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EXPERIMENTAL USE OF FERTILIZER IN THE PRODUCTION OF FISH-FOOD ORGANISMS AND FISH

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SUMMARY

Twenty-one ponds at three Michigan fish hatcheries were utilized in the summer of 1946 for experimental work to determine the value of fertilizers in the production of fish. Certain operational difficulties made evaluation of the effects of the fertilizer on the bass-bluegill combinations, and on the minnows difficult, but the general indication was that there was a greater production of these fish in fertilized waters. There was a more clear-cut indication of greater production of crayfish, tadpoles, and other fish in the fertilized waters and it was in the production of fish-food organisms, the lower invertebrates, aquatic insects, and plankton that the greatest difference was noted. The production of invertebrate organisms, as determined by dredge sampling, was 42 percent greater in the fertilized ponds than the non-fertilized ponds, and the production of plankton organisms was 3.3 times as great.

Experimental Use of Fertilizer In the Production of Fish-Food Organisms and Fish

*By ROBERT C. BALL**

During the past several years there has been an increasing demand for better fishing in public waters, and along with this there has developed an interest in the possibility of increasing the productivity of natural and artifically impounded waters by the use of fertilizers. This interest has resulted in many requests for information on the advisability and methods of using fertilizer on watered areas to increase fish production.

Much work has been done in southern states (Swingle, 1947; Surber, 1943, 1944) in investigating the effects of the application of fertilizer to fish ponds. Because of the many physical, chemical and climatological differences existing between southern and northern regions, however, it was believed that the recommendations for fertilizing southern ponds would not be applicable to those in Michigan.

To be able to make recommendations concerning methods and materials to be used in such fertilization, it was believed necessary to test the effectiveness of fertilizers on representative Michigan waters, and to determine the most effective rates of application, proper composition of fertilizers, fish species composition, and rates of stocking that can be expected to give desired results.

These broad aims have been only partially considered in this report which is intended as a progress report on certain of the findings.

As a result of the need for this type of information, a co-operative program was set up to investigate certain problems concerning fertilization of Michigan waters. The Institute for Fisheries Research of the Michigan Department of Conservation was to furnish certain materials and personnel, and Michigan State College was to make available facilities necessary to the carrying out of the problem. Three state-owned hatcheries, Wolf Lake, Drayton Plains, and Hastings, all located in southern Michigan, were made available, in part, for experimental work.

*In cooperation with Michigan Institute for Fisheries Research.

As part of the over-all study of fertilization, a fellowship was established by the Institute for Fisheries Research to enable a student at Michigan State College to follow in detail certain of the biological and chemical changes brought about by the application of fertilizer to ponds. This study resolved itself chiefly into a quantitative and qualitative evaluation of plankton from fertilized and unfertilized hatchery ponds and an appraisal of the methods used. The data have been compiled into a Master's thesis (VanDeusen, 1947) and will be published at a later date.

To make possible the collection of adequate data for certain phases of the fertilization project the Institute for Fisheries Research assigned two fisheries technicians for part-time aid on the project. One technician was assigned to Drayton Plains Hatchery and the other to Wolf Lake Hatchery. These men lived full time at the hatchery and worked both on the fertilization project and with the biologist in charge of the minnow-propagation project. As part of their assignment they made collections of fish-food organisms at regular intervals throughout the summer, fertilized the ponds, ran chemical analyses, collected plankton samples, made counts of fry placed in the ponds, and aided in draining the ponds. In many phases of their work they were aided by the hatchery personnel.

Figure 1 is a map of the Wolf Lake State Fish Hatchery, with the ponds used in the fertilization experiments shown in dark lines. These ponds varied considerably in the composition of the bottom-soil types, ranging from a marl-sand mixture to highly organic muck. As well as possible, the ponds were chosen for similarity of bottom type, basin conformation, and water source. The paired ponds utilized were those numbered on the map as follows: 4 (fertilized) and 5; 7 (fertilized) and 11; 9 (fertilized) and 17; and 12 (fertilized) and 10. All of these ponds with the exception of pond 17 received water from the number one spring. The level of the ponds was maintained and no water allowed to overflow the outlet of the fertilized ponds, thus the only loss of water was by evaporation and through the pond basin.

The water source for this hatchery is from three springs and is quite high in carbonate hardness. The methyl orange alkalinity of the three springs is approximately 160 parts per million. Little change was noted in the chemical composition of the water from the time it left the springs until it entered the experimental ponds. All ponds used were small, ranging from 1 acre to 1.8 acres, and having a maximum depth of 6 feet and an average depth of 2½ feet.

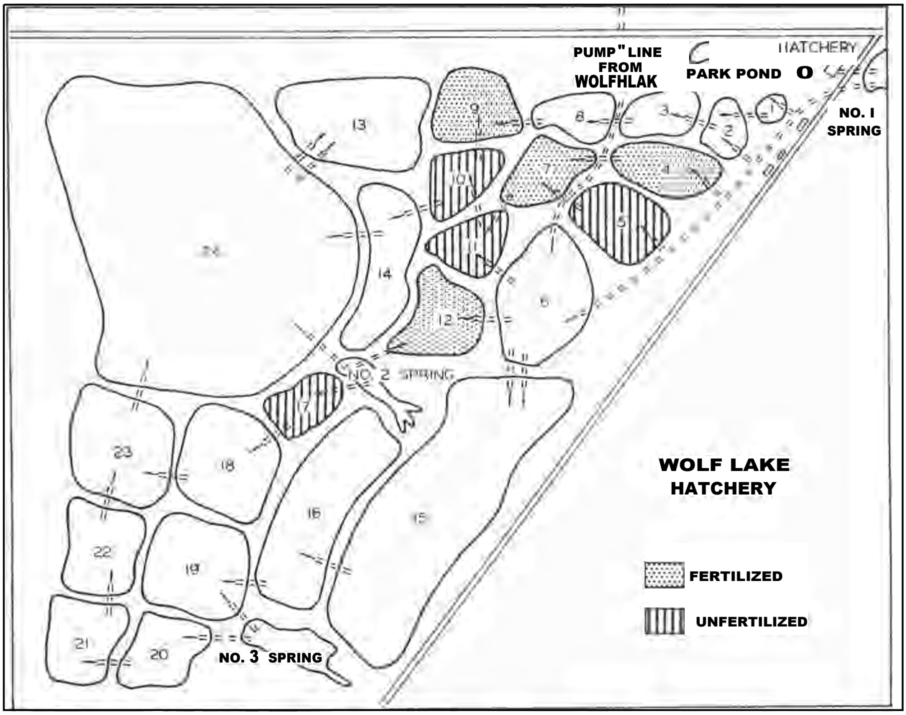

Fig. 1. Wolf Lake Hatchery.

