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Title FISH PRODUCTION AND RELATED LIMNOLOGY IN TWO EXPERIMENTAL PONDS AS INFLUENCED BY FERTILIZATION

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The merits of fertilizing warmwater fish ponds with dry organic manure were studied from October, 1964 to November, 1965 using two experimental ponds in the Willamette Valley. One pond (pond II) was fertilized with urea and single superphosphate and the other (pond III) was fertilized with dried manure as well as with urea and single superphosphate. A study of the important environmental variables and the growth and production of largemouth black bass, Micropterus salmoides (Lacepede), was employed in an attempt to test the effects of fertilization with manure.

The addition of manure to pond III failed to produce any striking effects in the physical and chemical characteristics in the pond; however, some reduction in the dissolved oxygen content of the bottom water of pond III, as compared with pond II, was noted.

Nearly equal biomasses of limnetic microcrustaceans were observed in the ponds during the course of the experiment.

The added manure first appeared to stimulate the abundance and weights of chironomid larvae and pupae and then depress them. Numbers and biomasses of these insects in pond III were more than double those of pond II during the early portion of the experiment. After the spring emergence periods they became greatly reduced in pond III as compared with pond II.

The mean weights of the three size classes of largemouth bass in pond II were greater at every sampling period compared with the corresponding size classes in pond III. The survival of adult bass was higher in pond II than that of pond III. The differences in growth and mortality of bass between the two ponds was thought to be due to the reduction in chironomids in pond III in the latter portion of the experiment and the larger populations of the rough-skinned newt, Taricha granulosa granulosa (possible competitor with bass) in pond III.

The addition of steer manure to pond III appeared to be of little value in respect to bass production. The production of bass on an acreage basis was more than doubled in pond II over that of pond III, leading to the rejection of the hypothesis that addition of organic matter in the form of dry composted steer manure would increase the production of largemouth bass.

FISH PRODUCTION AND RELATED LIMNOLOGY IN TWO EXPERIMENTAL PONDS AS INFLUENCED BY FERTILIZATION

by

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INTRODUCTION

Objectives

Two warmwater farm ponds in the Willamette Valley were studied from October, 1964 to November, 1965 as part of the Oregon Agricultural Experiment Station Project 294, Limnology and Management of Oregon Farm Fish Ponds and Small Impoundments.

The relative merits of two fertilization programs for increasing fish production were examined. One pond was enriched with urea and single superphosphate and the other was fertilized with dried manure as well as with urea and single superphosphate. A study of important environmental variables and the growth and production of largemouth black bass, Micropterus salmoides (Lacepede), was employed in an attempt to determine the effect of treatments.

The two morphologically similar ponds lie parallel with one another, separated by a narrow dike. The ponds would be expected to support similar assemblages of organisms and be comparable in their capacities to produce fish, because past treatments have been similar. In conjunction with the different fertilization treatments, sampling programs were carried out in order to detect any influences on the physical and biological characteristics caused by the fertilizers.

All organisms living in a closed system, such as a pond, are dependent upon energy made available by green plants within the system. Plants are able to utilize some of the energy from sunlight in the process of photosynthesis. The available energy that is not utilized by the plants in respiration is stored as potential energy in the form of tissues. It is this energy that all other organisms rely on for their activities. Fish, which are the most valued organisms in farm ponds, are dependent on energy which is passed through several different types of organisms or "trophic levels". Respiration and decomposition at each level reduce the amount of energy which is available to the next level (Lindeman, 1942). This process produces a pyramid in the production of a community of organisms. The production of green plants is greater than that of the organisms that consume the plants. This relationship holds true at each step in the pyramid.

The hypothesis tested in this study was that increasing the energy base of a pond by the addition of preformed organic matter would increase the production of the top member of the pyramid in farm ponds. The position of top carnivore of the pyramid in the ponds was filled by largemouth bass. Organic matter added could conceivably be utilized by the organisms in the ponds in three different ways. Detritus-feeding organisms could consume particulate organic matter and thereby influence the community; decomposers could utilize the energy in the organic matter and thus increase the food base of organisms that feed on decomposers and also release elemental nutrients that could be utilized by plants; or, certain organisms such as microcrustaceans and chironomids could utilize dissolved organic material. Meehean (1939) stated that micro-crustaceans and chironomids may utilize dissolved proteins and carbohydrates directly, or through the action of bacteria and protozoa.

Description of Ponds

The experimental ponds are located approximately 7 miles north of Corvallis on Oregon State University land near Soap Creek. Eight ponds have been constructed on this land. The lower four (ponds I, II, III and IV) were excavated in 1958 and the upper four (ponds V, VI, VII and VIII) in 1962. Only ponds II and III were utilized in this study.

The ponds are rectangular in shape with the long axis oriented east and west. Pond II has an average depth of 3.3 feet, a surface area of 0.60 acres and a volume of 1.980 acre-feet. Pond III has an average depth of 3.8 feet, a surface area of 0.49 acres and a volume of 1.862 acre-feet. The bottoms slope gradually from a shallow west end to a deeper east end. Past experiments have been terminated by draining the ponds and recovering the existing fish populations. They are quickly refilled with direct precipitation and stocked for the next experiment. During the summer, water lost by seepage and evaporation is replaced by water pumped from nearby Soap Creek. Water was pumped into the ponds twice in 1965, once during the first week of July and once in the second week of August.

History of the Ponds

The ponds have been used for fish productivity studies since their construction and have contained populations of bluegills, *Lepomis macrochirus* (Rafinesque), and largemouth black bass. In April, 1962 the western mosquito fish, *Gambusia affinis* (Baird and Girard) was introduced as a forage species and has been present in both ponds since that time.

Fertilization

Table 1 shows the amounts of fertilizer that have been added to the ponds during previous experiments. Treatments of the two ponds have not differed significantly since 1960. Fertilization during the present experiment was carried out in the two ponds in such a manner that the effects of the addition of preformed organic matter on the limnology of the ponds could be assessed. The organic source was "Webfoot" brand dry composted steer manure. Samples of the manure were analyzed by the Department of Agricultural Chemistry, Oregon State University, for nitrogen content, and the Department of Soils, Oregon State University, for inorganic constituents (Table 2).

Table 1. Fertilization history of experimental ponds.

	Total lbs./acre added during 1958-1959 experiment		Total lbs./acre added during 1960-1961 experiment		Total lbs./acre added during 1962-1963 experiment		Total lbs./acre added during 1964 experiment	
Pond No.	Urea 40-0-0	Single super-phosphate 0-20-0	Urea 40-0-0	Single super-phosphate 0-20-0	Urea 40-0-0	Single super-phosphate 0-20-0	Urea 40-0-0	super-phosphate 0-20-0
II	139	---	594	900	660	1000	263	400
III	190	284	594	900	807	1225	263	400

Table 2. Analysis of organic fertilizer applied to pond II.

Substance	Percent total weight
dry matter	83.7
nitrogen	0.7
phosphorus	0.37
sulfur	0.35
potassium	1.40
magnesium	0.56
calcium	1.07
sodium	0.37
zinc	0.0078

During the experiment, pond II received 460.8 pounds per acre of urea (40-0-0) and 700 pounds per acre of single superphosphate (0-20-0). Pond III received 2,040 pounds per acre of steer manure. The manure contained substances other than organic matter (Table 2) so in order to assure that any differences in the ponds were due to the effects of organic matter and not to some other substance, amounts of nutrients added to both ponds were the same in all respects except for organic matter. Each pond received equal portions per acre of all important inorganic elements. The total amounts of these elements in the organic matter were calculated, adjusted to acreage and added to pond II. Therefore, pond II received 2.94 pounds per acre of zinc sulfate, 46.9 pounds per acre of potassium chloride, and 99.4 pounds per acre of magnesium sulfate to account for the zinc, sulfur, potassium and magnesium added to pond III in the steer manure. During the experiment 427 pounds per acre of urea (40-0-0) and 598 pounds of single superphosphate (0-20-0) per acre were applied to pond III. These amounts of nitrogen and phosphorus are equal to the amounts applied to pond II on an acreage basis when adjusted by the amounts in the organic manure.

The fertilizers were applied monthly with the first application on February 28, 1965 and the last on September 6, 1965 (Table 3). The pelleted fertilizers were broadcast into the shallow areas of

Table 3. Amounts of fertilizer applied to ponds in pounds per acre per month.

Pond No.	Steer manure	Urea 40-0-0	Single super-phosphate 0-20-0	Potassium chloride	Zinc sulfate	Magne-sium sulfate
II	0	66	100	6.7	0.42	14.2
III	291.8	61	85.5	0	0	0

the ponds by hand. The organic fertilizer was distributed into pond III by towing the sacks behind a small boat. Holes were made in the sacks and the manure was slowly washed from the bags. In this way the material was evenly spread throughout the entire pond.

Stocking

The ponds were stocked in the fall of 1964 with three age classes of largemouth black bass, all of which were hatched in the Soap Creek ponds. The oldest fish were hatched in May, 1961 and at the time of stocking averaged 248 grams in weight. The medium age class was hatched in May, 1963 and averaged 92.4 grams at the time of stocking. The small fish were young-of-the-year and averaged 2.8 grams each when stocked.

Pond II was stocked on October 31, 1964 and pond III was stocked on November 2, 1964 at the rate of 50 three-year-old fish per acre, 150 one-year-old fish per acre and 1,000 young-of-the-year per acre. Table 4 presents the stocking information for each pond.

Table 4. Numbers of fish stocked in experimental ponds.

Pond No.	Age classes 3+	1+	0+
II	31	90	651
III	26	75	546

METHODS

Temperature

Maximum-minimum thermometers were suspended in the southeast corner of pond III from a styrofoam float. One thermometer was installed 2 inches beneath the surface and the other directly on the bottom. A thermograph that continuously recorded bottom, surface and air temperatures was installed in the southwest corner of pond II. The thermometers were checked and reset weekly.

Water Chemistry

Weekly surface and bottom water samples were obtained from station C (Figure 1) in both ponds. Most samples were collected between 10 and 11 a.m. Dissolved oxygen samples were fixed immediately after taking and titrated the same day. Water samples obtained with a Kemmerer water sampler from the bottom of the ponds gave inconsistent results when analyzed for dissolved oxygen, because the sampler contained water from a layer of water which equaled the length of the Kemmerer tube. Several oxygen determinations from one Kemmerer sample could vary greatly. For this reason a sampler which permitted sampling of a precise depth, namely, 6 inches from the bottom, was used. A rubber tube with a lead weight attached was lowered to within 6 inches of the bottom

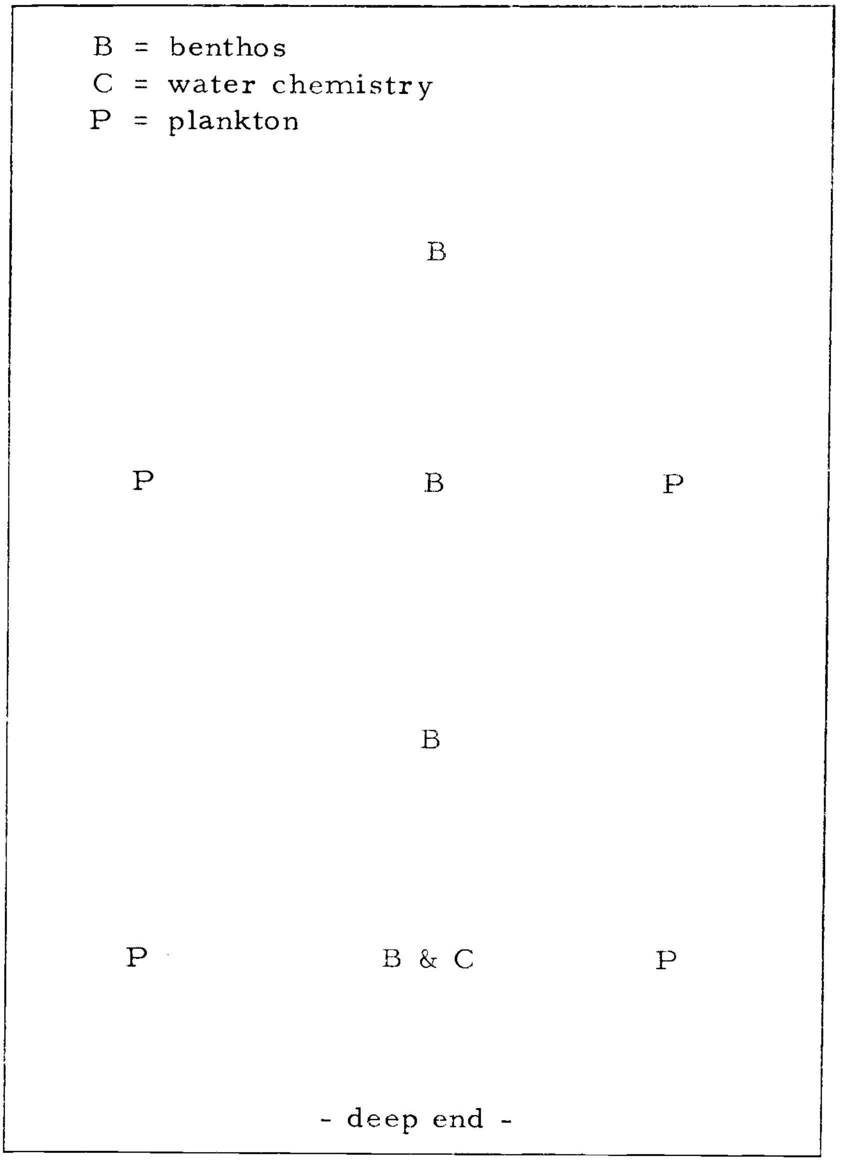

Figure 1. Sampling Stations in Ponds.

and a sample of water was drawn from this level using a small hand suction pump. All water samples taken from the bottom after June 26, 1965 were obtained by this method. Results of the chemical analyses are reported as surface and bottom values.

