zooplankton swarms, might well be worth trying in natural nursery ponds.

Though only a few of the important factors causing mortality of fry were eliminated in the field experiments in 1950, on an average 46% of the fry stocked survived in the nursery ponds, indicating approximately 500 per cent increase over the previous year's average.

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ON THE PLANKTON OF THREE FRESHWATER FISH PONDS IN MADRAS CITY, INDIA

by

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In Madras State there are innumerable ponds, tanks, wells and other types of inland waters, which if properly utilised would provide an ample supply of fish. The total area of these waters is about 900,000 acres. The Madras Fish es Department has a programme for their progressive utilisation for fish culture. The plankton of many of the waters has been studied at the Freshwater Fisheries Research Station, Madras, since 1942 and reported briefly in the annual progress reports (Job 1943 and 1944; Choodamani, 1945, Alikunhi, 1946, 1947 and 1949; and Chacko 1949, 1950, 1951 and 1953). The present communication is a comprehensive account of the common plankters of three freshwater ponds in Madras City and their seasonal and diurnal variations with reference to climatic and physico-chemical conditions, and of the productivity of the waters.

Materials and Methods

The three ponds in Madras City studied by us are ponds Nos. I and IV of Chetpet fish farm and the Gangadhareswarar temple pond in Puraswalkam Municipal division. Pond No. I is circular and has a circumference of 150 ft. The water in it is 6 feet in the wet season, 5 feet or even less in summer (April and May). Pond No. IV is rectangular, 200′ long and 75′ broad. Its depth also varies from 6′ to 3′ as in the pond I. The Gangadhareswarar temple pond is rectangular, 180′ long and 150′ broad. It is deeper in the middle and shallower along the margins; and its depth varies from 3.5 to 5.0 feet. All the three ponds have no inlets and outlets, depending on rainfall and sub-soil for their water supply.

Plankton from ponds I and IV was collected at 6 a.m. on a day in the first week of every month. The tow net used was of the international standard type and made of 178 mesh bolting silk. Each haul was taken across the longer axis of the ponds in both directions. The haul was then preserved with 5% formalin and sedimented. This was then transferred to the measuring jar and this volume was made up to 10 cc.

Materials for study of diurnal variations were collected from pond IV and the Gangad areswarar temple tank. The samples were collected both from the surface and bottom by means of 500 cc stoppered bottles. The bottom samples were collected by the simple deep sample collector described by Whipple *et al.* (1947). The collections were taken to the laboratory and filtered through 21x bolting silk. Five per cent formalin was added to this filtered plankton to bring the volume to 10 cc.

For a quantitative analysis of the zooplankton, the tube containing the 10 cc plankton collection was shaken well and 1 cc of it removed and spread evenly in a thin layer on a plankton-counting rafter and the number of organisms of each species was counted. For the analysis of the minute phytoplankton a slightly different method was used. After shaking the tube containing the 10 cc plankton collection, a small quantity was drawn into a capillary tube and one drop delivered on to a glass slide and covered with a cover-slip. The number of organisms of each species was counted under a microscope and the number in one cc computed by multiplying by 130, as 130 drops delivered from

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the capillary tube made 1 cc. The number of both phytoplankters and zooplankters thus obtained per cc multiplied by ten would give the total number of organisms in the entire haul.

Physico-chemical analysis of the water of the ponds was made as per the procedure of the American Public Health Association (1946).

Climatic Conditions

In Madras City the rainfall ranges from 35 to 40 inches distributed over 70-75 days. The climatological data for Madras City for a period of one year (1949-50) were studied with the monthly averages and range of variation of daily temperature, hours of bright sunshine, relative humidity and rainfall. The conspicuous features of the hot weather period were high temperature (maximum 42°C), a moderate rainfall of 10.24 inches and maximum number of hours of bright sunshine. The south-west monsoon period had much fewer hours of bright sunshine, moderately high temperature, and a rainfall of 18.93 inches. Moderate hours of bright sunshine, low temperature and a rainfall of 10.32 inches prevailed during the northeast monsoon season. Relatively more hours of bright sunshine, low temperature and scanty rainfall were features of the cold weather period. The percentage of relative humidity varied little (66.07 to 80.2) during the period of study.