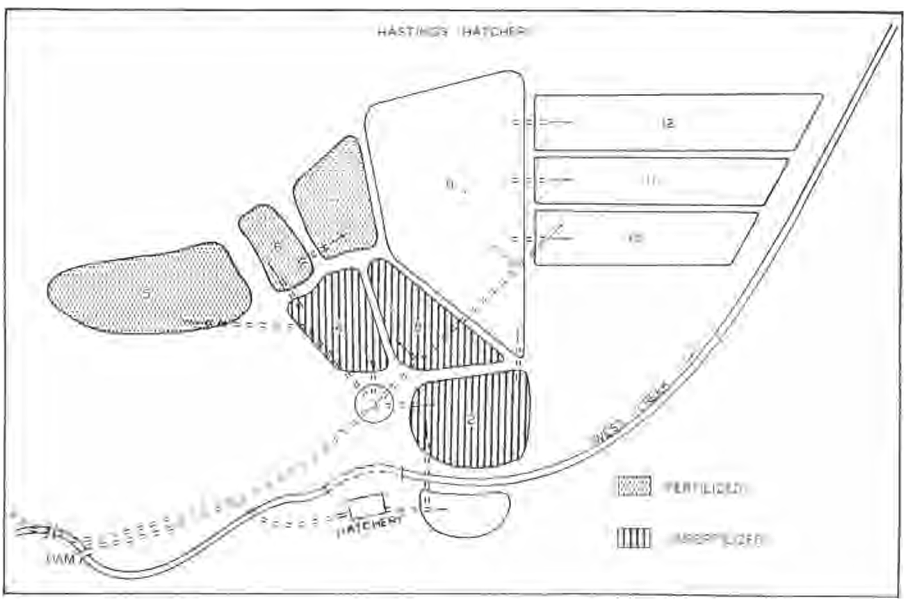

Fig. 2. Hastings State Fish Hatchery.

Figure 2 shows the arrangement of the ponds at the Hastings Hatchery and location of the ponds used in the fertilization experiments. These ponds were quite similar in size and depth to the ponds at Wolf Lake. The water supply is from West Creek, a small stream that supports trout in some sections. The ponds were maintained at a constant level throughout the summer with only enough water flowing in to replace loss through the pond bottom and by evaporation. The methyl orange alkalinity varied slightly during the summer and was approximately 215 parts per million.

The ponds were paired, one receiving fertilizer and the other serving as a control, and each of the pair stocked with fish at the same rate. Pond 5 (fertilized) and 12 were paired, as were pond 6 (fertilized) and 2, 7 (fertilized) and 11, and 8 (fertilized) and 10.

Figure 3 is the plan of the Drayton Plains Hatchery, showing the ponds used in the fertilization experiments. The variation of pond bottom types is greater here than at the other two hatcheries, the ponds having a bottom soil that varied considerably, with much of it being a mixture of sand and marl which does not support dense beds of vegetation such as are present in ponds at the other two hatcheries. Ponds 3 (fertilized) and 4 were paired and stocked with chubs. Ponds 8 and 10 were fertilized and stocked with bass and bluegills, with pond 6 (unfertilized) serving as a control.

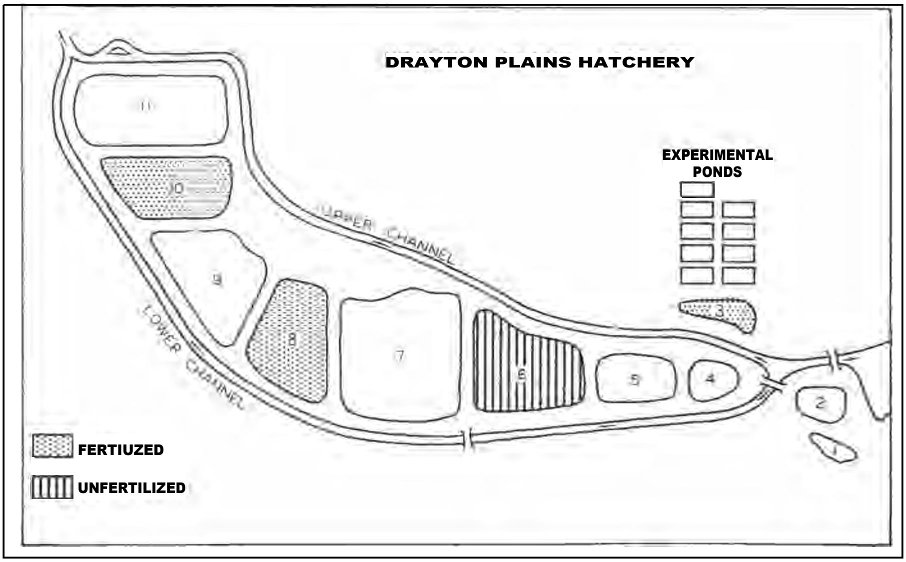

Fig. 3. Drayton Plains Fish Hatchery.

The water supply of this hatchery is from a branch of the Clinton River, a stream flowing through several resort lakes before reaching this hatchery, and is quite variable as to flow and chemical constituents.

ANALYSIS OF FERTILIZER AND METHOD OF APPLICATION

During the 3-month period preceding the start of the field work, greenhouse experiments were conducted under the direction of Dr. Peter I. Tack, of the Section of Zoology, with source waters from the three hatcheries, Wolf Lake, Hastings, and Drayton Plains, to determine the type of fertilizer best suited for these waters. Many fertilizers of different composition were tested and their value determined by the growth of plankton algae in the pots containing the different waters. It was found that a high-nitrogen high-phosphorous fertilizer produced good results (greatest amount of organic matter) in the greenhouse experiments. On the basis of those tests it was determined that a 10-6-4 (N-P_2O_5-K_2O) ratio would be accepted for the first summer's work at these hatcheries. This analysis fertilizer was available from a local distributor.

The commercial fertilizer was applied from a row boat by broadcasting it on the surface of the ponds as evenly as possible. The first application was made on June 18, 1946 and the last on August 26, 1946. The beginning date was later than had been planned, but the scarcity of fertilizer during the spring of 1946 delayed the delivery nearly 2 months. The date of the final application was determined arbitrarily and was approximately 4 weeks prior to the draining of the ponds. It was believed that any application of fertilizer later than this would not be effective in producing any observable change in the fish population before the ponds were drained.

Organic fertilizer in the form of barnyard manure was applied early in the spring to the ponds to be fertilized at both Wolf Lake and Hastings hatcheries, at the rate of 1 ton to each 1% acres of water surface. A phytoplankton bloom followed this application, and it had been planned to make the first application of inorganic fertilizer before this bloom disappeared, but owing to the delay in obtaining the fertilizer nearly 60 days elapsed before the first application of inorganic fertilizer was made.

To determine the proper interval between applications of fertilizer to the ponds for best results, three application schedules were set up at Wolf Lake Hatchery: once each week, once each 2 weeks, and at

3-week intervals, all applications being at the rate of 33.3 pounds per acre each week. At the conclusion of the summer's work the data on production of plankton showed no advantage in applying the fertilizer at 1- or 2-week intervals over the 3-week period, and the saving of labor in applying the fertilizer at less frequent intervals made its adoption desirable.