Chemical analyses included hydrogen-ion concentration (portable pH meter in the field), dissolved oxygen using the Alsterberg (azide) modification of the Winkler method outlined by the American Public Health Association (1955), phenolphthalein alkalinity and methyl orange alkalinity by titration with .02N sulfuric acid, total dissolved solids (American Public Health Association, 1955) and total phosphorus by the vanadate-molybdate-yellow method.

Biological Measurements (General)

Sampling began in February of 1965 and was continued until the ponds were drained in November of 1965. Biomasses of organisms important to trophic relationships in the ponds were estimated by weighing samples on a Mettler automatic balance, after being dried in an oven at 80°C.

Fish and Newts

Bass were sampled monthly beginning in March, 1964. A 200-foot bag-seine was used to capture the fish. One seine-haul the full length of the pond was usually sufficient to obtain an adequate sample. Seining was kept to a minimum to reduce the detrimental effects that seining might have on the pond community. The fish were taken from the seine, transferred to plastic holding tanks, anesthetized in Quinaldine, weighed to the nearest gram on a dietary scale, and measured (total length) to the nearest one-eight of an inch. Old marks were recorded and new ones applied. The fish were allowed to recover in fresh water before being replaced in the ponds. At the end of the experiment the ponds were drained and the total populations were weighed and measured.

During the first sampling period 20 bass of the medium and large size classes were marked with loops of monofilament nylon line. The line was inserted with a needle slightly posterior to the second dorsal fin, then pulled through the other side and both ends tied, making a loop. In subsequent sampling periods, numbered polyethylene dart tags were utilized as marks. Due to the frequent loss of the dart tags from the fish only the numbered tube portion of the dart tags, in combination with monofilament line, was used in the last three sampling periods. This tag resembled the monofilament loop marks, except that they were numbered and individual fish growth could be studied. Tags and applicators were soaked in zephiran chloride to reduce the possibility of infecting the fish during marking. The exact reason for the loss of dart tags could not be explained, but may have been to improper implantation. Fingerling bass were marked with combinations of fin clips. Processing of these fish differed only in this respect from that of the larger fish.

Two attempts to estimate mosquito fish populations were made by mark and recapture methods, one in April and one in July, 1965. The fish were captured by the use of fine-mesh seines. Fin clips were used as marks for the April estimate. The fish were returned to the ponds and were allowed to mix for a day before re-seining. In July the estimate was made by marking the fish with the dye, Bismarck Brown Y (Deacon, 1961). The value of the estimates obtained was questionable because of mortalities suffered by young fish in the dye solution and the loss of the dye color from the marked fish.

The rough-skinned newt, Taricha granulosa granulosa is commonly found in western Oregon farm ponds. Examinations of newt stomachs have indicated that they compete with bass for food. Therefore, large populations of newts may adversely affect production of bass. Newts were very abundant in the seine-hauls each month. A program of marking and measuring the newts was carried out in conjunction with the bass sampling by John Smith, graduate student in Zoology, Oregon State University.

Benthos

Benthic animals were sampled monthly with a one-fourth square-foot Ekman dredge. Four stations were set up in each pond (Figure 1). One grab was made at each station. The contents of the dredge were then washed with clean water on a screen (35 meshes/inch). The animals obtained from each sample were then combined and transferred to white porcelain trays and separated into family groups by means of forceps and pipettes. The samples were then taken to the laboratory to be counted, dried and weighed.

Littoral Organisms

A narrow band of emergent and submergent aquatic vegetation, about 1 meter in width, bordered the ponds. Aquatic insects that lived in this narrow strip of vegetation rarely appeared in the benthos samples. For sampling these organisms, permanent stations 10 feet apart along the perimeter of each pond were established. Each month one station from each side of the ponds was picked from a table of random numbers and was then sampled by the use of a one-meter square frame made of sheet stainless steel. The top and the bottom of the frame were left open. The sampler was placed on the selected station so that it extended exactly 1 meter into the pond, thereby enclosing one square meter along the shoreline. With the device in place, the bottom edge being pushed slightly into the pond bottom, a short-handled net was then vigorously passed through the water contained in the sampler. All vegetation within the sampler was hand picked for organisms. Netting and picking continued until further effort produced no additional organisms. The material was then treated similarly to the benthos samples.

Plankton

Net plankton samples were obtained weekly during the study period. Four stations (Figure 1) were employed in each pond. A vertical haul from the bottom to the water surface was made at each station with a nonclosing conical net attached to a number 12 Clarke-Bumpus bucket. The diameter of the net was 24 centimeters. The total distance that the net was raised at each station was recorded along with the date and station number. The plankton was preserved in 10% formalin. In the laboratory the volume of each sample was obtained. Four subsamples from each jar were taken with a one-milliliter Stemple pipette and placed in a petri dish. The subsamples were kept separate and the organisms were counted and identified with the aid of a stereomicroscope. A mean was computed for the four subsamples; thus, each station was represented by one sample which is a mean of four subsamples for each period. From knowledge of the tow length and diameter of the net opening, the total volume of water sampled during each tow was computed. The density of the plankton was expressed as numbers of organisms per liter of pond water.

An attempt was made to sample the nannoplankton by passing a certain volume of water through a Foerst continuous-flow centrifuge. It was believed that the centrifuge was not efficient in removing the suspended material and as a check, water samples were passed through a millipore filter (0.8 μ). This information showed that the centrifuge was only 6% as efficient as the millipore filter in removing suspended material from the pond water.

Primary Production

Rates of gross primary production were determined by the use of a light-and-dark-bottle method. Oxygen production and consumption by the organisms in 500 milliliter flasks were measured with the Alsterberg (azide) modification of the Winkler method. Flasks were filled with surface water, sealed, and mounted approximately 3 inches under the surface in the southwest corner of each pond. The bottles remained in the ponds from approximately 11 a.m. to 1 p.m.

RESULTS AND INTERPRETATIONS

Temperature

Temperature regimes of the two ponds were very similar. Presented in Figure 2 are weekly means of the surface and bottom temperatures of pond III, which are representative of both ponds. The high temperatures in both ponds occurred in the last week of July when surface temperatures reached 90°F and 88°F in ponds II and III, respectively. During the summer months there was usually a difference of about 5 degrees Fahrenheit between the values for the surface and bottom indicating slight thermal stratification.

Dissolved Oxygen

Dissolved oxygen at the surface of the ponds never fell below 6 mg/l (Figure 3 and 4). Thus, minimum oxygen concentrations could not be directly significant in explaining any differential mortality in the bass between the ponds. The bass were probably obliged to live in the upper layers of water during part of the summer because of low oxygen tensions in the bottom water. In avoidance chambers bass will respond to concentrations of oxygen as high as 4.5 mg/l, but will not avoid markedly any concentration above 1.5 mg/l (Whitmore, Warren and Doudoroff, 1960). In June both ponds started to show signs of depleted oxygen concentrations

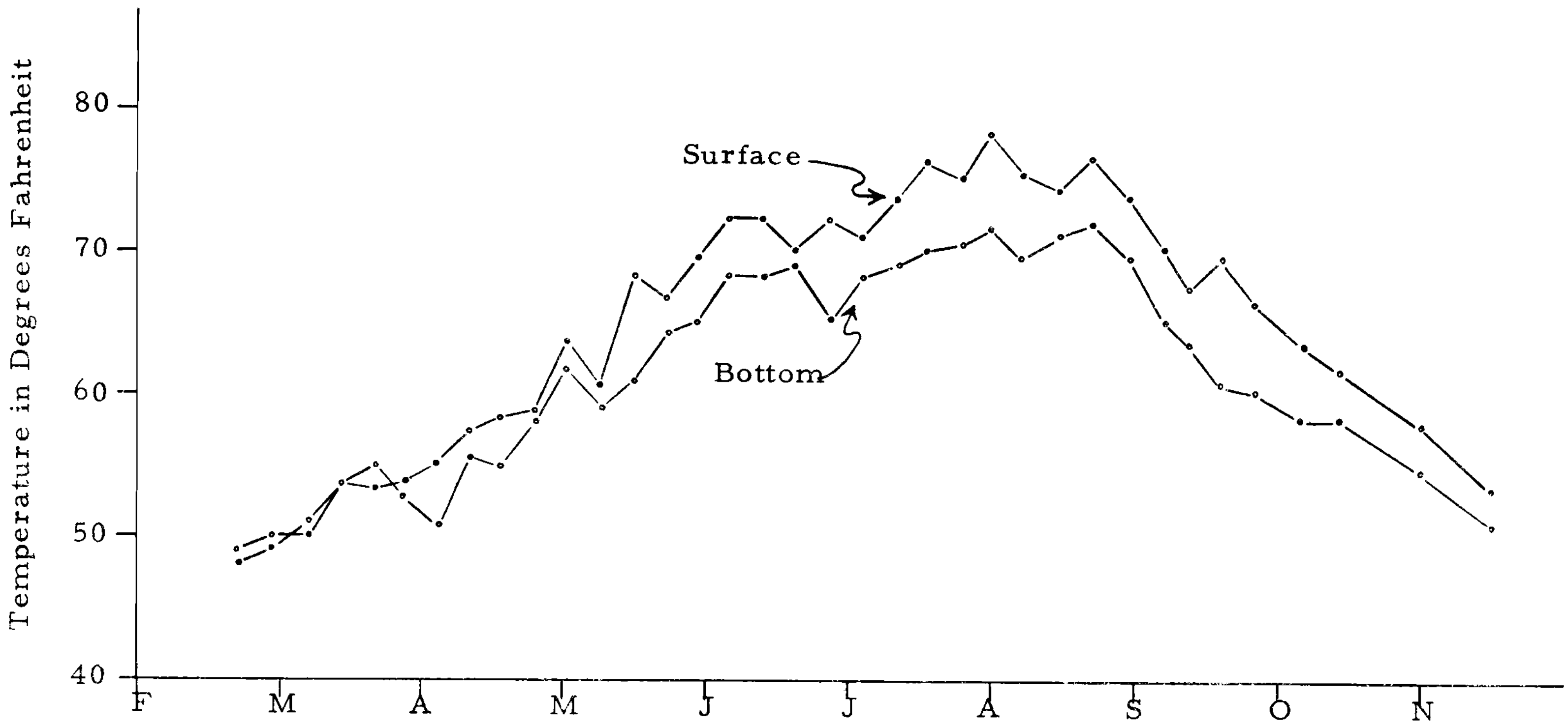

Figure 2. Weekly Means of Maximum-Minimum Surface and Bottom Temperatures for Pond III, February through November, 1965.

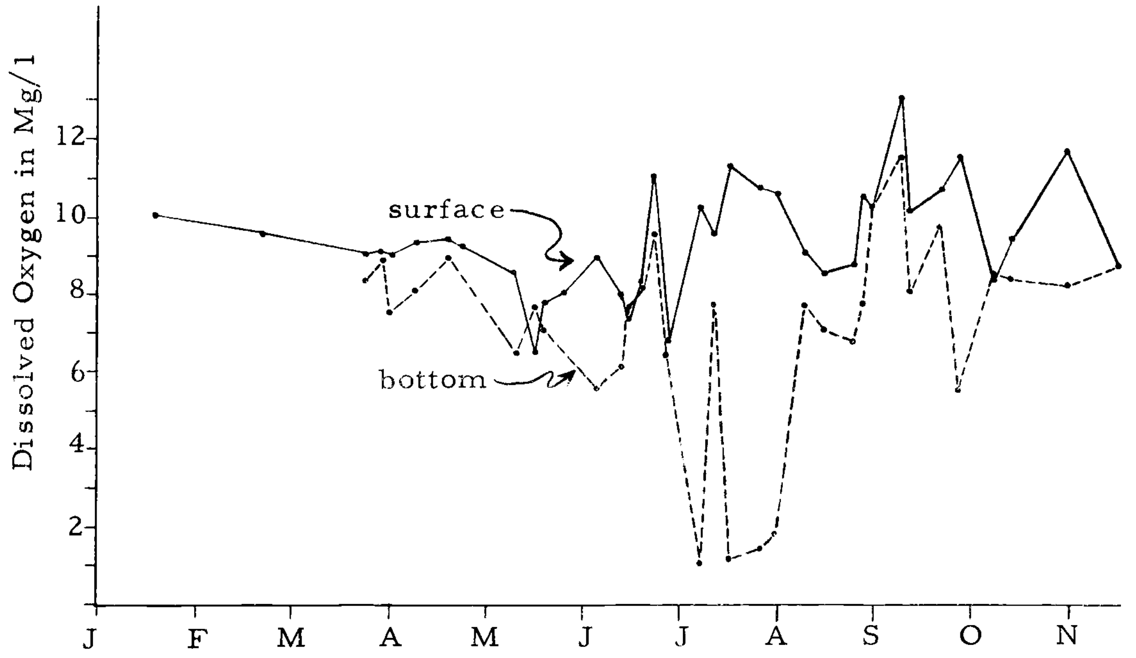

Figure 3. Surface and Bottom Oxygen Concentrations for Pond II, January through November, 1965.