Seasonal Fluctuations of Plankters

The frequency of the dominant planktonic organisms and the range of variation in the physico-chemical conditions in ponds I and IV of the Chetpet fish farm during the quinquennium 1947-48—1951-52 were also studied.

In 1947-48, there were two maxima for phytoplankton and zooplankton, occurring in June-July and November-December. A rich bloom of *Pediastrum* was characteristic of the phytoplankton in pond I during the period of maximum. Zooplankton represented by the copepods and cladocerans swarmed the waters during the peak periods. Pond IV had an almost permanent bloom of *Microcystis* besides a fair representation of a variety of other planktonic algae. The zooplankton was also rich. The maximum water temperature was recorded in the hot months (April and May) and the lowest temperature in December and January. The high pH value (8.3—9.1) and the supersaturation of dissolved oxygen in Pond IV are possibly the results of the almost permanent algal blooms in it. Chloride was generally low in both ponds.

In 1948-49, there were two maxima in July-August and in October in Pond I, and in May-June and November-March in Pond IV. The predominant organisms were *Gomphosphaerium*, *Eudorina* and *Navicula* in the former pond and *Microcystis*, *Oscillatoria*, *Melosira*, *Nitzschia* and *Synedra* in the latter. The maximum temperature was recorded in May and September; and the pH ranged from 7.7 to 8.8. Both the ponds were supersaturated with dissolved O_2 in May, 1948, and March, 1949.

In 1949-50, there was a maximum in May-June, and another in November-January in Pond I, the predominant organisms being *Anabaena*, *Ankistrodesmus*, *Navicula* and *Staurastrum*. In Pond IV the maxima were in April-October and in January, the chief plankters being *Ankistrodesmus*, *Chlamydomonas*, *Navicula* and *Nitzschia*. The highest temperatures were recorded in April, May and September. The pH ranged from 7.1 to 9.2. The water of both the ponds was supersaturated in November.

In 1950-51, pond I was dry from May to September, and consequently plankton was poor in it. There was a bloom of *Anabaena* in February, 1951. In pond IV there was a maximum characterised by *Navicula* and *Cyclotella* in July-August, and another of *Navicula* and *Euglena* in March. The maximum temperature was recorded in April, 1950. The pH ranged from 7.8 to 8.3. The waters in ponds I and IV had very high dissolved oxygen content in the months of January, 1951, and March, 1951, respectively.

In 1951-52 there were blooms of *Euglena* in October and of *Navicula* in November and March in pond I. Zooplanktonic organisms were fairly represented. In pond IV, *Navicula* was present in good numbers throughout the year. There were peaks of *Cyclotella* in May and December, *Merismopedia* in June, *Anabaena* in July, *Oscillatoria* in September and March, and *Euglena* in October. Copepods and daphnids were the common zooplankters. The maximum temperature of 34.4° C was recorded in August, 1951, in pond I, and 36.4° C in July, 1951, in pond IV. The minimum temperature was noted in February, 1952, in both ponds. The pH ranged from 7.2 to 8.8.

The two ponds present a series of interesting changes in the plankters. There are frequent successions of blue-green algae, green algae, diatoms and euglenoids. The zooplankters exhibit only some slight periodicity and are not predominant over the phytoplankton. Generally there are two maxima in the plankton, one in the hot season and the other in the monsoonic wet season. Whipple *et al.* (1947) and Welch (1935) have attributed the cause of the seasonal distribution of phytoplankton to light and temperature. In South India and other tropical countries, unlike the temperate countries, there is bright sunlight almost throughout the year, and this explains the abundance of heliotactic plant organisms, which depend upon sunlight for their phytosynthetic activities. The optimum physico-chemical conditions such as dissolved oxygen, carbon etc., are also responsible for the rich plankton growth. The amount of plankton is greater in pond IV than in pond I and this high productivity is due to the excessive nutrients that are washed into it from the adjoining cattle shed.