Fertilization of the ponds at Drayton Plains and Hastings hatcheries was carried out in much the same manner as at Wolf Lake, except that all ponds were treated at 3-week intervals. The ponds at Hastings Hatchery were treated with barnyard manure prior to the application of inorganic fertilizer. The Drayton Plains ponds received no manure.

PRODUCTION OF MINNOWS

A test of the effectiveness of fertilization in the production of minnows was undertaken in conjunction with the bait-minnow propagation experiment being conducted at the same time by the Institute for Fisheries Research. Two species of minnows, the creek chub, *Semotilis atromaculatus* and the common sucker, *Catostomus commersonii* were used in the experiment.

Ponds at three fish hatcheries were stocked at rates estimated to give the most information concerning the production of these fish for sale as bait. At the hatcheries, ponds were selected in pairs, one to be fertilized and one to serve as a control. These were chosen as nearly as possible for similarity of size, water source, general basin conformation and bottom type. The ponds were fertilized as previously indicated, at the rate of 100 pounds per acre surface area each 3-week interval.

SUCKERS

The suckers were planted as eyed eggs in the ponds at Wolf Lake Hatchery as early in the spring as they were available and were not harvested until the growing season was nearly at an end, so that the production as recorded in Table 1 represents that obtained in nearly the maximum growing season at the latitude of the ponds in Michigan.

From these data only rather broad generalization as to the effect of fertilization can be drawn. The suckers were placed in the ponds in trays in the eyed egg stage, and it was in this stage that the greatest mortality is believed to have taken place. Approximately 7 percent of the eyed sucker eggs that were placed in the fertilized ponds in the spring hatched and lived until the ponds were drained in the

TABLE **1-Data** *concerning production of suckers in ponds at Wolf Lake Hatchery, 1946*

Pond number	Area of pond (acres)	Species planted	Number of fish planted per acre	Number of fish recovered per acre'	Percent survival	Pounds of fish recovered per acre'	Pounds of other fish per acre'	Pounds of all organisms per acre'	Average length (inches)	Number pound	Length when planted inches	Days in pond
4 (fertilized)...	1.0	Suckers	100,000	8,239	8.2	86.7	0	204	3.3	95	Eyed eggs	144
5 (unfertilized).	1.0	Suckers	100,000	5,769	5.8	96.1	0	183	3.8	60	Eyed *eggs*	143
7 (fertilized)...	1.5	Suckers	10,000	2,058	20.0	206.0	45	271	6.7	10	Eyed eggs	148
11 (unfertilized).	1.3	Suckers	10,000	287	2.9	34.1	0	56	7.0	8	Eyed eggs	150
9 (fertilized)...	1.7	Suckers	50,000	491	1.0	101.0	59	174	8.2	5	Eyed eggs	145
17 (unfertilized).	1.3	Suckers	50,000	5,322	10.6	102.4	0	141	4.0	52	Eyed *eggs*	149
12 (fertilized)...	1.8	Suckers	25,000	1,739	6.9	217.4	0	279	7.2	8	Eyed eggs	150
10 (unfertilized).	1.5	Suckers	25,000	24	0.1	0.4	91	267	6.6	6	Eyed eggs	148

'Species of fish planted in experiment.
'Volunteers in pond.
'Crayfish, tadpoles, and all fish.

fall. This compares favorably with the survival figures given for Minnesota ponds (Dobie, 1947).

There does appear to be an indication of a greater survival in the fertilized ponds than in the unfertilized ponds, but it should be noted that survival was modified in these experiments to varying and unknown degrees by factors which cannot be quantitatively evaluated, such as loss in the egg stage after being placed in the ponds, predation, and competition by the "volunteer" fish in the ponds, etc. The number and size of unwanted fish in the ponds unquestionably modified the survival of the suckers, and the number of these fish was not constant in the several ponds. That this variability in survival and production may be expected is seen from the experiments in bait-fish production in other states as reported by Dobie, Meehean, and Washburn (1948).

Because of the relatively low survival of suckers it is not probable that the productive capacity of the ponds was reached, unless it was in ponds 5 and 11, both of which were unfertilized and normally quite barren. In these ponds the suckers were observed to be consistently digging small pits in search of food and it was the opinion of the biologist stationed at the hatchery that this digging was only common where the food supply was severely taxed by the number of fish present.

In addition to the suckers, other organisms were present at the time of draining. The bulk of these by weight were tadpoles and crayfish. Their importance as competitors for food in the ponds is not known, but it is quite certain that they were not utilized as food by suckers of the size that were present.

Several other species of fish, including sunfish and darters, were present in the pond. These fish probably were direct competitors for food as well as predators on the small suckers.

The size of the suckers appears to be inversely proportionate to the number present. It was observed that the suckers in the fertilized ponds were of a very uniform size whereas the size of those in the unfertilized ponds was quite variable. This uniformity of size would be quite an advantage in raising bait minnows. Fig. 4 shows graphically the weight relationship of suckers, other organisms, fish-food organisms and plankton.

CHUBS

The fertilization experiment concerning the production of chubs was carried out in eight ponds at the Hastings Hatchery, four fer-