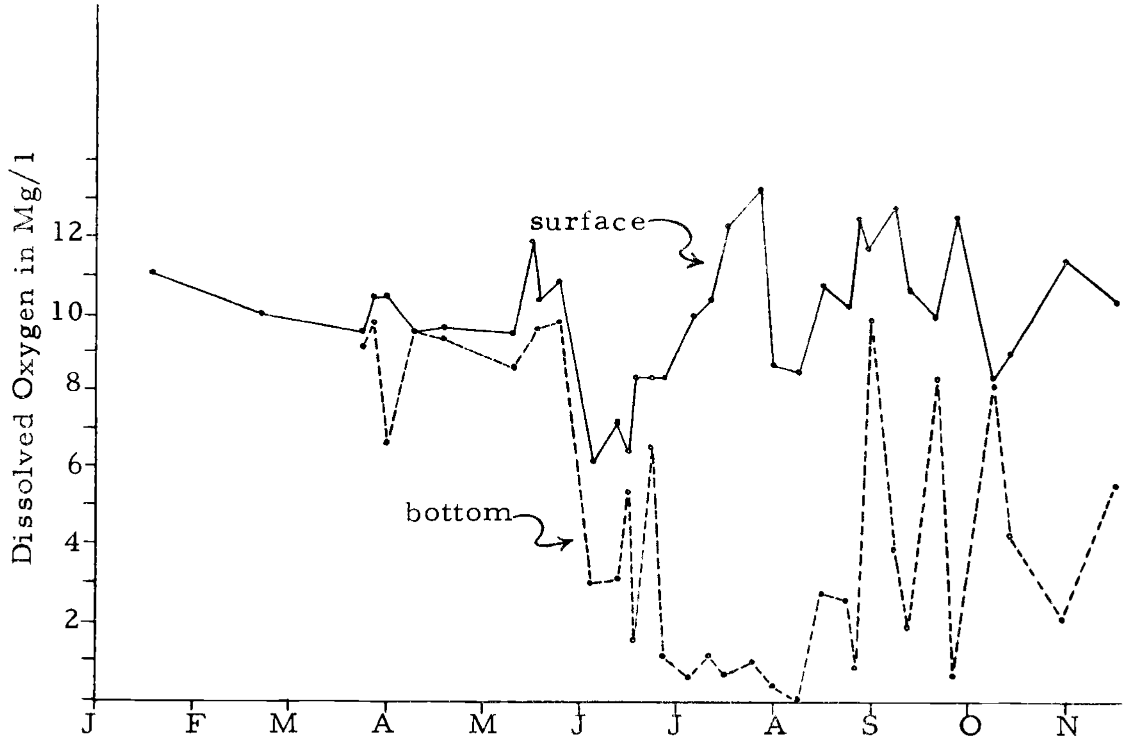

Figure 4. Surface and Bottom Oxygen Concentrations for Pond III, January through November, 1965.

in the bottom water. Well oxygenated water from Soap Creek was pumped into the ponds in the first week of July and the middle of August, which tended to upset the oxygen stratification in pond II. Pond III remained stratified from the middle of June to the middle of September. The depletion of oxygen in the pond water is shown in greater detail in Figure 5. The data plotted in this graph were collected on August 23, 1965. On this date pond III was stratified with respect to oxygen but pond II contained well oxygenated water throughout (Figures 3 and 4). The rate of change in oxygen concentration in pond III was greatest between 1.5 and 3.5 feet from the bottom (Figure 5). The oxygen profile of pond II was steep on this date, showing well oxygenated water at all depths. The differences in oxygen concentration between the ponds probably were due to the oxidation of the organic material that was added to pond III.

To get an indication of how the oxygen tensions varied over a twenty four-hour period, samples were taken from the top and bottom every three hours on July 16 and 17. This information is plotted in Figure 6. The surface water showed a typical diurnal curve with the low tensions occurring at 6 a.m. and the high tensions occurring in the evening around 9 p.m. The oxygen concentrations at the bottom did not follow a definite pattern. The variation in the oxygen concentration in the surface during this sampling

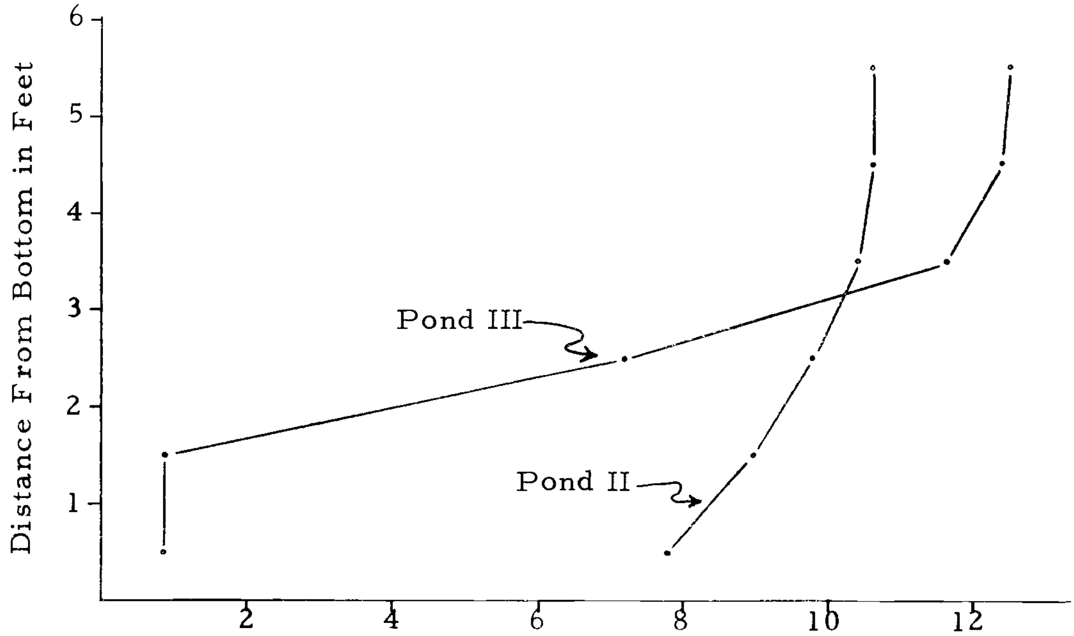

Figure 5. Dissolved Oxygen Profiles for Ponds II and III, August 23, 1965.

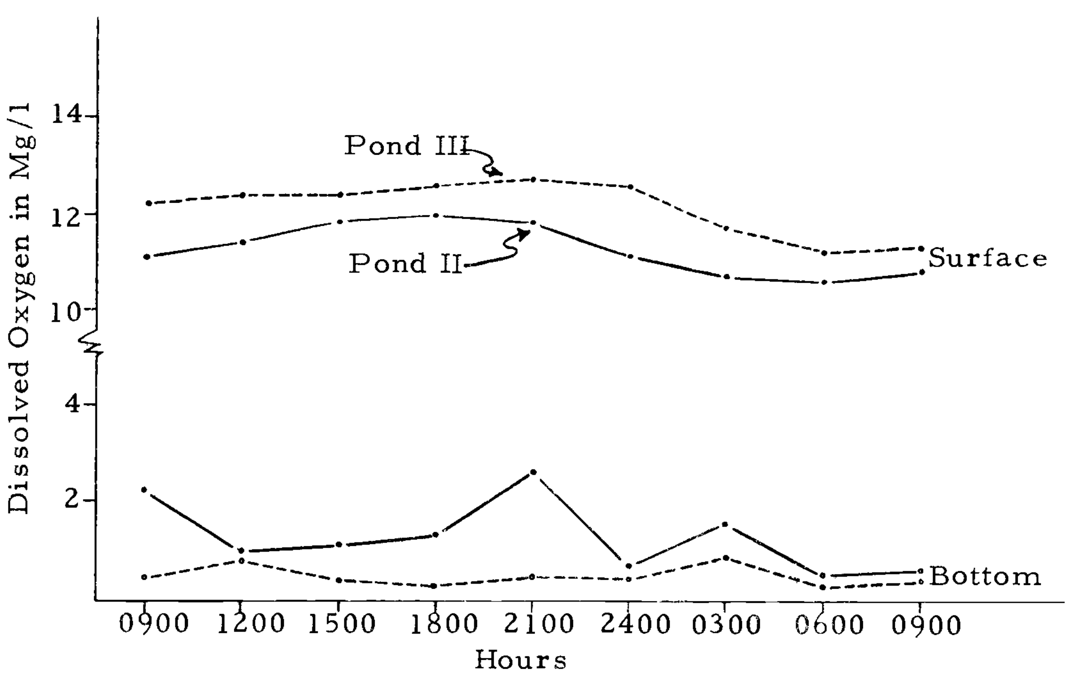

Figure 6. Diel Oxygen Pulse in Ponds II and III, July 16-17, 1965.

period was about 1.5 mg/l, indicating that gross primary production was not very high. In conjunction with work on ponds II and III, information on the other six Soap Creek ponds was also collected. Pond I, during July, contained an extremely dense population of Volvox sp. The oxygen concentration in the surface water of this pond increased from a minimum of 5.4 mg/l at 6 a.m. to a maximum of 17.1 mg/l at 6 p.m. on July 16. This represents a change of 11.7 mg/l in 12 hours, indicating high levels of primary production.

Hydrogen-ion Concentration

The pH values ranged from a low value of 6.7 to a high of 8.9 in pond II and from 6.5 to 9.3 in pond III (Table 5). The high values occurred during the daytime in the surface water during photosynthetic activity.

Total Dissolved Solids

Total dissolved material in the ponds increased during the experiment from early spring to fall. This would be expected because monthly applications of fertilizers were made and processes such as decomposition and evaporation occur at greater rates as the temperature increases. The most striking increase in total dissolved solids was observed in the bottom layer of water in

Table 5. The pH values for the experimental ponds, December, 1964 through November, 1965.

Date	Pond II Surface	Pond II Bottom	Pond III Surface	Pond III Bottom
December 17	---	---	7.6	---
January 17	7.6	---	8.7	---
February 20	7.3	---	7.2	---
March 20	6.7	---	7.1	---
March 24	7.3	7.3	7.4	7.4
April 24	8.1	---	8.3	---
May 15	7.6	7.5	8.6	---
June 16	7.2	7.3	7.0	6.5
June 25	8.1	7.9	8.4	7.5
July 1	8.1	7.6	8.8	7.0
July 14	8.0	6.7	8.0	6.5
August 10	8.5	8.5	9.3	7.7
September 30	8.9	8.8	9.1	9.0
November 14	8.0	7.8	7.7	7.7

pond III (Figure 7). Considering the fertilization treatments these results were expected because the added organic matter upon decomposition would release soluble material into the surrounding water.

Alkalinity

Alkalinity in both ponds generally increased from January through September (Table 6 and Figure 8). In the spring and early summer, before pH values above eight were obtained, the alkalinity was mainly in the bicarbonate form as detected by the use of methyl orange as an indicator. At higher pH values some alkalinity was shifted to the carbonate form as detected with phenolphthalein

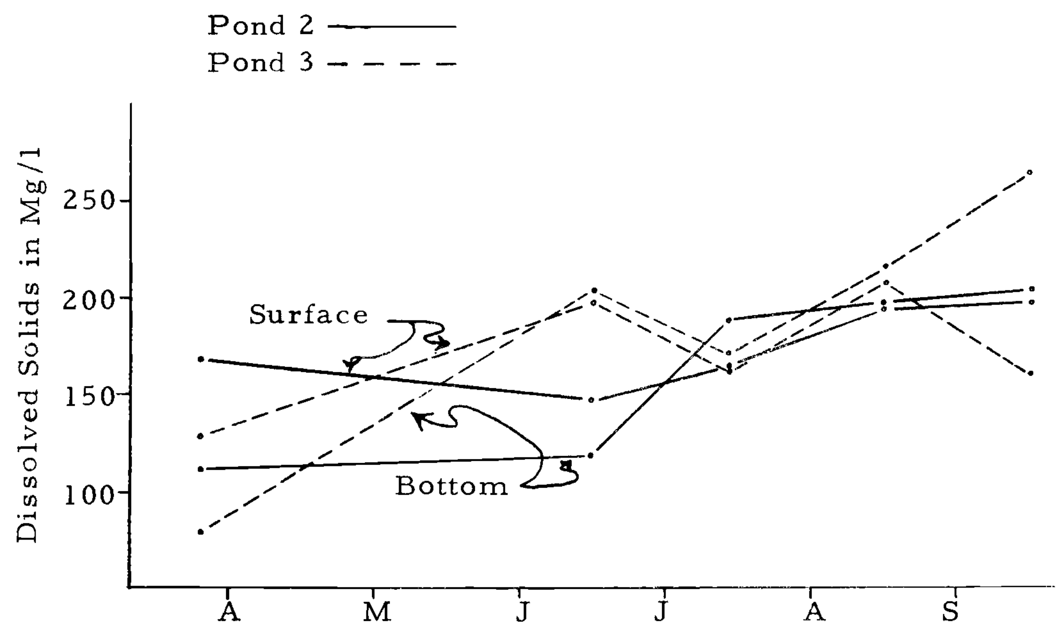

Figure 7. Total Dissolved Solids for Ponds II and III, March through September, 1965.

