuttack, Orissa, has been made, and the possible sources of injury to and causes of mortality of the tender carp fry during these operations have been indicated.

2. The general lay-out of the Zobra and Killa experimental nursery ponds (numbering 71 in all) has been described.

3. Details of the kind, dose and quantity of organic and inorganic manures applied in 30 nursery ponds have been tabulated.

4. Physico-chemical data relating to 18 ponds, collected at weekly intervals during the large-scale fry rearing operations in the ponds, have been tabulated and discussed in detail.

5. A preliminary attempt has been made to correlate the dose of manure applied with the time taken for plankton production, and that during which high plankton production was maintained. The dose of manure applied and the important physico-chemical factors (pH, alkalinity, phosphate content) have been correlated with the fish production in the pond.

6. Detailed analysis of plankton in terms of fluctuations in volume, in number and in dry weight have been made from all the 30 ponds during the period of rearing, for purposes of possible correlation with the survival and growth of carp fry in them.

7. The common algæ forming water blooms and zooplankton organisms occurring in swarms have been listed and the duration of blooms and swarms and their associations have been indicated.

8. Rearing of carp fry in large cement cisterns under semi-natural but almost completely controlled conditions has resulted in over 95 per cent survival of fry, indicating that an abundance of zooplankton and absence of predators largely ensure maximum survival of the stock.

9. Data relating to the survival and growth of fry stocked in the 30 selected ponds have been presented and discussed in detail, the general trends confirming the cistern observations in spite of obvious limitations under field conditions.

10. The necessity for eradicating predatory aquatic insects from nursery ponds before stocking fry has been discussed and emphasised.

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XIV. References

Alikunhi, K. H. 1952 .. On the food of young carp fry, *J. zool. Soc. India*, **4** (1): 77–84.

———, Ramachandran, V. and Chaudhuri, H. 1951 Mortality of carp fry under supersaturation of dissolved oxygen in water. *Proc. nat. Inst. Sci. India*, **17** (4): 261–64.

———, Chaudhuri, H. and Ramachandran, V. 1952 Response to transplantation of fishes in India with special reference to conditions of existence of carp fry. *J. Asiat. Soc. (Sci)*, **18** (1): 35–53.

——— and Chaudhuri, H. The role of 'weed fish' in the economy of carp nurseries and stocking ponds (unpublished).

Carbine, W. F. 1948 .. Bangos culture in the Philippines. *Progr. Fish Cult.*, **10** (4): 187–197.

Hopstede, A. E., Ardiwinata, Pr O. and Botke, F. 1953 Fishculture in Indonesia, *Indo-Pacific Fish Coun. Spl. Publ.* No. 2.

Hora, S. L. 1948 .. Role of vegetation in fishery tanks. *Sci.* and *Cult.*, 7 (8): 324–27.

Krumholz, L. A. 1949 .. Rates of survival and growth of Bluegill yolk fry stocked at different densities in hatchery ponds. *Trans. Amer. Fish. Soc.*, **76** (1946): 190–203.

Lin, S. Y. 1949 .. Notes on fish fry industry of China. *Proc. Indo-Pacific Fish. Council*, 1st Meeting, Singapore, 65–71.

———, 1950 .. Fish culture in ponds. A handbook of existing practices in South East Asia and the Far East, F.A.O. of the U.N. Washington D.C., U.S.A. (Photostat copy of manuscript), p. 56.

Moyle, John, B. 1949 .. Some indices of lake productivity. *Trans. Amer. Fish. Soc.*, **76**, (1946): 322–334.

Prashad, Baini. 1919 .. Notes on carp culture in Bengal, Bihar and Orissa, *Bull. Dept. Fish. Beng., Calcutta*, **13**.

Schuster, W. H. 1952 .. Fish-culture in brackish water ponds of Java. *Indo-Pacific Fish. Coun. Spl. Publ.* No. 1.

Smith, E. V. and Swingle, H. S. 1943 Percentages of survival of Bluegills (*Lepomis macrochirus*) and large mouth Black Bass (*Huro salmoides*) when planted in new ponds. *Trans. Amer. Fish. Soc.*, **72** (1942): 63–71.

Tal, S. and Shelubsky, M. 1952 Review of the fish farming industry in Israel. *Trans. Amer. Fish. Soc.*, **81** (1951): 208–213.

Welch, Paul. 1952 .. *Limnology* (2nd Edn.), McGraw-Hill Book Company, New York.