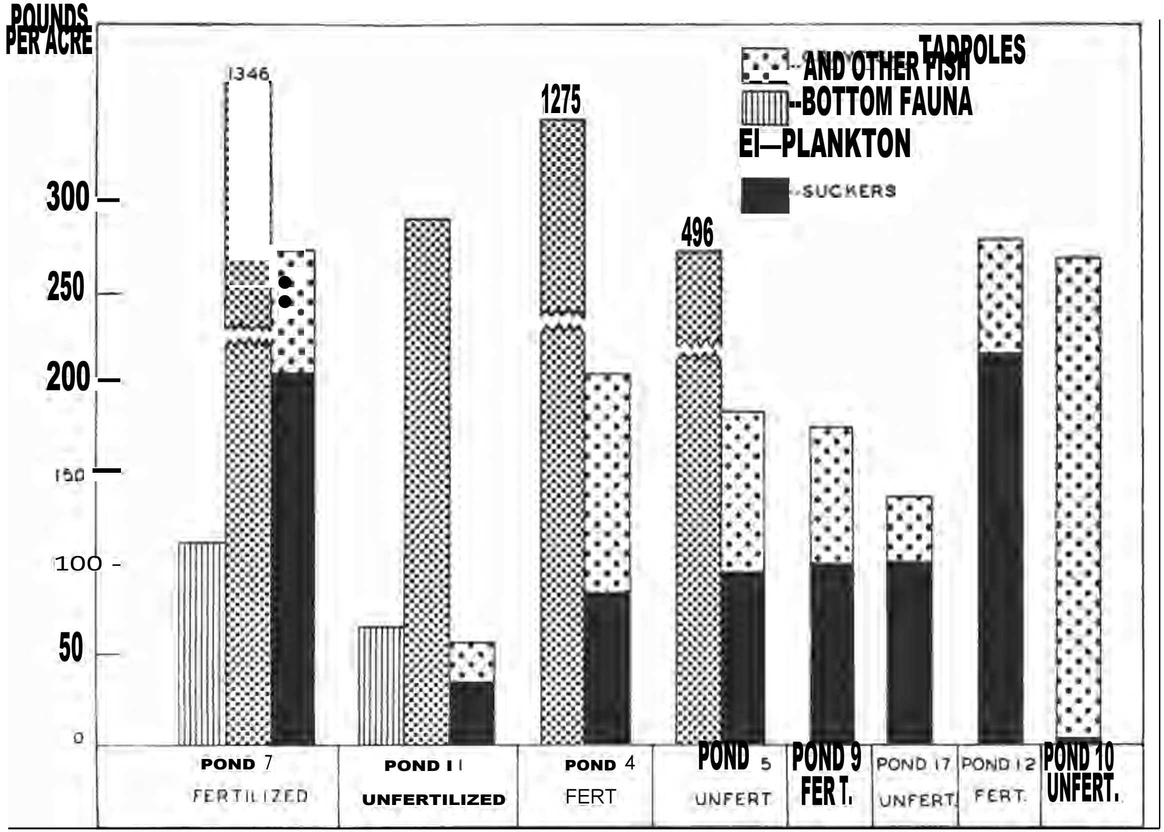

Fig. 4. Production of suckers, bottom fauna, plankton, and other organisms in fertilized and unfertilized ponds at Wolf Lake, 1946.

TABLE *2-Data concerning production of chubs at Hastings Hatchery, 1946*

Pond number	Area of pond (acres)	Species planted	Number of fish planted per acre	Number of fish recovered per acre[1]	Percent survival	Pounds of fish recovered per acre[1]	Pounds of other fish per acre[2]	Pounds of all organisms per acre[3]	Average length (inches)	Number per pound	Length when planted (inches)	Days in pond
5 (fertilized)...	2.1	Chubs	10,000	200	2.0	10.8	....	96	4.8	18	Sac fry	135
12 (unfertilized).	1.5	Chubs	10,000	145	1.5	4.7		45	4.3	31	Sac fry	135
6 (fertilized)...	.6	Chubs	44,000	6,875	15.6	136.5	....	352	3.9	50	Sac fry	129
2 (unfertilized).	1.0	Chubs	25,000	4,500	18.0	50.0	....	250	3.1	90	Sac fry	129
8 (fertilized)...	1.0	Chubs	35,000	1,312	3.8	31.0		160	3.7	43	Sac fry	128
10 (unfertilized).	1.0	Chubs	35,000	2,880	8.2	80.0	....	122	3.7	36	Sac fry	129
7 (fertilized)...	1.1	Chubs	25,000	308	1.2	8.1	....	70	4.4	38	Sac fry	135
11 (unfertilized).	1.3	Chubs	25,000	67	.3	1.8	....	53	4.2	32	Sac fry	135

[1]Species of fish planted in experiment.
[2]Volunteers in pond.
[3]Crayfish, tadpoles, and all fish.

tilized and four controls, and one pair of ponds at the Drayton Plains Hatchery. Each pair of ponds was stocked at the same rate with sac fry, which had been hatched in hatchery jars and held in troughs until the yolk sac was nearly absorbed.

Table 2 shows the data pertaining to the production of chubs at the Hastings Hatchery. The same factors affected the survival of these fry as were considered for the Wolf Lake experiment with suckers and, in general, the same tentative conclusions as to the effect of fertilizer apply. The survival of chubs at Hastings was 6.3 percent. Variation of the rate of survival in the several ponds was large. Here, too, the factors affecting survival were not closely, if at all, tied in with fertilization and no evaluation of the effect of fertilization on survival can be made. In the draining of these ponds, no effort was made to separate the volunteer fish from the other organisms (crayfish and tadpoles) and the weight of these is shown in the table under the heading "all organisms". The fertilized ponds produced, without exception, a greater total weight of organism than did the unfertilized ponds, in most cases considerably greater. The weight relationship of the chubs in fertilized and unfertilized ponds at the Hastings Hatchery, and this relationship to other organisms is shown in Fig. 5. Two small ponds at the Drayton Plains Hatchery were stocked with chub fry and data on the production of these two ponds are shown in Table 3. These fish had a somewhat shorter growing season than those at Hastings and the production in pounds per acre was considerably less, notwithstanding the greater survival. A comparison of the production of these two ponds is shown graphically in Fig. 6.

PRODUCTION OF BASS AND BLUEGILLS

To be better able to make recommendations concerning desirable species combinations and the rates at which different components of the population should be stocked, the workers stocked largemouth bass and bluegills at different rates in ponds at Drayton Plains Hatchery. The stocking rates, rate of recovery, and the size of fish recovered in the three experimental ponds are shown in Table 3. From this table it can be seen the survival rate of the bass, which were planted as advanced fry of about one inch in length, was high, whereas the survival of the bluegills, which were planted as golden fry, was quite low. The survival and production of both the bass and bluegills was influenced by the presence of other fish in ponds 6 and 10. The Brook Stickleback *(Eucalia inconstans)* was the most important "volunteer" fish,

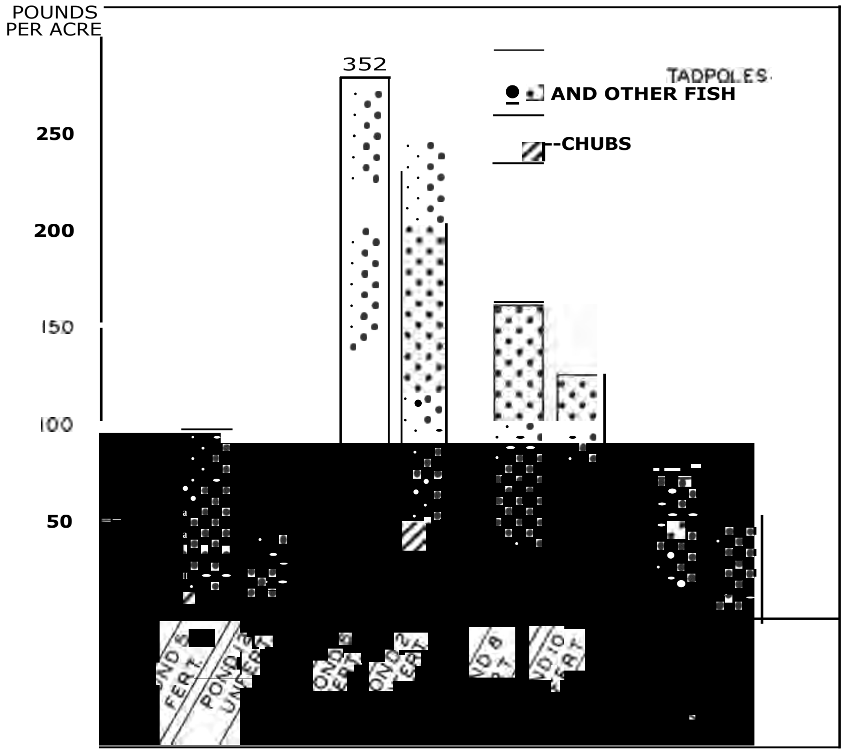

Fig. 5. Production of chubs and other organisms in fertilized and unfertilized ponds at Hastings Hatchery, 1946.

there being approximately 113,000 in pond 6 at the time it was drained. It is extremely difficult to keep the ponds free from this fish if it occurs in the water supply and it is both a competitor of and predator on the young of other fish.