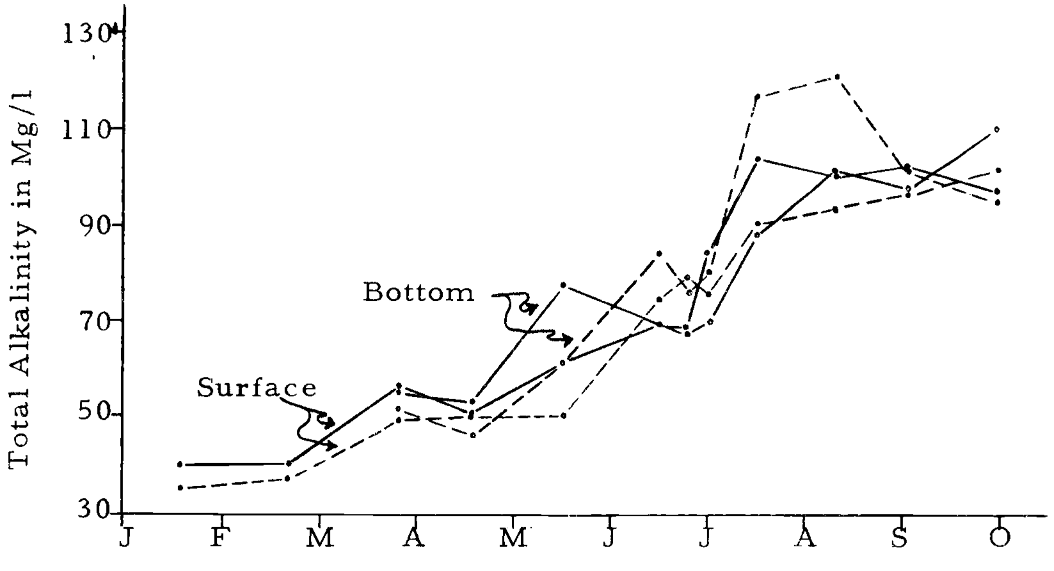

Figure 8. Total Alkalinity for Ponds II and III, January through September, 1965.

Table 6. Alkalinity of experimental ponds, January through September, 1965.

Date	Pond II						Pond III					
	Surface			Bottom			Surface			Bottom		
	bicarb.	carb.	total	bicarb.	carb.	total	bicarb.	carb.	total	bicarb.	carb.	total
Jan. 17	40	0	40	--	--	--	35	0	35	--	--	--
Feb. 20	40	0	40	--	--	--	37	0	37	--	--	--
Mar. 25	56	0	56	55	0	55	49	0	49	51	0	51
April 17	50	0	50	53	0	53	50	0	50	46	0	46
May 15	58	3	61	77	0	77	50	0	50	63	0	63
June 15	69	0	69	69	0	69	74	0	74	84	0	84
June 25	67	0	67	68	0	68	79	0	79	76	0	76
July 1	70	0	70	84	0	84	75	0	75	80	0	80
July 15	82	6	88	104	0	104	80	10	90	117	0	117
Aug. 10	94	7	101	96	4	100	70	23	93	121	0	121
Sept. 2	87	10	97	95	7	102	69	27	96	101	0	101
Sept. 29	96	14	110	90	7	97	84	17	101	84	11	95

indicator. The values at the surface in pond II ranged from 40 mg/l on February 20 to 110 mg/l on September 29. Bottom alkalinity measurements were not made until March 25 when a low value of 55 mg/l was recorded. The surface values reached a high of 104 mg/l on July 15. The alkalinity values for pond III were quite similar to pond II. At the surface the values ranged from 35 mg/l on January 17 to 101 mg/l on September 29. Values at the bottom of pond III varied from 46 mg/l on April 17 to 121 mg/l on August 10. Alkalinity remained in the bicarbonate form in the bottom water of pond III until September. This was caused by higher hydrogen-ion concentration in the water due to a reduction of photosynthetic activity. The added organic matter seemed to keep the turbidity quite high in pond III, reducing light penetration and decreasing plant photosynthetic activity.

Total Phosphorus

Total phosphorus concentrations in the ponds remained below 0.3 mg/l until after the June fertilization period. After this application rapid increases in phosphorus were noted in both ponds, especially in the bottom water (Figure 9). Concentrations fell in both ponds from the high values observed in July and August. Phosphorus levels in natural waters are influenced by many factors making meaningful relationships difficult to establish. Organisms

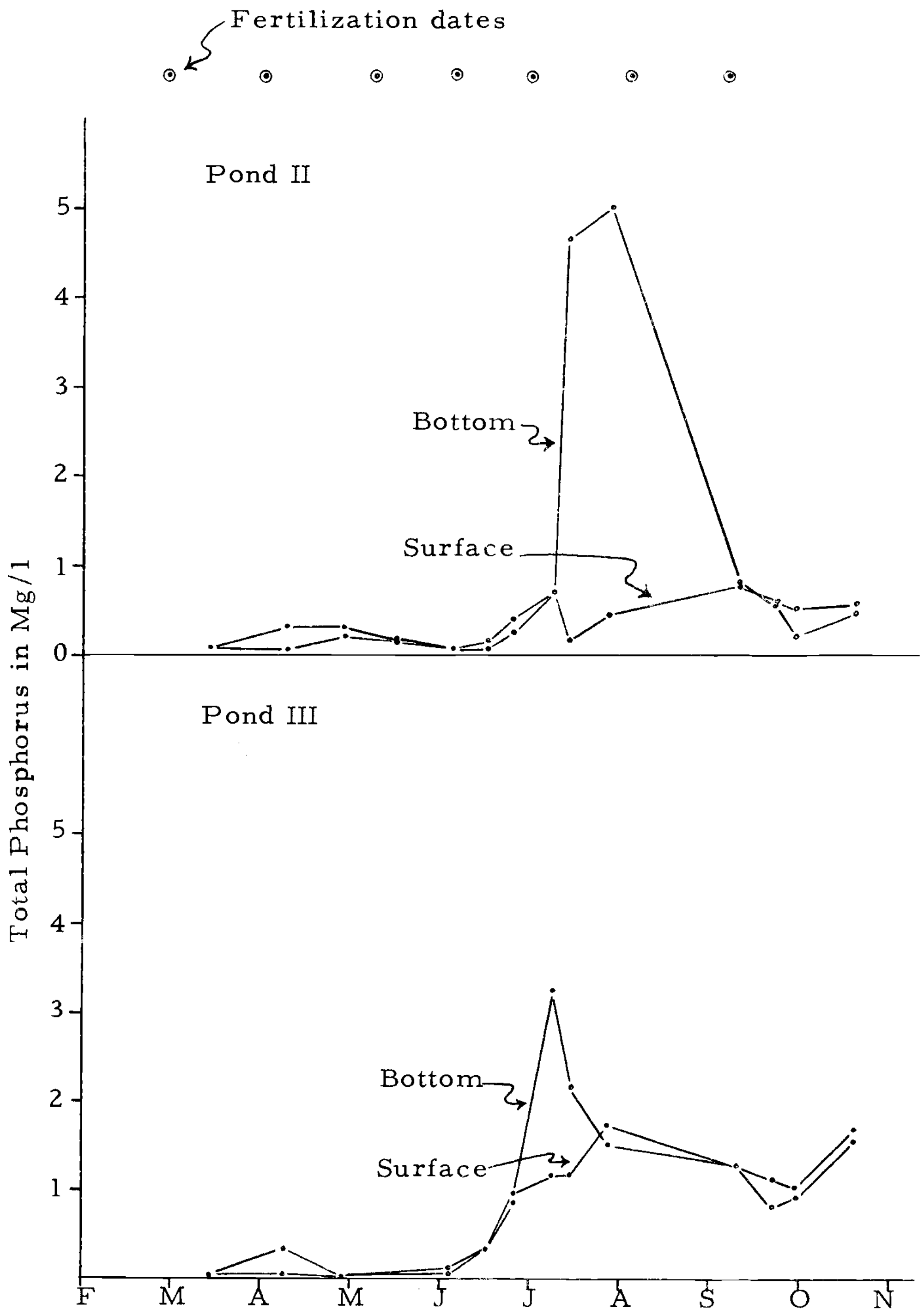

Figure 9. Total Phosphorus Concentrations for Ponds II and III, February through November, 1965.

can absorb and store available phosphorus in amounts greater than those needed for immediate metabolism. Soluble inorganic phosphorus can be absorbed by bottom sediments and remain in an exchangeable form or be taken out of solution as insoluble precipitates. Phosphorus in these unavailable forms can be regenerated from the bottom, depending upon the pH, alkalinity, oxygen concentration and other factors.

There is an inverse relationship between dissolved inorganic phosphorus and methyl orange alkalinity (Barrett, 1952). At alkalinities above 120 mg/l phosphorus can be precipitated out of solution, possibly as tricalcium phosphate. The ratio of marl to organic material of the bottom sediments is also important in the immobilization of phosphorus. Sediments low in organic matter and high in marl content tie up phosphorus readily. Insoluble ferric phosphate is precipitated from solution when ferrous iron and phosphate occur together in oxygenated water. When oxygen is lacking, iron is reduced from the ferric to the ferrous state and phosphorus is free to go into solution. This may account for the high levels of phosphorus in the bottom water of the pond during July and August (Figure 9). High phosphorus concentrations occurred during the time of low oxygen concentrations (Figures 3, 4, and 9). Monthly applications of fertilizer showed no relationship to total phosphorus content in the ponds (Figure 9).

Primary Production

The rates of gross photosynthesis at the surface of the ponds did not differ greatly (Table 7). The highest rate recorded occurred in pond II on September 2. The addition of organic material to pond III appeared to have little effect on surface phytoplankton production.

Table 7. Photosynthetic rates in experimental ponds expressed as milligrams of oxygen produced per liter per hour.

Date	Pond II	Pond III
June 5	0.6	0.9
June 24	0.2	0.3
July 2	1.0	0.7
July 15	0.5	0.6
August 11	0.3	0.4
September 2	1.4	0.8
Average	0.66	0.61

Net Plankton

Plankton entomostraca were represented in the ponds by the three species, Daphnia pulex, Diaptomus forbesi, Leydigia acanthocercoides, and a species of the genus Cyclops. The addition of organic fertilizer to pond III failed to produce any effect on the qualitative aspects of the limnetic net zooplankton, since both ponds contained populations of the four species. From a species standpoint, the composition of the net zooplankton was very simple. At any one time, except during short periods in the spring and fall, there were only two important limnetic microcrustaceans present. These findings are in agreement with those of Pennak (1957) in his study of 27 Colorado lakes.

The cladoceran Leydigia acanthocercoides was observed in two sampling periods in pond II, and three periods in pond III during August and September, but never became more abundant than one individual per liter. Information on the other three more abundant plankters is presented in Figures 10 and 11. Daphnia was observed in both ponds in all samples taken and appears to be a year-round resident. Numbers of Daphnia in pond II reached two high levels; one on June 3 and the other on September 22, when the number of individuals per liter was 37 and 48, respectively. Daphnia reached a dominant peak in pond III on June 3 when 63 individuals per liter were noted. Daphnia was relatively more numerous in pond III than pond II. This may have been due to the addition of manure, since the organisms are known to feed on living and dead particulate organic matter filtered from the water.

Water temperature appeared to have a governing affect on the numbers of Diaptomus and Cyclops. When the mid-water temperature reached 65-70°F in the spring, numbers of Cyclops began to

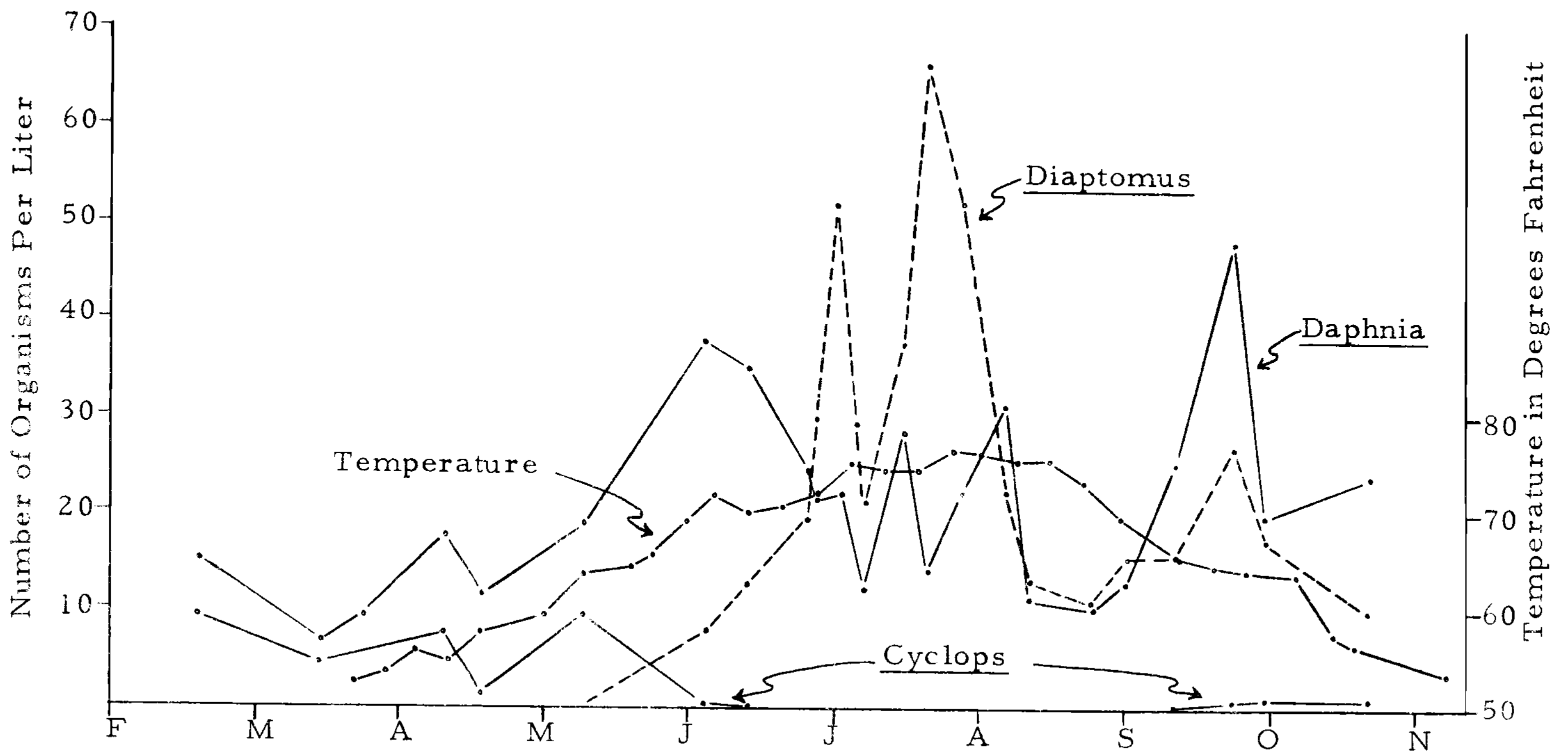

Figure 10. Numbers of Net Zooplankton in Relation to Mid-Water Temperatures for Pond II, February through November, 1965.