Diurnal Variations

The diurnal variations at six-hourly intervals of ten typical organisms in pond IV of Chetpet fish farm were studied. It was seen that in the case of algal forms like *Pediastrum calthratum*, *Microcystis aeruginosa*, *Anabaena flosaquae*, *Scenedesmus acuminatus* and *Oscillatoria splendida*, the number is generally greater at the surface layer of the pond at 6 in the morning. This difference is reduced by 12 noon and at 6 p.m. the number becomes almost equal in both the surface and bottom layers. At midnight the number is more at the bottom than at the surface and this condition is suddenly reversed at 6 a.m. the next day. In the case of diatoms like *Navicula cuspidata*, *Nitzschia pallea* and *Synedra ulna*, diurnal variations more or less similar to that of the algae is noticed. But the important zooplankters, *Mesocyclops leuckarti* and *Brachionus falcatus*, show a different type of diurnal migration. They are more at the surface than at the bottom in the morning; and as the sun rises they go to the lower level at such a rapid rate that at 12 noon most of them are at the bottom. This condition is slowly reversed from sunset onwards until at midnight when there is a preponderance at the surface.

It is seen that the phytoplankters are more in the surface layers during daytime. This may be due to the preference of the chlorophyll-bearing organisms for the upper zone where the water is warm, the light strong and oxygen abundant. In the evening more or less homothermal conditions prevail and this is responsible for the uniform vertical distribution of the phytoplankters at about 6 p.m. Birge and Juday (1914, 1921 and 1922), working on vertical distribution of plankton in a number of Amercian lakes observed that the chlorophyll-bearing organisms were confined chiefly to the epilimnion where light conditions were favourable to their photosynthetic activities.

The zooplankters are more at the surface during the night and *vice versa* during the daytime in the two ponds investigated by us. This is because these organisms, which are capable of independent mobility, avoid the bright light and higher temperature of the upper layer. This phenomenon has already been explained in detail by Juday (1904), Russel (1927) Worthington (1931), Clarke(1933), Langford (1938), Ricker (1938) and Johnson and Raymont (1939).

Water Blooms

Blooms of one or more species of algae are characteristic of tropical waters. As explained earlier, *Chlorophyceae* and *Cyanophyceae* collect

Organism	Number per cc			
	Surface		Bottom	
Cyanophyceae :				
Microcystis	90 000	May	40 000	May
Merismopedium	40 000	May	1 000	May
Oscillatoria	2 250	July	3 600	July
Anabaena	1 350	February	570	July
Chlorophyceae :				
Ankistrodesmus	180	July	930	July
Scenedesmus	900	July	900	February
Pediastrum	570	July	nil	Throughout the year
Bacillariaceae :				
Nitzchia	38 700	July	45 900	July
Euglenophyceae :				
Trachelomonas	900	March	900	March

Table 1—Plankter incidence in surface and bottom.

near the surface, and in many cases they form unsightly and ill-smelling scums. Permanent blooms of *Microcystis* spp. is a feature of South Indian temple ponds and other waters where there is organic contamination. The hydrobiological conditions with reference to the vertical distribution of such a bloom in the Gangadhareswarar temple pond were studied for one year (April, 1949, to March, 1950), and the following are the salient features of results obtained.

The maximum numbers of the planktonic organisms observed per cc in the surface and bottom samples and the months in which they were noted are furnished in Table 1. The collection for these observations were made only at 11 a.m. on a day in the first week of the month.

Microcystis not only formed a bloom throughout the year but was the dominant organism in all the seasons with a maximum during the hot weather period when the temperature (34.2—42.8°C), pH (8.5—9.6), carbonates (3.42—6.56 p.p. 100,000), bicarbonates (10.73—20.31 p.p. 100,000), silicates (1.47—2.50 p.p. 100,000) and phosphates (0.163—0.38 p.p. 100,000) were found to be relatively high. During the period of study, temperature in the surface and bottom layers ranged from 25.6 to 42.8°C, and sunshine from 5.03 to 9.94 hours a day. Worthington (1943) observed that tropical waters are generally more productive on account of the high water temperature and lack of a winter season. The temperature of the bottom layer of water is relatively high as compared with the temperate region, and so the bacterial decomposition of the bottom deposits in tropical ponds must release large amounts of nutrient substances. These are carried to the surface probably by diurnal thermal stratification and diurnal turnover.