From these experiments it can be seen that stocking of bluegill fry was not satisfactory under the conditions existing at the time. The difficulties a pond owner would have in obtaining and positively identifying bluegill fry, and of predicting survival to adult size, which must be done to assure a proper balance in the pond, make it desirable that the bluegills be stocked as adults and the bass as fingerlings or adults.

The actual survival of the young bass and bluegills was not accurately established in pond 6, as indicated by the taking of more small bass at the end of the growing period than were planted as advanced fry. This was due to the water source being well supplied with fry of the same size as those planted, and the screening between the water

TABLE 3—*Data on production of largemouth bass, blue gills, and chubs, and the survival of young fish in ponds at Drayton Plains Hatchery, 1946*

Pond number	Area of pond (acres)	Species planted'	Number of fish planted per acre	Number of fish recovered per acre'	Percent survival	Pounds of fish recovered per acre'	Pounds of other fish per acre'	Pounds of all organisms per acre'	Average length (inches)	Number per pound	Length when planted (inches)	Days in pond
6 (unfertilized).	3.7	Bass	200	• 236	118	15.1	30.6	153.5	4.9	16	1	67
		Bluegills	3,000	300	10	1.7			2.5	200	Fry	
8 (fertilized)...	3.7	Bass	270	220	79	7.1	0	30.0	4.3	32	1	71
		Bluegills	4,000	220	18.2	1.0			1.9	220	Fry	
10 (fertilized)...	7.1	Bass	1,000	720	71	25.8	3.5	247.5	4.3	27	1	73
		Bluegills	15,000	930	6.3	5.5			2.1	170	Fry	
3 (fertilized)...	.46	Chubs	38,500	19,908	51	102.6	0	246	2.5	194	Fry	114
4 (unfertilized).	.48	Chubs	32,000	23,380	73	112.5	0	133.3	2.5	208	Fry	114

'Species of fish planted in experiment.
'Volunteers in pond.
'Crayfish, tadpoles, and all fish.

source and this pond not adequate to keep out the smallest fish. It does not seem that the carrying capacity of any of the ponds was approached in the number and weight of bass and bluegills produced. Figure 6 shows the relationship of bass and bluegills to other organisms and to the average standing crop of invertebrate fish-food organisms.

The data on the production in the two ponds at Drayton Plains Hatchery that were stocked with chubs, shown in Fig. 6, indicate a considerably greater production of total organisms in the fertilized pond than in the unfertilized pond, but the production of chubs was lower in the fertilized pond.

The somewhat lower production of chubs may have been due to the competition of the other organisms for food. Very little can be concluded as to the value of fertilizeration in the production of bass, bluegills, and chubs from this experiment, but there is experimental

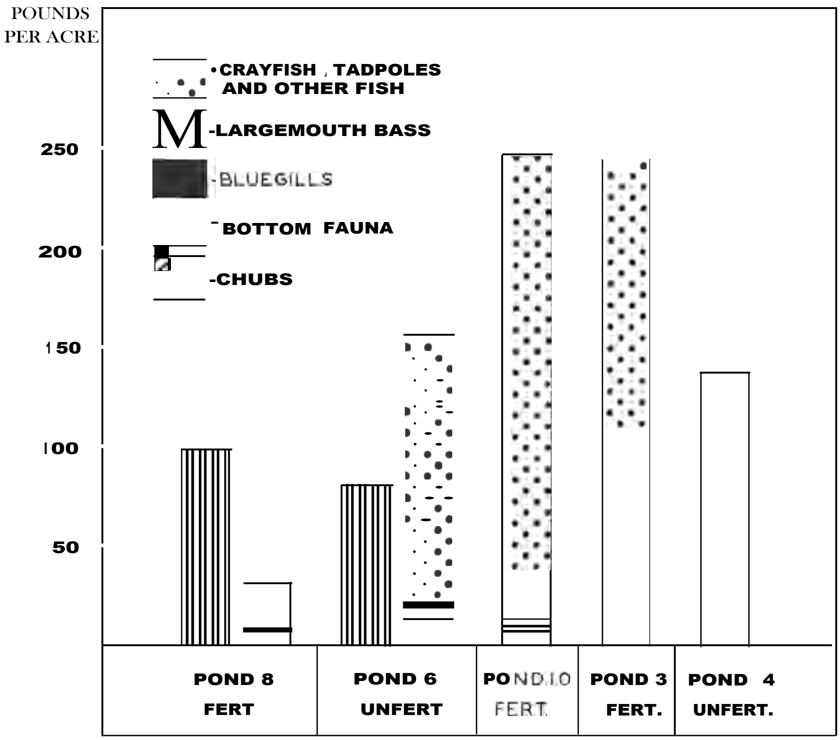

Fig. 6. Production of fish, bottom fauna, and other organisms in fertilized and unfertilized ponds at Drayton Plains Hatchery, 1946.

evidence that the addition of fertilizer to a pond does produce greater total weight of all organisms, (fish, crayfish, tadpoles, invertebrates).

FISH-FOOD ORGANISMS

To evaluate further the effects of fertilizer and more thoroughly understand the action of fertilizer on the food chain of the fish, a program of sampling the invertebrate fish-food organisms was undertaken at both the Wolf Lake and Drayton Plains hatcheries. These samples were collected at regular intervals from each of a pair of ponds, one fertilized and one unfertilized, by the biologist stationed at each hatchery. The sampling was by means of either a Peterson or Ekman dredge, depending upon the bottom type.