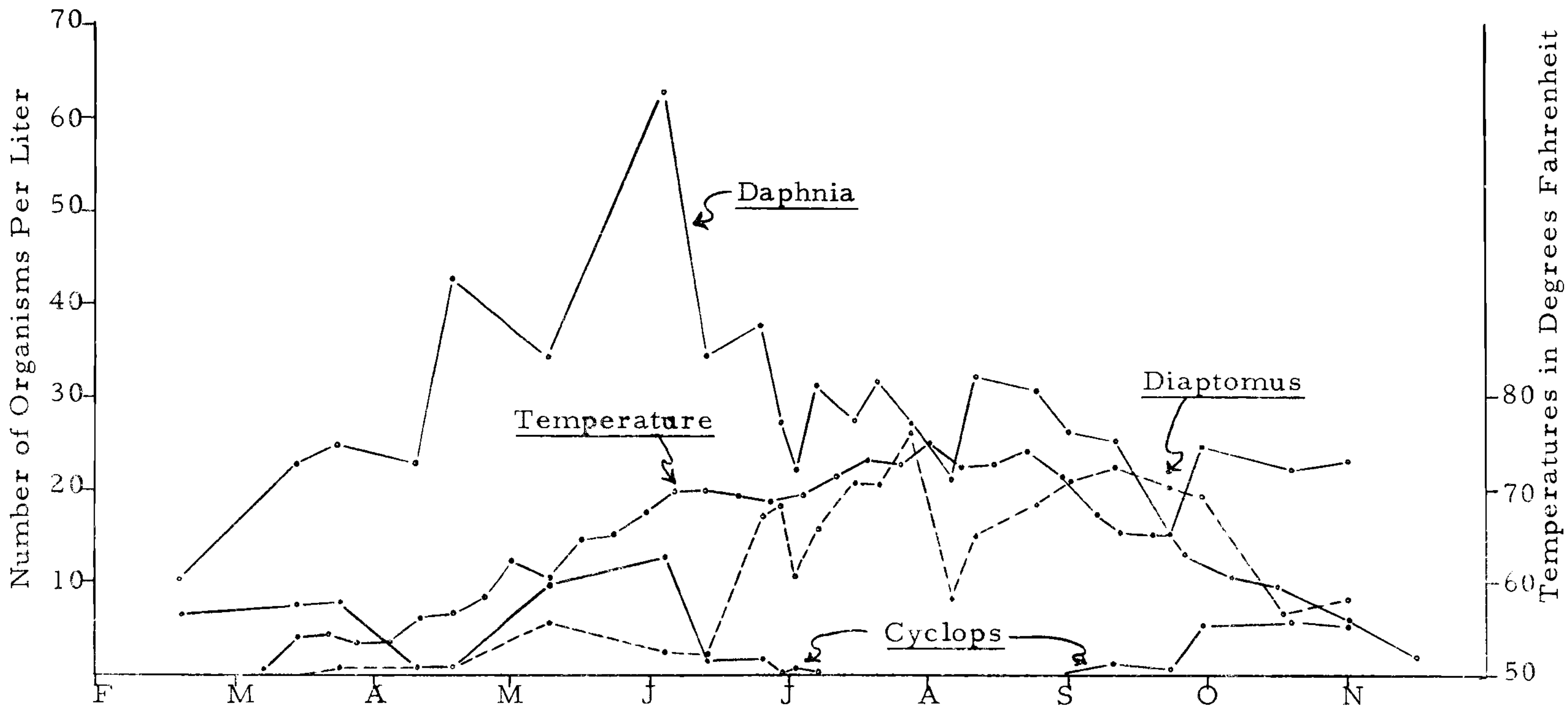

Figure 11. Numbers of Net Zooplankton in Relation to Mid-Water Temperatures for Pond III, February through November, 1965.

decline. As Cyclops became less abundant Diaptomus gradually increased and finally replaced Cyclops (Figures 10 and 11).

Two pulses of the colonial flagellate Volvox sp. occurred in each pond. Peak numbers of 608 and 933 colonies per liter occurred in pond II on June 24 and August 23, respectively. The pulses in pond III were of smaller magnitude, 212 and 614 colonies per liter, and occurred on June 28 and July 26, respectively. No correlation could be demonstrated between the Volvox blooms and other variables measured.

When dry weights of net zooplankton are plotted in milligrams of dry weight per liter of pond water, comparable values can be noted in pond II; lending support to the rejection of the hypothesis that organic material added in the form of composted steer manure would increase zooplankton biomass (Figure 12).

Littoral Organisms

Animals sampled in the narrow strip of vegetation that borders the ponds were represented by insects, amphipods and gastropods. Six orders of aquatic insects were found in the ponds during the experiment. Organisms that were commonly collected are presented in Table 8.

The littoral community of pond III was more complex than that of pond II which lacked mayflies and amphipods. Biomasses of

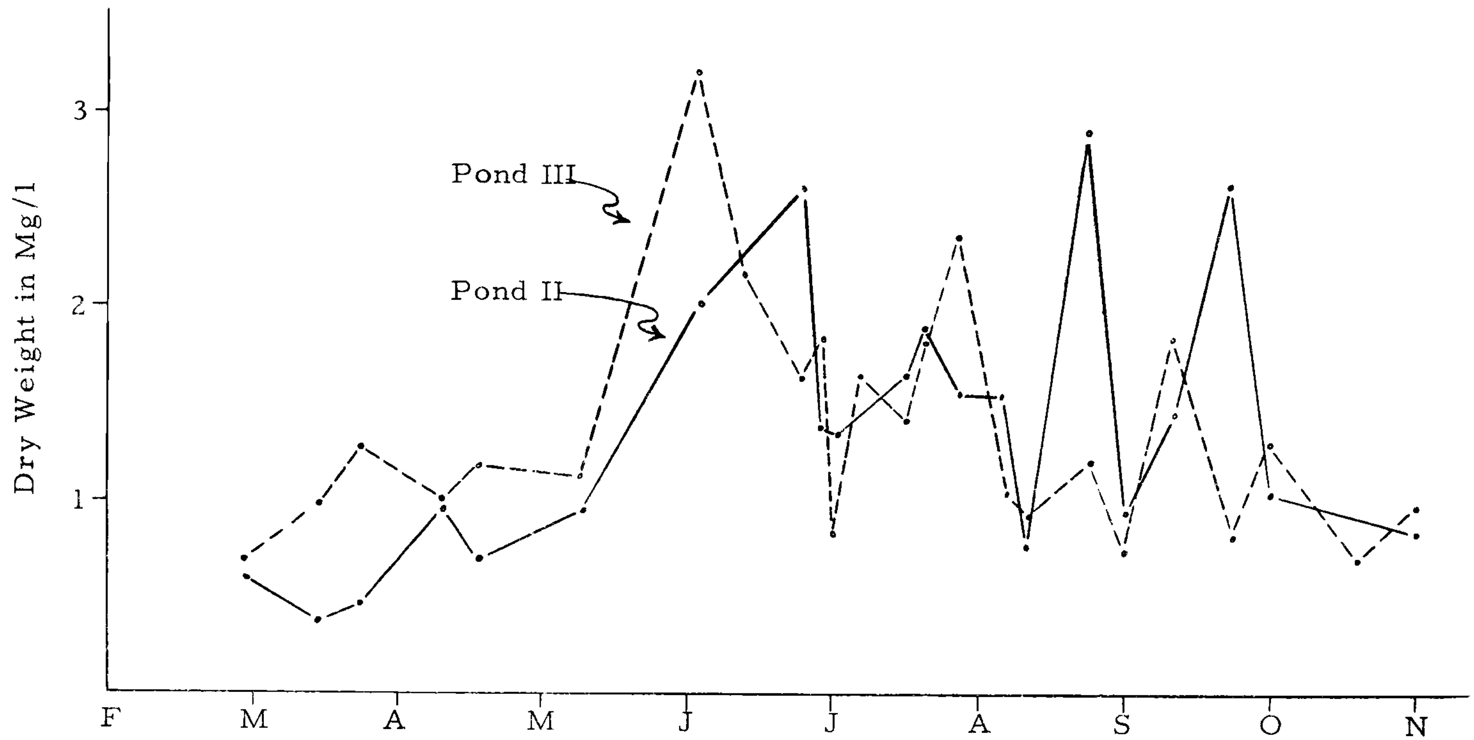

Figure 12. Dry Weight of Net Zooplankton for Ponds II and III, February through November, 1965.

Table 8. Taxonomic groups of littoral organisms.

Pond II	Pond III
Odonata	Ephemeroptera
Coenagrionidae	Baetidae
Libellulidae	Odonata
Aeshnidae	Coenagrionidae
Hemiptera	Libellulidae
Nepidae	Aeshnidae
Belostomatidae	Hemiptera
Corixidae	Nepidae
Megaloptera	Belostomatidae
Sialidae	Corixidae
Trichoptera	Megaloptera
Limnephilidae	Sialidae
Coleoptera	Trichoptera
Dytiscidae	Limnephilidae
Pulmonata	Coleoptera
Limnaea	Dytiscidae
Helisoma	Amphipoda
	Hyalella
	Pulmonata
	Limnaea
	Helisoma

the littoral animals excluding snails are given in Figure 13. Weights were low in July and the first part of August, then increased rapidly during the last two weeks of August and into the first part of September. The low biomasses during the summer were due primarily to the emergence of the insects. Of the animals sampled in the littoral areas, dragonflies and damselflies were the most important animals utilized for food by adult bass. Monthly biomass estimates plus numbers per meter of these organisms are plotted in Figure 14.

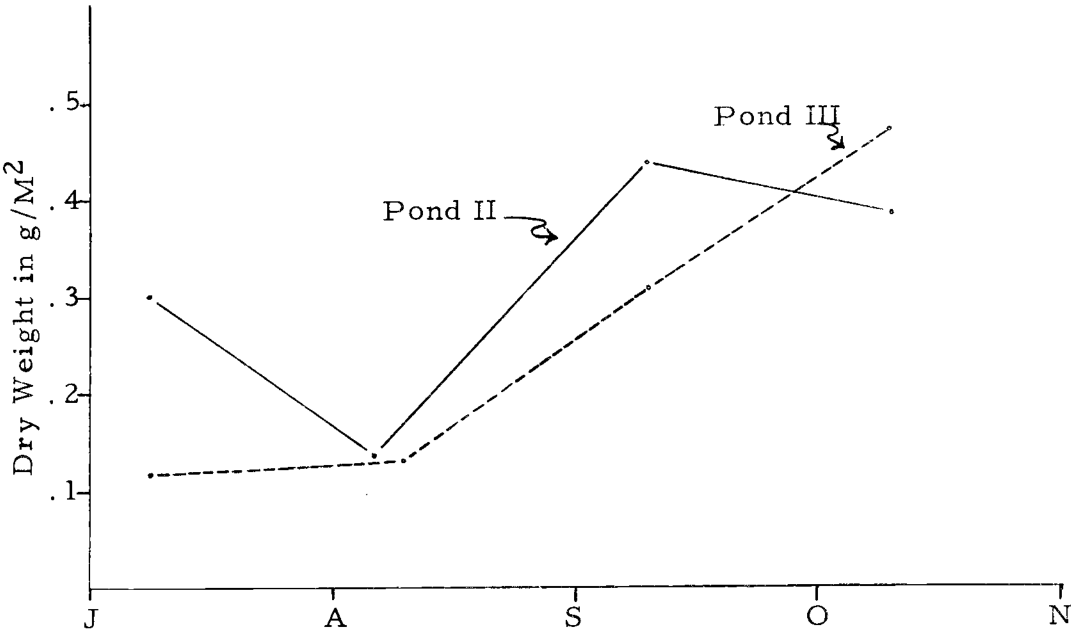

Figure 13. Dry Weight of All Littoral Organisms, Except Snails, Sampled in Ponds II and III, July through October, 1965.