Plankton Production by Manuring

It has been observed that fertilisers increase the productivity of waters. Experiments conducted in the two fish ponds of the Chetpet farm in Madras City have proved that organic manure is superior to inorganic manures, especially when the bottom is sandy. Of organic fertilisers, diluted sewage is found to be the best, giving rise to blooms of algae and to remarkable growth of fishes like *Chanos chanos*, *Mugil cephalus* and *Etroplus suratensis*. Farm yard manure consisting of cowdung and hay was found useful for fish-ponds in which carps like *Catla catla* and *Cirrhina mrigala* are grown. Addition of ash to the cowdung was beneficial for balancing the pH of the water. A mixture of cowdung and ash generates blooms of *Oscillatoria*, *Scenedesmus*, *Euglena*, *Phacus* and *Brachionus* in the pond. The application of bonemeal at weekly intervals produced rich blooms, of *Pediastrum clathratum* and *Pediastrum duplex*. Ammonium sulphate, $(NH_4)_2SO_4$, was good for causing blooms of *Gomphosphaerium*, *Eudorina*, *Tribonema* and *Euglena*; and ammonium phosphate, $(NH_4)_3PO_4$, for blooms of diatoms like *Navicula*, *Cyclotella* and *Gomphonema*. A mixture of ammonium sulphate and ammonium phosphate increased production of the diatom *Cyclotella*. A combination of bonemeal with ammonium sulphate or ammonium phosphate and also a mixture of these three were found suitable for the development of *Oscillatoria*, *Navicula*, *Chlamydomonas*, and *Euglena*. Ammonium nitrate, NH_4NO_3, produced blooms of *Oscillatoria*, and ammonium chloride, NH_4Cl, of *Gomphosphaerium* and *Navicula*.

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FEEDING HABITS OF THE POND-SMELT, *HYPOMESUS OLIDUS* AND THE PLANKTON SUCCESSION IN LAKE SUWA

(PART I)

by

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ABSTRACT

1. The feeding habits of *H. olidus* was studied in the year 1951 referring to the succession of plankton in Lake Suwa, Nagano Prefecture, and the object of the study was directed to the filling of a gap in the information on the food-chain in the water as well as to obtaining the basic knowledge on which the management of the species could stand.

2. The pond-smelt, usually with only one year of life span, is economically the most important species, the annual catch amounting to one-third of the total fish production in the lake. Lake Suwa is 14.65 sq. miles in surface area with the average depth of 4.61 m, and 18 species of fish dwell in this eutrophic lake.

3. Samples of fish totalling 2,441 were collected monthly by cast net and gill net. The content of the stomach of each sample was examined qualitatively and quantitatively.

4. The pond-smelt in the lake was found to feed on 28 forms of both planktonic and benthic animals, of which *Bosmina*, *Cyclops*, *Leptodora* and *Diaphanosoma* were major items of food. Thus, the pond-smelt, *H. olidus* may be said to be a plankton feeder.

5. In the summer months, June to September, the fish was seen to eat more *Bosmina* than others, and in winter, September to April, *Cyclops* was the major food item, whereas the macro-plankters, *Leptodora* and *Diaphanosoma*, were eaten abundantly in August and September. The midge larvae *Chironomus* were eaten throughout the year, but they appeared in the fish stomach more abundantly in the months of June and October and during the winter months; the chironomid insect emerges in these two months from larval form to pupae and adult; the fish tends to dwell near the bottom during the winter months.

6. By weight, *Bosmina* and *Cyclops* were found to be much less significant than when they were considered numerically. The macro-plankton *Leptodora* and *Diaphanosoma*, however, did not lose the significance whether expressed in number or in weight. The chironomids, occupied 80% of stomach content in weight, probably forming a valuable nutritive element in the diet.

7. The amount of food taken by the fish varies from 10 to 80 mg at a time, and the fish are seen to eat more before the spawning season while the survivors after spawning continue to feed subsequently. The amount of food expressed in percentage of body weight is extremely high when the fish is in the juvenile stage, but it decreases with the growth of the fish.

8. The plankton of the lake showed spring and fall swarming in the year as in other lakes in Japan.

9. The amount of stomach content did not necessarily correspond to the abundance of plank-

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