The results of collections made in ponds 6 and 8 at Drayton Plains are tabulated in tables 4 and 5. The organisms shown in the tables have been tabulated by percentage of total volume and percentage

TABLE 4-Invertebrate fauna collected by bottom sampling, *1946,* Drayton Plains Hatchery Pond No. *6* (unfertilized)

Collection period		June	July		August		Totals	Percent of total
		16-30	1-15	16-31	1-15	16-31		
No. of samples		6	17	13	10	10	56	....
Total area (sq. ft.)		4.97	14.07	10.76	8.28	8.28		
Total no. of org.		103	813	921	288	204	2329	....
No. org. per sq. ft		21	58	86	35	25	(ave.)50	....
Total vol. organisms		5.10	13.25	8.80	8.20	4.40		
Vol. org. per sq. ft		1.03	0.94	0.82	0.99	0.53	(ave.)0. 86	....
Chironomidae	No Vol. (cc)	38 0.25	621 1.50	668 2.00	130 0.55	84 0.50	1541 4.80	66.1 12.1
Anisoptera	No Vol.	20 1.20	35 4.45	26 2.95	7 0.25	19 0.60	107 9.45	4.6 23.8
					6	6	19 0.60	0.8 1.5
Ephemerida	No Vol.	4 0.15	100 0.70	149 0.65	94 0.55	67 0.50	415 2.55	17.8 6.4
Trichoptera	No Vol.	1 0.05	....	24 0.50	7 0.25	6 0.20	38 1.00	1.6 2.5
Coleoptera	No Vol.	12 0.20	10 0.30	23 0.50	16 0.40	10 0.30	72 1.70	3.1 4.3
Hemiptera	No	....	4	4	....	....	8	....
Annelida	No Vol.	2.85	6.00	1.90	5.95	2.05	18.75	46.5
Amphipoda	No	16	2	....	....	....	18 0.45	0.8 1.1

TABLE 5-*Invertebrate fauna collected by bottom sampling, 1946, Drayton Plains Hatchery Pond No. 8 (fertilized)*

Collection period		June 16-30	July 1-15	July 16-31	August 1-15	August 16-31	Tot als	Percent of total
No. of samples		7	15	14	8	10	54	
Total area (sq. ft.)		5.80	12.42	11.60	6.62	8.28		
Total no. of org		125	1337	1350	603	657	4072	
No. org. per sq. ft		22	108	116	91	79	(ave.) 101	....
Total vol. organisms		4.15	9.00	13.15	9.60	10.45		
Vol. org. per sq. ft		0.72	0.81	1.13	1.45	1.25	(ave.) 1.04	....
Chironomidae	No	84	1002	996	398	425	2905	71.3
	Vol. (cc)	0.45	4.00	4.65	0.65	1.80	10.55	22.8
Anisoptera	No	30	11	11	13	14	79	1.9
	Vol.	1.35	1.60	0.55	0.80	0.65	4.95	10.7
Zygoptera	No	....	1	23	34	36	94	2.3
	Vol.	....	0.05	0.40	0.35	0.40	1.20	2.6
Ephemerida	No	....	289	285	130	161	865	21.24
	Vol.	....	1.30	1.45	0.75	1.15	4.65	10.0
Trichoptera	No	3	....	....	1	....		
Coleoptera	No	....	20	17	7	6	50	1.2
	Vol.	....	0.50	0.35	0.15	0.20	1.20	2.6
Hemiptera	No	....	1			....	2	....
Lepidoptera	No	....	2	....	....	....	2	....
	Vol.	Z..5	[illegible]	[illegible]	6.70	7.40	3.30	561i

of total number. From these data it can be seen that the Annelida constitute a large percentage of the total volume in all ponds, ranging from approximately 33 percent to more than 50 percent of the total. Included under the heading "Annelida" were the large aquatic earthworms which were common in all ponds at Wolf Lake Hatchery, the smaller tubificids, and the leeches. The annelids were not considered of much importance as fish food in these ponds as the large earthworms were deep enough in the pond bottom material to be unavailable to the fish. The tubificids were few in number, and the leeches, which were volumetrically important in the samples from Drayton Plains, were nearly all very large individuals and, thus, not available as food for the young-of-the-year fish.

The results of the collections from the two ponds at Drayton Plains are shown graphically in Fig. 8. From the chart, which was plotted from the data on the daily collections, it can be seen that the volume of bottom-dwelling organisms was greater in pond 6, the unfertilized pond, at the beginning of the fertilization period. This is believed to be a true representation of the productivity of the ponds, which, although chosen as being quite similar in size and depth, proved quite different biologically. The bottom material in pond 6 was richer in organic matter and was without the sand-marl deposits which made areas of the bottom of pond 8 quite barren.

The curves representing the volumes of organisms per unit area of the paired ponds show the low point of the collection period to be early in summer, a condition found in a natural lake in the same general area (Ball, 1948) and one which corresponds with the period of

TABLE *6-Invertebrate fauna collected by dredge sampling, 1946, Wolf Lake Hatchery Pond No. 7 (fertilized)*

Collection period		June	July		Aug.		Sept.	Totals	Percent of total
		16-30	1-15	16-31	1-15	16-31	1-15		
No. of samples....		10	20	13	7	18	16	84	
Total area (sq. ft.)		8.28	8.28	5.38	2.90	7.45	6.63	38.92	....
Total no. of org......		385	136	245	278	288	145	1479	....
No. org. per sq. ft		47	16	45	96	39	22	(ave.) 38	....
Total vol. organisms...... ...		12.90	5.05	4.65	5.50	9.70	8.20	46.00	....
Vol. org. per sq. ft		1.55	0.61	0.86	1.90	1.30	1.24	(ave.) 1.18	....
Chironomidae...	No ...... Vol. (cc)..	195 4.05	54 1.05	89 1.00	215 2.40	264 3.25	132 1.35	949 13.10	64.1 28.5
Anisoptera........	No ...... Vol......	1 0.05	3 1.35	1 0.05	3 0.75	2 0.10	....	10 2.30	0.7 5.0
					1	1	....	5	....
Ephemerida......	No ...... Vol.	106 0.85	38 0.55	130 0.85	24 0.25	6 0.10	....	309 2.60	20.9 5.6
								7	....
Coleoptera......	No	15	5	1	....	....	....	21 0.55	1.4 1.2
Hemiptera... . .	No	5	1	....	....	....	....	6	....
	Vol..... .	6.20	1.15	2.30	1.70	5.90	6.40	23.65	50.8
Nematoda.	No .... Vol.	....	5 0.15	....	6 0.10	4 0.15	5 0.15	20 0.55	1.4 1.2
Amphipoda.. . .	No ...... Vol.	16 0.20	14 0.15	19 0.25	28 0.20	13 0.15	6 0.20	96 1.15	6.5 2.5
Arachnida	No	3						4	....
Snails.	No ...... Vol.	23 0.50	15 0.30	0.05	....	....	0.05	40 0.90	2.7 2.0

peak emergence in lakes in this latitude. Following this low point the production in both ponds took an upward swing and the standing crops of fish-food organisms were about equal in the third week of July, but from this time on the fertilized pond showed an increase in the volume of organisms per unit area and the unfertilized pond did not.

Data concerning the collections of fish-food organisms in fertilized and unfertilized ponds at Wolf Lake are tabulated in Tables 6 and 7.