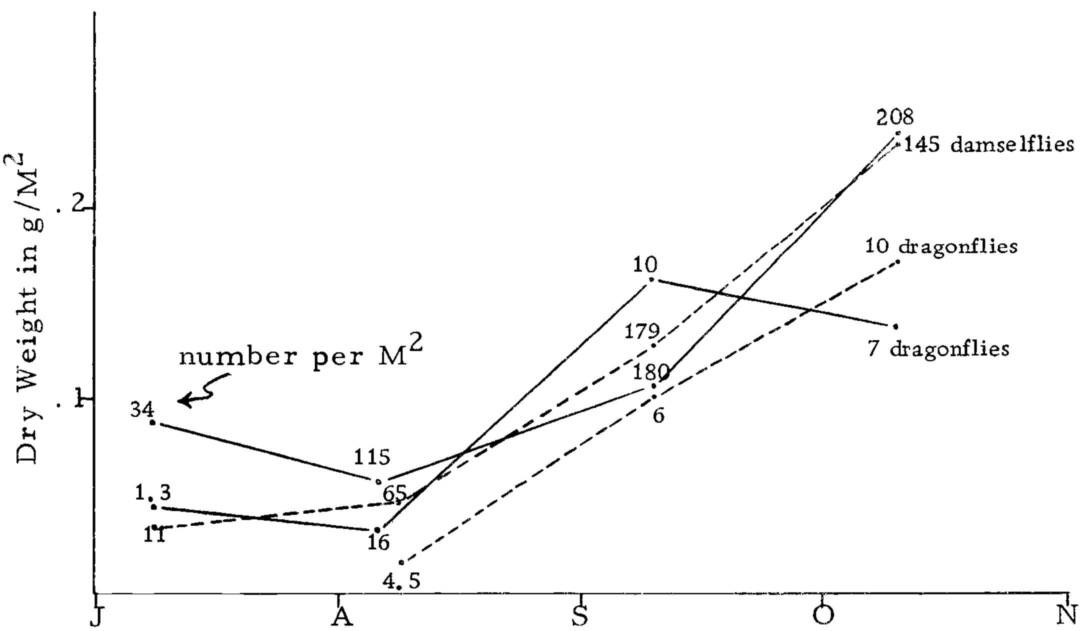

Figure 14. Dry Weights and Numbers of Odonata for Ponds II and III, July through October, 1965.

Damselflies were observed emerging in June and August. The emergence of dragonflies was not observed after the last of July.

The greatest rate of increase in biomass of damselflies occurred in September and early October; whereas the greatest rate of increase in weight of dragonflies took place in August and early September. The rates of change in numbers of odonates were greatest in July in both ponds. The highest numbers of damselflies occurred during October in pond II and during September in pond III, and these amounted to 208 and 179 individuals per square meter, respectively. The largest populations of dragonflies were observed in August in pond II, 16 individuals per square meter, and in October in pond III, 10 individuals per square meter.

Large dragonfly naiads were not taken in the samples after July, indicating that the emergence of this age group of insects was complete by this date. In the August sample a new age group of dragonflies was observed, which ranged in total length from 5-10 millimeters. The range in length by September was from 10-15 millimeters and by October had increased to nearly 20 millimeters. A few large damselfly naiads occurred in the August samples, indicating that emergence of these insects was not yet complete by this date.

The manure added to pond III appeared to produce no noticeable effects on the numbers of average size of the predaceous odonates. (Figure 14).

Benthos

The most important benthic invertebrates appearing in the samples from pond II were *Chironomus*, *Chaoborus*, *Tubifex*, *Limnaea*, *Helisoma* and a species of Sialidae. In samples from pond III all but the phantom midge were taken. Sialids were found in only a few of the benthic samples. Phantom midges were found in the samples from pond II from April to July. Snails occurred sporadically in the samples throughout the experiment.

Tubificids and chironomids were found in all samples and comprised the bulk of the weight of the benthic animals taken. Biomasses in grams dry weight and numbers of chironomid larvae and pupae per square meter of bottom area have been plotted in Figure 15 to show the seasonal differences between the two ponds. In pond II there was a decline of biomass of chironomids from 1.4 to 0.24 grams per square meter between March 22 and June 21. Biomasses increased from the low June 21 value to 2.3 grams per square meter on October 27 when sampling was terminated. Chironomid biomasses in pond III were greater than those in pond II during the spring; 4.5 grams per square meter in pond III compared with 1.19 grams per square meter in pond II on April 21. Chironomid biomasses in pond III declined markedly between April 21 and June 21 and remained low throughout the remainder of the experiment. On October 27 the biomass in this pond was only 0.08 grams per

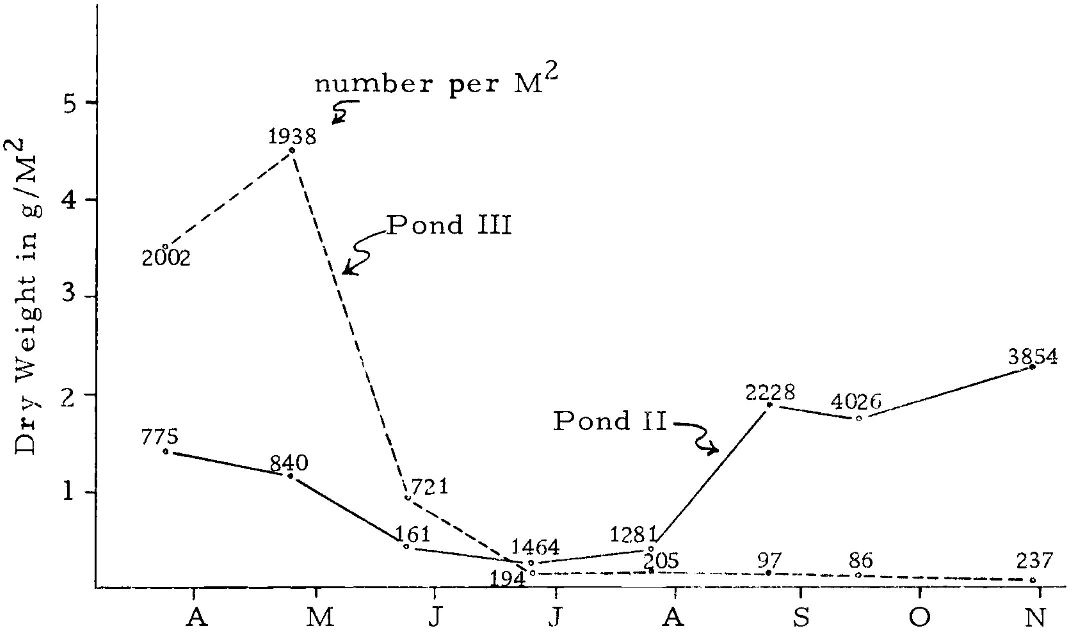

Figure 15. Dry Weights and Numbers of Chironomid Larvae and Pupae for Ponds II and III, April through November, 1965.

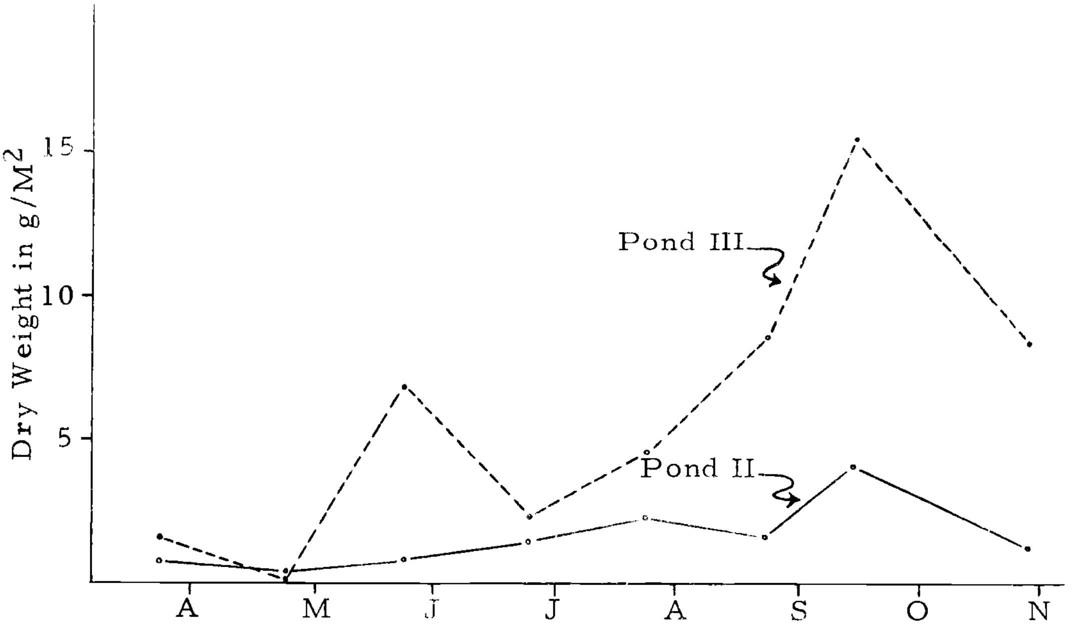

Figure 16. Dry Weights of Tubifex for Ponds II and III, April through November, 1965.

square meter. The numbers of chironomids in pond II followed the same trend observed for biomass with large numbers in the spring, low numbers in the summer followed by an increase in numbers during the fall. In pond III the numbers of chironomids remained low following the spring emergence.

Accompanied by a decrease in the biomass of chironomids in pond III was an increase in the biomass of tubificids (Figure 16). Biomasses of tubificids remained comparatively low in pond II. The increase in tubificids probably can be attributed to the added manure, since they are known to thrive in environments low in oxygen and high in organic matter. Competition between tubificids and chironomids for space and food may have caused the decrease in chironomids observed in pond III. However, a more responsible factor was probably the low dissolved oxygen tensions which occurred at the bottom of pond III (Figure 4). Dissolved oxygen dropped to 0 mg/l on August 7. Even though the larger individuals of chironomid larvae contain a red blood pigment which could be of benefit at low oxygen concentration the younger stages, which are usually prevalent at this time of the year, do not and could have suffered from the low oxygen tensions that occurred in this pond.

Tubificids were found only once in stomachs of bass and chironomids were found in all that were examined; therefore, increases of tubificids and losses of chironomids could be detrimental to the production of bass.

The data presented in Figure 16 are quite variable and this variability may be attributable to three factors.

1. Small numbers of Ekman dredge samples taken.
2. Tubificids were observed with the aid of scuba gear to be clumped in their distribution on the pond bottoms.
3. Tubificids were observed to penetrate the substrate as far as 6 inches which is beyond the sampling depth of the Ekman dredge.

The information, however, can be useful as a comparison between the two ponds.

The earliest date that chironomids were seen to emerge was March 22. Several other emergence periods were recorded between this date and April 10, thus explaining the loss of insects from the ponds during the spring. Other "hatches" were observed in pond II on August 19, August 24, September 2, September 6 and September 15 and this may explain the small reduction in biomass noted between August and September (Figure 15). Emergence occurred on days that were calm and warm. Predation by bass was heavy during the "hatching" periods. The fish were seen taking the insects on the surface before the newly-emerged adults could fly away. During the peak of emergence, 50 to 60 instances per minute of fish rising to take the insects were counted.

Newts

Population estimates of _Taricha granulosa granulosa_ were taken from unpublished data collected by John Smith, graduate student in the Department of Zoology, Oregon State University (Table 9).

Table 9. Population estimates of _Taricha granulosa granulosa_.

	Population estimates in numbers per acre		Known population at end of experiment	
Date	Pond II	Pond III	Pond II	Pond III
May 29	862	2478	---	---
June 29	942	1851	---	---
August 2	1000	1780	---	---
September 4	758	1451	---	---
November 22	---	---	---	367
December 8	---	---	390	---

The estimates are probably reliable since the sample sizes were large. Four hundred or more animals were usually processed during each sampling period in each pond. Most of the newts leave the ponds in late summer and fall and become terrestrial. Stomach examinations have shown that the newts consume food organisms that are utilized by bass; however, it is risky to assume that they compete with bass unless the two animals share an important resource which is in short supply. Assuming that the same food resources are shared by both animals, the size of newt populations may have been important in causing differences in bass production between the two ponds.

Fish

Estimates of population size, mean individual weights and production have been calculated for the adult bass. The estimated individual mean weights of the two adult-size classes are probably quite accurate because the sample sizes were large. Sample sizes ranged from 46% to 98% (mean 74%) of the estimates of the population in pond II and from 40% to 90% (mean 63%) of the estimates of the population in pond III.

The mean weights of the three size classes of fish in pond II were greater at every sampling period compared with the corresponding size classes in pond III (Figure 17). The large fish in pond II increased in weight from the stocking date until April, when they averaged 300 grams each, and then lost weight until September. The mean weight of this size class was 265 grams at the termination of the experiment. The corresponding size group in pond III gained less weight during the first part of the study but began to lose weight at a later date compared with the fish in pond II. These fish reached a maximum mean weight of 266 grams in June and averaged 220 grams at the end of the experiment. The medium size class in pond II never exhibited a weight loss; however, in pond III there

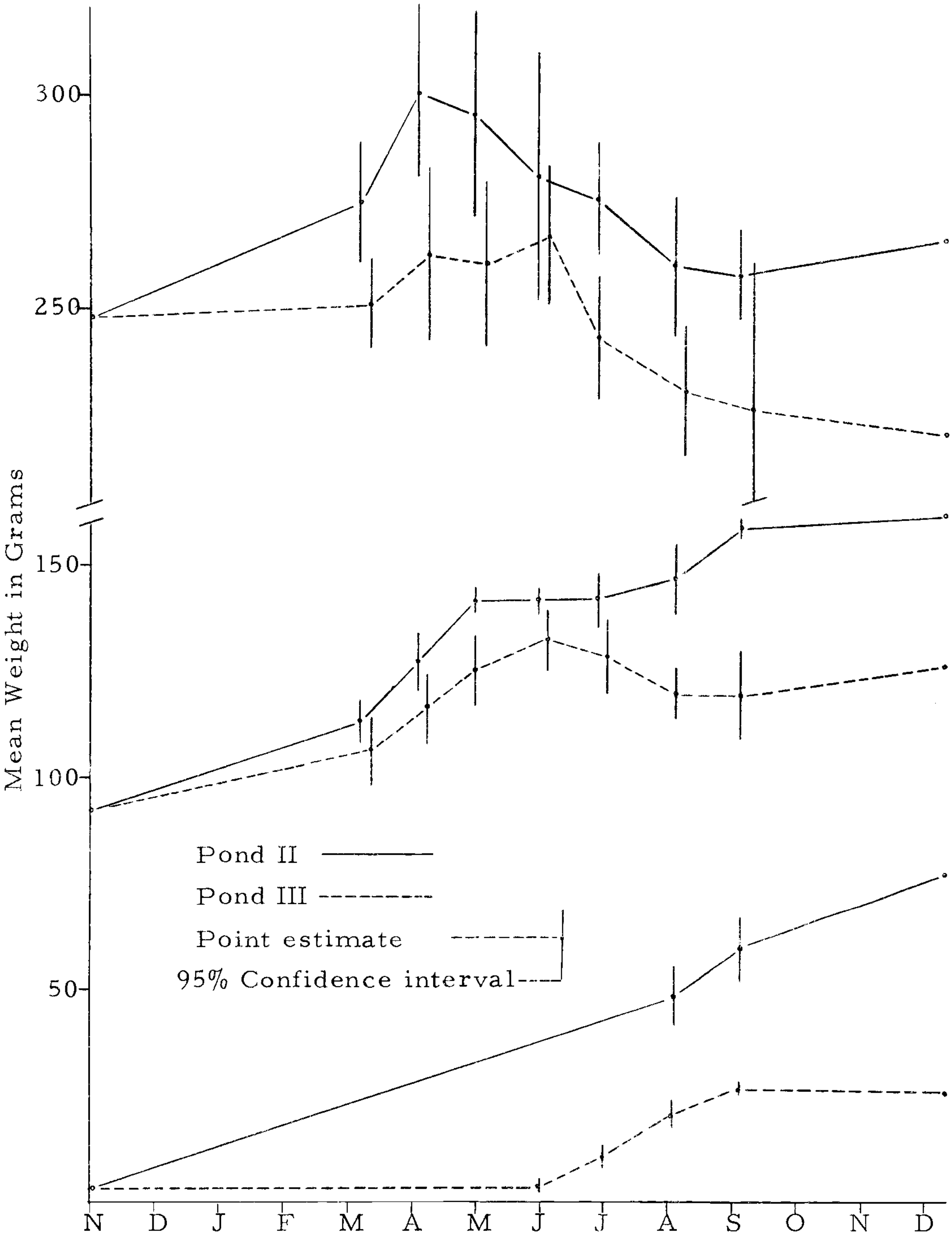

Figure 17. Mean Individual Weights of Three Size Classes of Bass for Ponds II and III, November, 1964 through December, 1965.

were three periods during which weight losses were recorded for this size class between June and September. At the termination date they averaged 161 grams in pond II and 126 grams in pond III.

All physical and chemical factors measured were similar between the ponds, except for oxygen concentrations in the summer months which became significantly different during the month of July. By July there was already a difference in growth of bass between the ponds, the bass in pond II being larger. Therefore, chemical and physical factors mentioned above probably are not directly important in explaining the observed differences in bass growth. Availability of food or competition from other species are the important factors to be considered in this respect.

The estimated weights of newts for pond III were approximately double those of pond II. On August 2 the estimated biomass of newts in pond III was 102 pounds per acre compared with 35 pounds per acre of adult bass in the pond. Competition for food by newts very easily could have been a factor contributing to the differences in growth of bass in the ponds.

Differences in the biomasses of food organisms important to the bass may have contributed to the differences in bass growth between the two ponds. Examination of Figures 11 through 15 shows that although the biomasses of most food organisms did not differ greatly between the ponds, the biomasses of midges were significantly reduced in pond III after July. Bass growth was reduced in pond III during this same period. Although this reduction in bass growth may have been due to some other factor, it was probably associated with the reduction in chironomids.

The only other known factor that could have been operative in this regard was the mosquito fish populations, but because of their low densities in both ponds at any point in time, they probably should not be considered to be a major one. The April and July estimates amounted to 780 and 512 fish in pond III and 2900 and 1267 fish in pond II. Known populations were counted at the end of the experiment and amounted to 807 and 914 individuals in ponds III and II, respectively. Cropping by bass kept the mosquito fish at low levels, thereby reducing their capacity to produce. They became extremely abundant in two other Soap Creek ponds that lacked the predaceous bass.

Bass, of the large size class, lost weight during the late spring and early summer months. From April 3 to September 4 the mean individual weight loss in pond II was 43 grams. The mean weight loss of individuals of the same class in pond III was 46 grams. Some of the weight loss was undoubtedly due to spawning activities. Higher summer water temperatures result in increases of the maintenance costs in the fish. This fact plus the reduced food base was probably responsible for most of the weight losses observed.

The tendency for bass to lose weight in the summer is greater in larger fish (Figure 17). This is not surprising because the larger the fish the further removed they are from the basic energy source of the ponds.

The data gathered on growth in the ponds indicate that bass can grow during the winter at temperatures below 50^{o}F. Most of the growth of the large size class occurred during the five-month period from November to April. These fish in pond II increased in weight from 247 to 300 grams during this period. The mid-water temperature was below 50^{o}F. during this period except for possibly the first few days in November and the last few days in March. According to some authors bass cease to grow at temperatures of 50^{o}F. and below. The work of Markus (1932) has indicated that bass will feed at temperatures 61^{o}F. and above, and not at all at temperatures below 50^{o}F. In experiments conducted by the author on digestion rates, digestion occurred at temperatures under 50^{o}F. when bass were force fed mosquito fish.

Population estimates made periodically of the two large-size classes of bass are shown in Figure 18. The Peterson mark and recapture method, which is given in the following equation, was used to estimate the numbers of fish in the population.

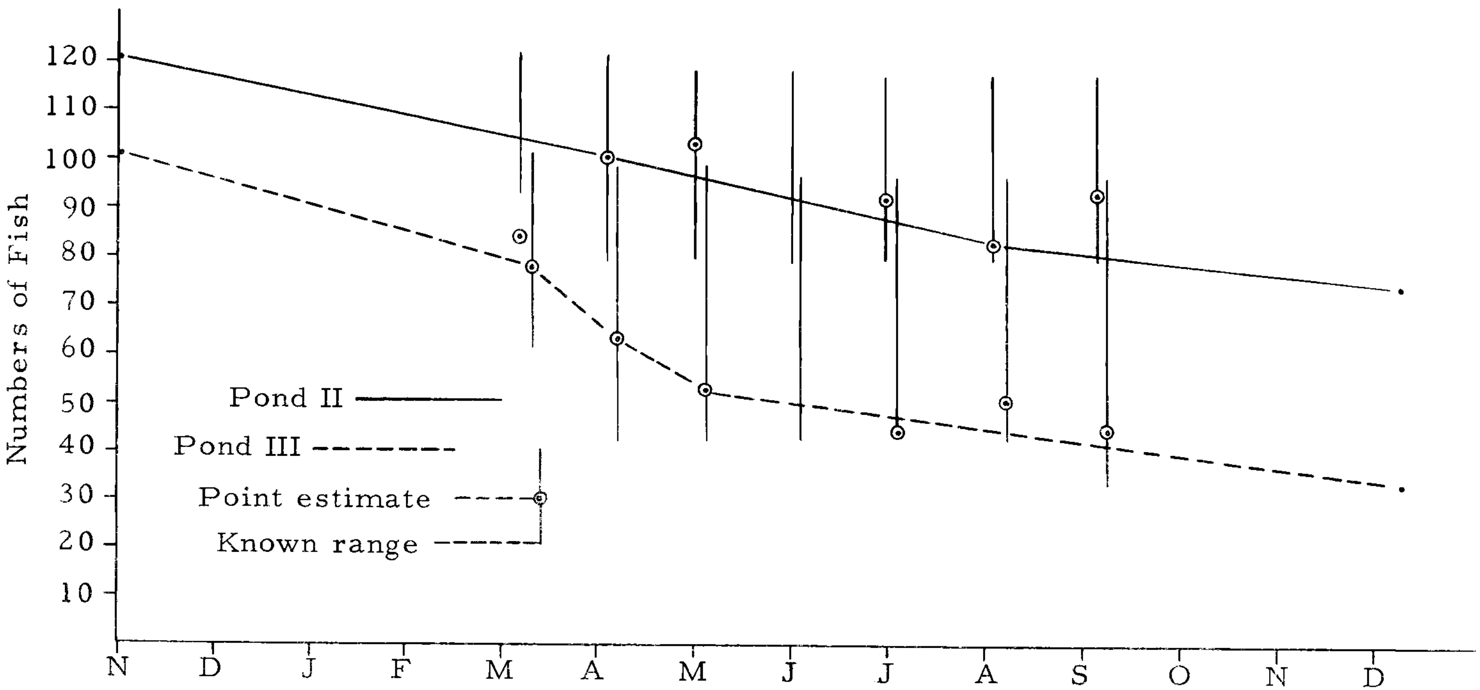

Figure 18. Population Sizes of Adult Bass of Ponds II and III, November, 1964 through December, 1965.

$$N = \frac{M \cdot C}{R}$$

Where N = estimated population at time T_0

M = number marked at T_0

C = total fish recaptured at T_1

R = number of recaptured marked fish T_1

The two large-size classes were treated as one in the estimates because of the partial failure of the marking program. Little error should result from this since there is no reason to suspect that the sampling of the two classes of fish were biassed in any way due to gear selectivity or behavioral differences. The March estimates are based on 20 fish in each pond marked with monofilament nylon loops. The April and May estimates are based on individuals marked with numbered dart tags. However, as stated earlier, these tags were frequently lost from the fish. The tags were applied to the right side of the fish in April and the left side in May. Fish that lost their tags were easily recognized because of the obvious scar resulting from the dart wound. Therefore, satisfactory recovery information was obtained for April and May, even though extensive dart tag loss had occurred. Attempts were made to improve tagging procedures during the subsequent sampling periods and again dart tags were applied to the right side of the fish. However, seining 1 month later revealed that again tag loss had occurred. Because fish marked in April could not be distinguished from fish marked on May 29, a population estimate on this date was impossible. More reliable marks were used in the last three marking periods and reasonable estimates were made for these periods.

Confidence intervals were calculated for each estimate using the tables published by Adams (1951) but are not included in Figure 18 because the known ranges were narrower in all cases, except one, than the 95% confidence zone. The upper limit was determined by the number stocked in the fall of 1964 minus any dead fish recovered up to the time of the estimate. The lower limit was the largest number counted in any one subsequent sampling period. In plotting the population curves, emphasis was given to sample sizes, mark and recapture ratios, the point estimate and recovery dates of dead fish; therefore, the line does not necessarily pass through each point estimate.

The survival of adult bass was higher in pond II than pond III. In pond II 60% of the adults survived for 1 year, as compared to 33% survival in pond III. Greater mortality of the yearling bass occurred in pond II. Only 11 fish of this size group were recovered at the end of the experiment in pond II compared with 83 in pond III.

For further comparison of the adult bass population in the two ponds, production figures for each pond were calculated using the graphical method developed by Allen (1951). Total populations in numbers at several times during the year and periodic estimates of mean individual weights are necessary raw data for this method. The numbers of individuals are plotted on the ordinate and the mean individual weight on the abscissa and the area under the curve between any two points in time as measured with a planimeter equals the production in the population during any period (Figures 19 and 20). Production is defined in this study as the elaboration of tissue in a given time, regardless of the fate of the tissue. Negative production was added to positive production in arriving at total production for the year.

Production, per acre per year, in pond II amounted to 32 pounds which is more than double the figure of 13 pounds obtained in pond III during the same period (Table 10). Factors considered previously, in connection with growth and mortality, are important in production since it is a function of both growth and mortality.