TABLE *7-Invertebrate fauna collected by dredge sampling, 1946, Wolfe Lake Hatchery Pond No. 11 (unfertilized)*

Collection period		June	July		Aug.		Sept.	Totals	Percent of total
		16-30	1-15	16-31	1-15	16-31	1-15		
No. of samples....		10	20	14	10	28	2	84	
Total area (sq. ft.)		7.28	8.28	5.80	4.14	11.59	.83	38.98	....
Total no. of org...........		254	221	247	128	280	15	1145	....
No. org. per sq. ft		35	27	43	31	24	18	(ave.) 29	....
Total vol. organisms...... ...		9.00	**4.15**	4.45	2.10	7.25	.25		
Vol. org. per sq. ft		1.24	0.50	0.77	0.51	0.63	.63	(ave.) 0.70	....
Chironomidae...	No . . .... Vol. (cc)..	144 0.95	113 0.95	46 0.60	57 0.60	179 1.60	13 .10	552 **4.80**	48.2 17.6
Other diptera ...	No ...... Vol.........	3	2	....	1	....	....	6 0.25	.... 0.9
Anisoptera	No ...... Vol	24 0.75	3 0.15	8 0.40	3 0.10	0.40	....	42 1.80	3.7 6.6
Zygoptera......	No .... Vol.........	....	1 0.05	7 0.20	1 0.05	0.50	....	25 0.80	2.2 2.9
Ephemeridae......	No .... Vol.........	4 0.15	61 0.60	106 0.75	22 0.40	29 1.15	....	222 3.05	19.4 11.2
Trichoptera.....	No .... Vol.	6 0.15	2 0.05	0.05	....	0.05	....	10 0.30	0.9 1.1
Coleoptera	Vol.	0.05	1 0.05	0.05	....	0.05	....	10	0.9
				2	....	....	2	4	....
	Vol.......							4	....
Annelida	No .... Vol.........	3.ao	0.90	1.66	0.40	.60	.O:io	.b0	2.i
Amphipoda.....	No .... Vol.	60 0.65	30 0.45	69 0.60	39 0.35	0.75	....	242 2.80	21.1 10.3
Crayfish...	No .... Vol.........	3						5 3.50	.... 12.9
	Vol.........							1	....
Snails.	No .... Vol.........	3 0.10	4 0.15	0.10	....	0.15	....	12 0.50	1.0 1.8

These data are shown graphically in Fig. 8. This chart shows about the same condition as was noted in collections from the Drayton Plains ponds; that is, the high point for the season during which collections were made was early in the period, followed by a rapid falling off of the volume during mid-July. The recovery of volume of organisms in the fertilized pond following this period was quite rapid but the unfertilized pond did not show this rapid recovery.

About the middle of July the fish in the ponds reached a size at which they began feeding on the macroscopic invertebrates, and as is seen in both Figs. 7 and 8 the invertebrates in the fertilized ponds were able to maintain themselves or increased in spite of the increasing size of the fish population with the accompanying demand on the food supply, whereas the total volume of invertebrates in the untreated ponds declined as the fish population increased.

This increase in volume and maintenance of a greater volume of fish food in the fertilized pond is even more significant in view of the

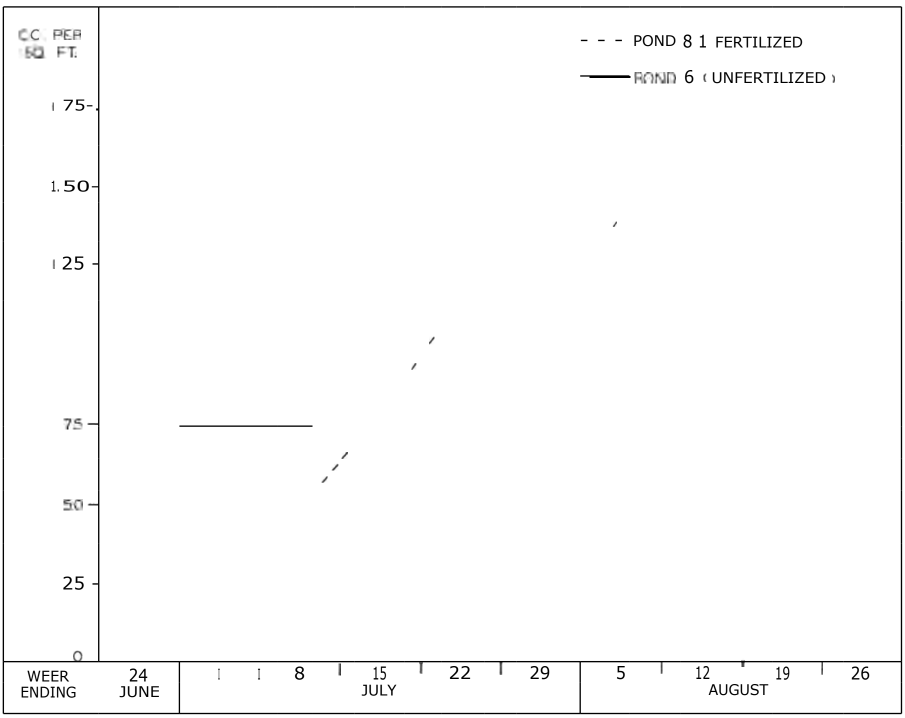

Fig. 7. Volume per unit area of invertebrate fish-food organisms in fertilized and unfertilized ponds at Drayton Plains Hatchery, 1946.

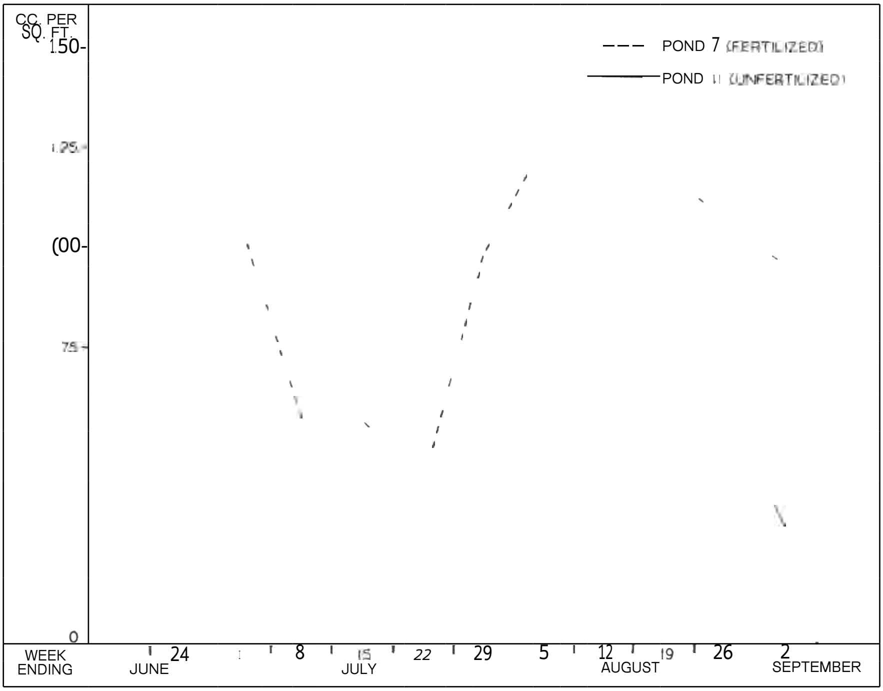

Fig. 8. Production of invertebrate fish-food organisms in fertilized and ***un-fertilized*** *ponds at Wolf Lake, 1946.*

expressed belief by the hatchery superintendent that, of the paired ponds at Drayton Plains, the unfertilized pond had been, in past years, more productive than the fertilized pond.

In Table 8 are presented the data showing the percentage composition by volume, of invertebrates collected from the ponds.

TABLE 8—*Percent by volume composition of important invertebrates in dredge samples from fertilized and unfertilized ponds*[1]

Species	Drayton Plains		Wolf Lake	
	Fertilized	Unfertilized	Fertilized	Unfertilized
Midges	22.8	12.0	28.5	17.6
	13.3	25.3	5.4	9.5
	10.0	6.4	5.7	11.2
Beetles	2.6	4.3	1.2	0.7
	50.3	46.5	50.8	32.7

[1] Those constituting more than 1 percent of the total volume.

Observations on paired ponds indicate that of the aquatic insects it often is the midge population that increases first and most rapidly in ponds where fertilizer is applied. The midges, having more than one generation per year, respond rapidly to a favorable change in the environment such as presumably is brought about by the fertilizer.

The difference of the average standing crops of macroscopic invertebrates as determined by sampling in the four ponds is shown in Table 9. From this table it can be seen that the potential fish food, as measured in pounds per acre, is considerably greater in the fertilized ponds, as much as 68 percent in the paired ponds at Wolf Lake and 21 percent in the ponds at Drayton Plains Hatchery. It is believed that this appreciably greater standing crop of fish-food organisms in the fertilized ponds can be considered as a direct result of fertilization.

COMPARISON OF SIZE OF INDIVIDUAL ORGANISMS IN FERTILIZED AND UNFERTILIZED PONDS

In the belief that the effects of fertilization might be reflected in the size (volume) of the individual organisms, the average volume of individual organisms was determined for several of the invertebrates in both fertilized and non-fertilized ponds. From this comparison came an indication that the individual chironomids are larger in the fertilized ponds. This difference in size was not so pronounced, or not evident at all, in other forms considered. The specific identification of species involved was not determined and it may be that had such been

TABLE 9—*Volume of fish-food organisms collected in ponds at Wolf Lake and Drayton Plains hatcheries, 1946*

Pond number	Average number per square foot	Average volume per square foot c.c.	Pounds per acre
Wolf Lake			
7 (fertilized)	38	1.18	113.3
11 (unfertilized)	29	.70	67.2
Drayton Plains			
8 (fertilized)	91	1.04	99.9
6 (unfertilized)	50	.86	82.6

done the differences in size would not have been valid but it is indicated that the general tendency is toward larger individual size in the fertilized ponds.

PLANKTON

Plankton samples throughout the period of fertilization were taken at weekly intervals from two fertilized and two non-fertilized ponds at the Wolf Lake Hatchery. These collections were evaluated in several ways (VanDeusen, ms.) but for purposes of this report only the counts, which were made by the Sedgwick-Rafter method, and the volumetric estimates, which were made by precipitating out the plankton organisms with a mercuric chloride solution and measuring in a graduated centrifuge tube are considered. In computing the total volume of plankton, zooplankton and phytoplankton organisms were considered together but this lumping of the two groups changed the total volume very little as there were few zooplankters in the ponds during most of the summer. It is assumed that the volume of phytoplankton is a better criterion of production of organic matter than are the numerical counts.

A tabulation of these collections by number of organisms is shown in Table 10 and by volume of organisms in Table 11. From these tables it is seen that the number of plankters per unit volume of water is far greater throughout the entire period considered in fertilized

TABLE *10—Number of plankton organisms per liter in fertilized and unfertilized ponds at Wolf Lake Hatchery, 1946**

Date	Pond 4 (fertilized)	Pond 5 (unfertilized)	Pond 7 (fertilized)	Pond 11 (unfertilized)
		1,014,000	376,000	376,000
		654,000	458,000	376,000
		392,500	441,500	327,000
		441,500	212,500	474,500
		131,000	310,500	245,500
		310,500	2,191,500	147,000
		327,000	2,534,500	294,500
	8,536,500	294,500	8,373,000	245,500
26........	8,749,500	327,000	13,573,500	376,000
Sept. 3........................	13,606,500	474,500	22,748,500	359,500
		507,000	9,484,500	425,000
Total....................	115,881,500	4,873,500	60,705,000	3,646,500
Average.......	10,534,682	443,046	5,518,637	331,500

*Data from VanDeusen (ms).

TABLE 11-Weight *of plankton organisms in grams per liter in fertilized and unfertilized ponds at Wolf Lake Hatchery, 1946**

Date	Pond 4 (fertilized)	Pond 5 (control)	Pond 7 (fertilized)	Pond 11 (control)
July		0.15 g/l	0.27 g/l	0.03 g/l
	.13	.12	.11	.04
	.23	.07	.06	.05
	.24	.13	.05	.05
	.17	.05	.07	.05
	.18	.03	.15	.03
	.22	.07	.15	.03
	.18	.03	.21	.05
	.17	.03	.45	.04
	.18	.02	.28	.05
	.18	.06	.33	.05
Average.......	0.18	0.07	0.19	0.04
Pounds per acre average depth	1275	496	1346	283
Pounds per acre foot	510	198	538	113

*Data modified from VanDeusen (ms).

than in the non-fertilized ponds. The volume of plankton organisms per unit was also higher in fertilized ponds, averaging 510 pounds per acre foot for the two fertilized ponds as compared with an average of 156 pounds per acre foot in the two untreated ponds.

Table 12 summarizes the weights of fish, tadpoles and crayfish, invertebrate fish-food organisms, and plankton produced in fertilized and unfertilized ponds during a single growing season. These data are averages of all ponds utilized in the fertilization studies at the three state fish hatcheries where the studies were carried out and as a result show the over-all picture without pointing out the individual variations that did occur. From the other data presented in this paper it is evident that not in every case will the fertilized pond produce greater weights of organisms per unit area than a similar non-fertilized

TABLE 12-Summary *of production in pounds per acre of fish and other organisms in fertilized and non-fertilized ponds at three state fish hatcheries, 1946*

	Large-mouth Bass	Chubs	Bluegills	Suckers	Bottom Organisms	Tadpoles	Plankton
Fertilized ponds. .	16.5	75	3.3	153	106	113	524*
Unfertilized ponds	15.1	74	1.7	58	75	76	156*

*Weight per acre foot.

one. It is also evident from this work that ponds which have been chosen for similarity of physical, chemical, and biological detail will often react quite differently to the stimulus of an application of fertilizer. These differences in similar ponds have been observed by other workers who have attempted to use untreated ponds as controls for fertilized ponds, (Swingle, 1947) however, the data presented in the table do show a uniformity in that, in every case, the average production of fertilized ponds was greater than the unfertilized ponds.

While there may not be enough data to justify a generalization, it does appear that the closer the feeding habits of the fish concerned are to the base of the food chain the more the effects of fertilizer are reflected in total weight of fish produced. The effect of fertilizer upon the lower vertebrates, invertebrates, and plankton organisms is much more pronounced than on the fish.

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