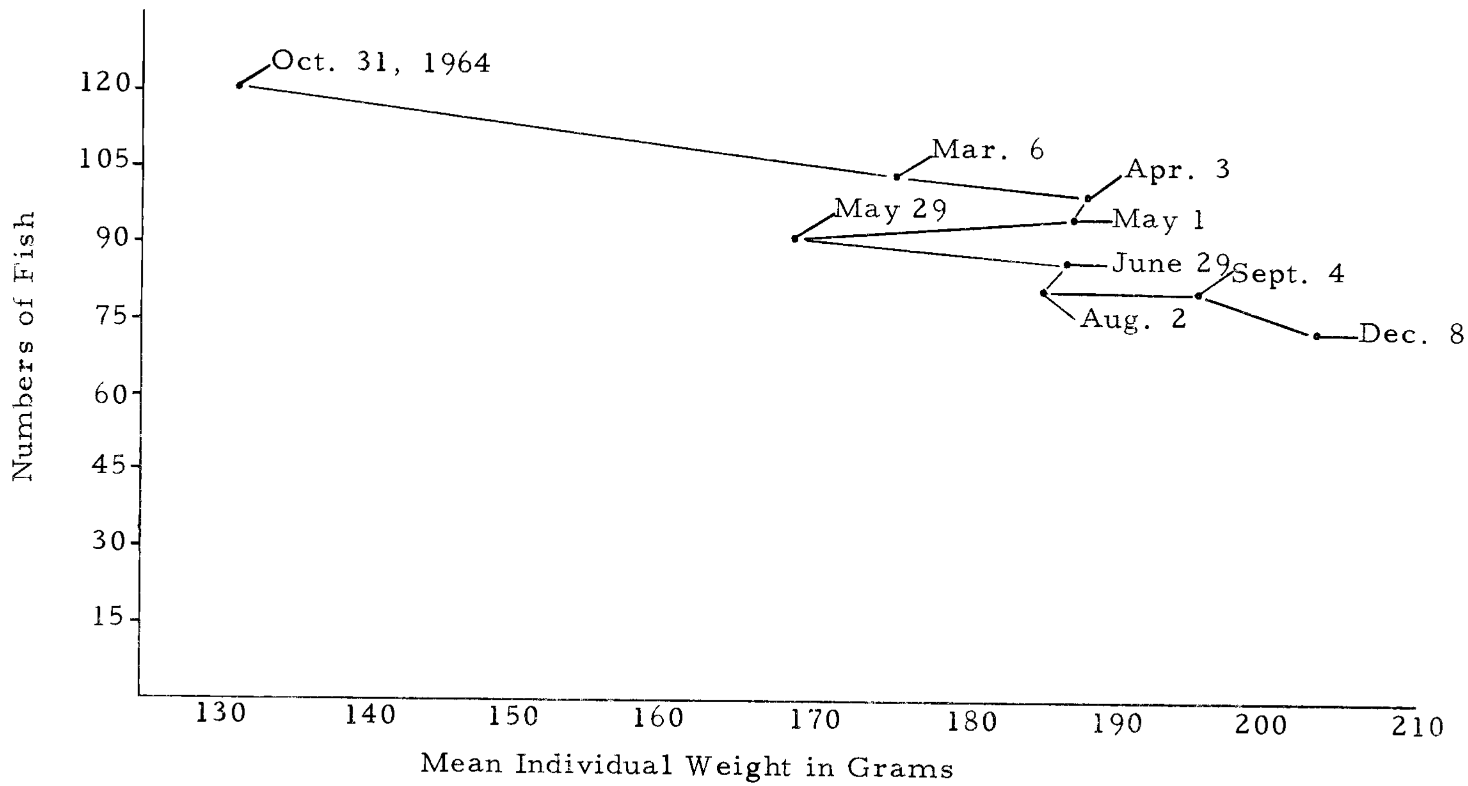

Figure 19. Production of Adult Bass in Pond II, October, 1964 through December, 1965.

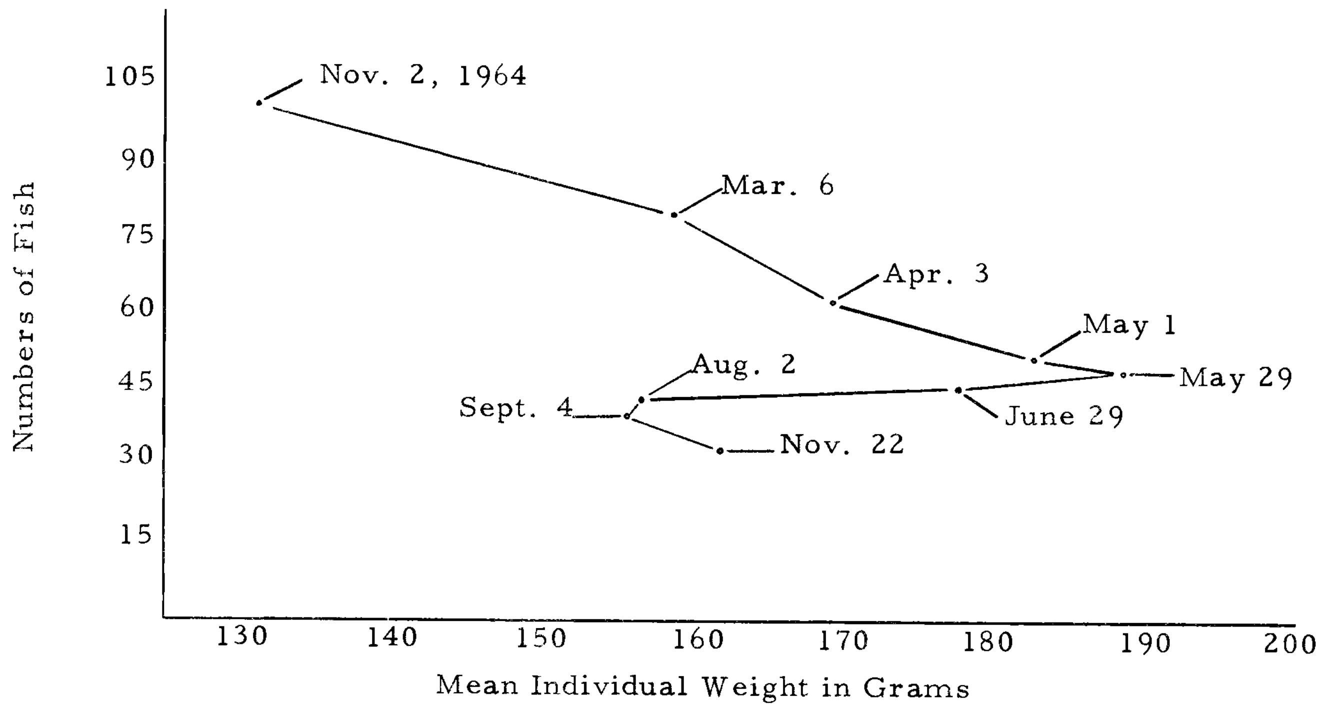

Figure 20. Production of Adult Bass in Pond III, November, 1964 through November, 1965.

Table 10. Production estimates of adult bass, October, 1964 through December, 1965.

Date			Pond II			Pond III		
			Production Figures			Production Figures		
			grams	pounds	pounds/acre	grams	pounds	pounds/acre
Oct. 31	-	Mar. 6	5801	12.79	21.32	2438.5	5.38	10.98
Mar. 6	-	Apr. 3	1486.5	3.28	5.47	619.8	1.37	2.80
Apr. 13	-	May 1	- 68.6	- .15	- .25	819.9	1.81	3.69
May 1	-	May 29	-2050.6	- 4.52	- 7.53	348.6	.77	1.57
May 29	-	June 29	1928.6	4.25	7.08	- 568.1	-1.25	- 2.55
June 29	-	Aug. 2	- 182.9	- .40	- .67	- 949.1	-2.09	- 4.27
Aug. 2	-	Sept. 4	1044.3	2.30	3.83	- 38.7	- .09	- .18
Sept. 4	-	Nov. 22	---	---	---	226.0	.50	1.02
Sept. 4	-	Dec. 8	647.9	1.43	2.38	---	---	---
	Totals		8606.2	18.98	31.63	2896.9	6.40	13.06

DISCUSSION

From February 28, 1965 to September 6, 1965 monthly additions of composted steer manure amounting to approximately 79,100 kilocalories of energy per application were added to pond III. By the end of the last application 553,700 kilocalories of energy had been added. The manure, after being placed in the pond, was essentially detrital material available for use as an energy source for decomposers and detritus feeders. Some workers have attached great importance to detritus as a source of food for many aquatic organisms (Darnell, 1961). Ivlev (1945) reported that chironomids can be cultured using pure cellulose as an energy source. The detrital material may not be consumed directly by these organisms, but they probably fulfill their needs by feeding on microorganisms that utilize the complex organic material.

The manure apparently had little effect in increasing the biomasses of organisms in pond III, except perhaps for chironomids, and appeared to be relatively unimportant as a source of energy to the pond community. During the early portion of the study the biomasses of chironomids in pond III were greater than those in pond II (Figure 15). Apparently most of the organisms were unable to utilize the manure as an energy source. A great deal of organic material in ponds is not immediately utilized by pond organisms, as shown by the well known build-up of these materials in pond bottoms. The addition of steer manure apparently only added to this build-up of materials.

Experiments conducted in the past in the Soap Creek ponds have largely been concerned with young fish (Hansen, 1963 and Young, 1964). Yearling bass stocked alone in the ponds are able to produce over 120 pounds per acre in one growing season (Figure 21). A growing season in this case is considered to be from March to November. Production figures for two-year-old fish are reduced from this amount and in the past have ranged between 18-42 pounds per acre per growing season. From 3 to 15 pounds have been produced per acre in the same amount of time when three-year-old fish were stocked. For the present experiment a mixture of two-year-old fish and four-year-old fish was used and production amounted to only 2 to 10 pounds per acre per growing season.

According to these figures it is most advantageous to begin harvesting bass in small Oregon farm ponds after their second summer of growth and harvest as many as possible within a year. The production of adult bass is so small under these conditions that it does not seem worth the effort involved to grow them unless the pond owner is interested in the angling provided by the few adult bass which can be grown under these conditions.

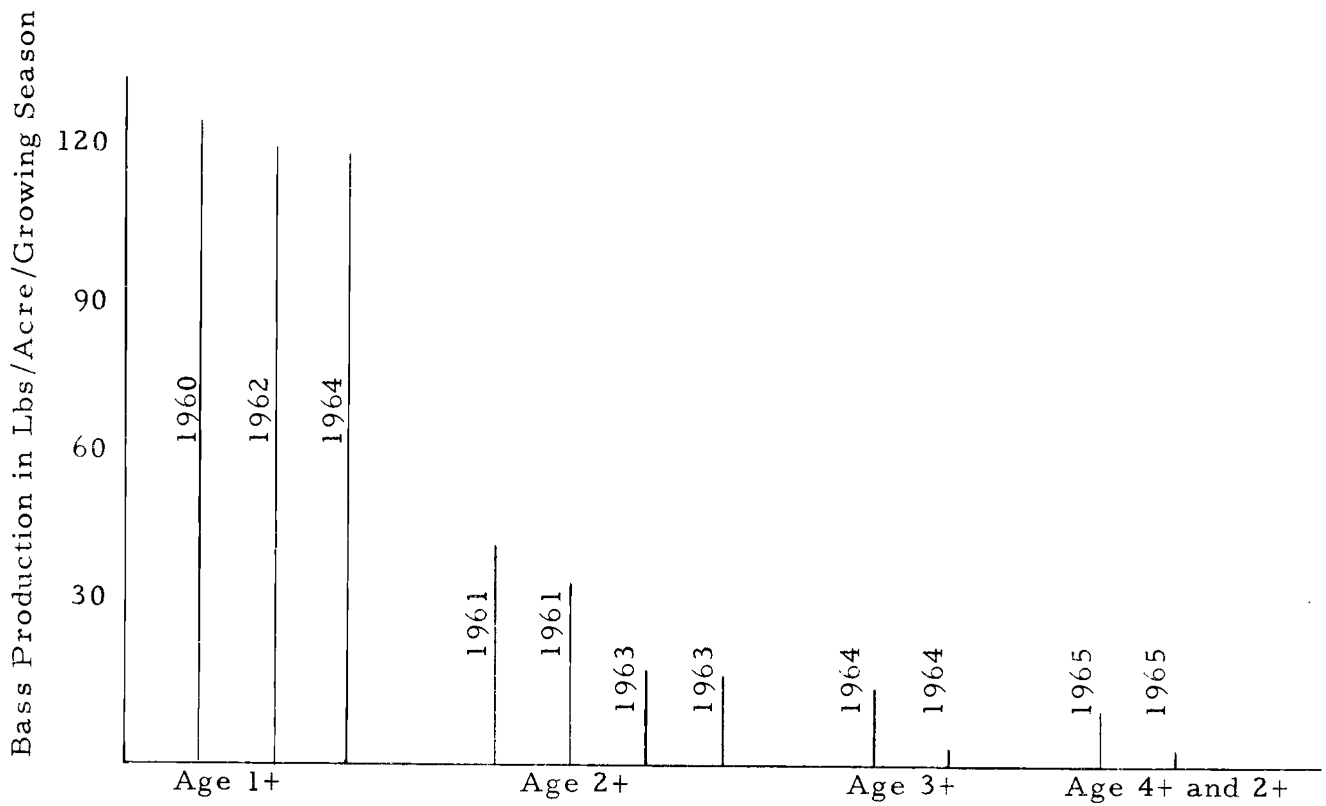

Figure 21. Production of Bass in Soap Creek Ponds, 1960 through 1965.

The ponds produce large quantities of small food organisms such as zooplankton and some insect larvae, however the large fish may be barely able to meet requirements and still have enough left for growth when they are forced to feed on such small organisms. The addition to the ponds of one or more kinds of larger food organisms, such as crayfish, bullfrogs or plankton-feeding fish, that could play a role in the conversion of the energy resource of the ponds ultimately making them available for bass, would be necessary if larger bass are desired. The addition of bluegills in this respect can not be highly recommended because of the tendency to over-populate. It should be noted in Figure 21 that the addition of mosquito fish to the ponds in 1962 has not resulted in greater production of bass.

Little success has been made with relating bass production to biomasses of food organisms. A more informative but difficult approach would be to relate production of bass with production of food organisms, or with utilization of food organisms. Hayne and Ball (1956) were able to show that utilization of food organisms by three species of centrarchid fish in 1 year in ponds may be 8 to 27 times as great as the average biomasses of food organisms. In a study by Gerking (1962) consumption of midges by bluegills between the months of July and August was nearly equal to the July estimate of midges. From the present study it appears that changes in biomasses of chironomids may be correlated with observed differences in the bass production between the ponds. An understanding of the role of the rough-skinned newt, a possible competitor with bass, might aid in explaining the differences in the amount of bass production in the two ponds, since the newts were nearly twice as numerous in pond III and in pond II.

The addition of steer manure to pond III appeared to be of little value in respect to bass production. In pond III the water was more turbid, dissolved oxygen concentrations were reduced in the bottom water and the biomasses of food organisms were not increased (possible exception may have been chironomids in the spring) as compared with pond II. The production of bass on an acreage basis was more than doubled in pond II over that of pond III, leading to the rejection of the hypothesis that increasing the energy base of a pond by the addition of dry composted steer manure will increase the production of largemouth bass.

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