

RELATIONSHIPS OF A FISH POPULATION
TO THE INVERTEBRATE FAUNA IN TWO
SMALL PONDS

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

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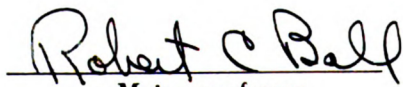
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RELATIONSHIPS OF A FISH POPULATION TO THE
INVERTEBRATE FAUNA IN TWO SMALL PONDS

By

LLOYD PRICE WILKINS

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INTRODUCTION

The increasing demands made upon existing fish stocks in bodies of water, due primarily to expanding fishing intensity, have resulted in a more critical examination of factors controlling the magnitude of fish and fish food abundance. With more complete information concerning these limiting influences, it may be possible to expand production at one or more trophic food chain levels and subsequently increase the yield of food organisms and fish at higher levels.

Maximum fish yield in an aquatic environment cannot exceed the ability of the habitat to produce the food necessary for maintenance of normal metabolic activity and increase in growth. Therefore, from a fishery management standpoint, the relationship of fish to their food supply is perhaps the most important of the many interactions occurring in the ecological complex of bodies of water. The investigation described here was designed to further our knowledge of this interrelation. The particular phase chosen was that of a primary carnivore fish population to the benthic fauna in small ponds.

A bottom fauna study was conducted to record the reaction of invertebrate fauna to the introduction and removal of a fish population closely dependent upon it. Two ponds, similar in morphometric, physical, and biological characteristics, were chosen for the experiment. One was stocked in

April, 1951 with fish and the other not stocked. Sampling of the benthic fauna was begun immediately, and collections were made at a uniform rate during May and June. During the first week of July, the pond containing fish was drained, its fish population removed, and was refilled immediately. The fish were counted, weighed, and a poundage equal to that initially released was transferred to the pond previously without fish. Bottom sampling was continued at the same rate throughout July and August until termination of the experiment the first week of September. At this time the fish were removed to allow determination of their increase in weight.

A feeding habit study was conducted concurrently with the bottom fauna study to indicate not only the benthic groups present in the environment but those actually important in the food chain economy.

Another consideration involved the use of forage ratio in tracing the variation in feeding habits of fish as the composition of food items changed during the season.

A correlation between average standing crop of bottom fauna and weight of fish produced from it during the two sampling and growth intervals is recorded. Certain of these data were applicable to a study of food conversion by comparing the volume of benthic organisms ingested with the resultant amount of fish growth.

DESCRIPTION OF PONDS

The two ponds used in this experiment are located at the Wolf Lake State Fish Hatchery, 10 miles west of Kalamazoo in Van Buren County, Michigan. They were selected for the study because of their similarity in size, depth, basin conformation, bottom type, and common water supply. The ponds each have a surface area of approximately one acre, a maximum depth of 6.5 feet and an average depth of 3.0 feet. The water supply is very high in carbonate hardness (160 p.p.m.) and comes directly from a large spring which is the main water supply for the hatchery. A nearly uniform water level with a minimum of overflow was maintained at all times. Black, organic muck covers the bottom of both bodies of water except for a narrow fringe of sandy shoreline.

A growth of Chara developed over most of the bottom of each pond (Figure 1) within three weeks after filling. The only other higher vegetation to develop was a bed of Potamogeton pectinatus near the outlet of Pond 4. There was no appreciable change in these plant beds as the season progressed.

Turbidity readings were made each week by means of a Secchi disk. The disk was visible at the deepest point of Pond 5 throughout the spring and summer. A phytoplankton growth began to develop in Pond 4 the second week in May and reached a climax on May 26 with a recorded Secchi reading of

Figure 1. Pond 4 during the draining process.



36 inches. Five days of cold, rainy weather followed and 10 days later all traces of the bloom had disappeared. This was the only plankton bloom observed during the experiment.

A plankton growth, induced by the application of fertilizer, has been employed successfully to control undesirable submerged aquatic plants (Smith and Swingle, 1942; Surber, 1945; Hogan, 1949; Swingle and Smith, 1950). The controlling action is one of reduced light penetration causing photosynthesis to be retarded in the higher aquatic plants to a point where they die.

Plankton turbidity in Pond 4 was of such short duration it had no visible effect on the Chara and sago pondweed (Potamogeton pectinatus). The phytoplankton development may have been due to the residual effect of fertilizer applied to this pond as part of a fertilization project by Ball (1949) during the summer of 1946.

INVESTIGATIONAL TECHNIQUES AND EQUIPMENT

Stocking the Ponds

Bluegills (Lepomis macrochirus) and pumpkinseed sunfish (Lepomis gibbosus) were selected as stock for the ponds because of their dependence for food upon invertebrate fauna. A small number of redear sunfish (Lepomis microlophus) were also released in an attempt to secure a more extensive usage of mollusks and hard-bodied insects.

The initial release, made in Pond 4 on April 21, consisted of 1,935 bluegills and 933 pumpkinseeds or a total of 124 pounds of sunfish per acre. These data plus the size range and weight of the fish stocked are given in Table 1.

TABLE 1

SIZE RANGE, NUMBER, AND WEIGHT OF FISH IN ORIGINAL RELEASE

Species	Size-range (inches)*	Number	Weight (pounds)
Bluegill	3.0- 4.8	1,413	32.5
	4.9- 7.8	515	45.5
	9.3-10.0	7	6.0
Total		1,935	84.0
Pumpkinseed	2.0- 4.2	298	8.1
	4.3- 6.0	635	31.9
Total		933	40.0
Total--both species		2,868	124.0

* Total length.

Fish of a wide size range were used to effect a more efficient use of the available benthic fauna.

Following release of the fish, the variations in standing crop of benthic fauna due to fish predation, insect emergences, and natural mortality were measured by bottom sampling. Pond 5, containing no fish, was sampled at the same rate to facilitate the quantitative comparison of bottom fauna abundance in the two ponds.

Pond 4 was drained on July 3 and all fish were removed for weighing and counting. The pond was allowed to refill immediately in order to disturb its aquatic resources as little as possible. The smaller size classes of fish, or those approximating the size initially stocked in Pond 4, were selected by screening and the exact poundage of each species originally released was transferred to Pond 5. This release was made on July 9.

Bluegills, and to a lesser degree pumpkinseeds, are subject to heavy mortality due to handling. Most of the handling losses which occurred the day of release and the day following were recovered, weighed, and replaced by an equal poundage.

Bottom sampling was continued throughout the remainder of July and all of August to determine the effect of fish predation on the abundant food supply of Pond 5 and to follow the recovery of benthic fauna in Pond 4.

Also to be considered as pond stock are the thousands of

fry produced in Pond 4. Nesting activity was first noted on May 9, but extensive spawning did not occur until the third week of May. Most of the fry present when Pond 4 was drained were less than one inch long and were probably incapable of seriously affecting the benthic groups dealt with in this study. No young-of-the-year fish were transferred to Pond 5, and the small number of fry produced there by late spawners was inconsequential.

The average numerical loss of fish during the entire investigation was approximately 25 per cent of the population of each of the three species concerned. This does not include the observed loss from handling. Complete data concerning the release and removal of fish in the two ponds are given in Table 2. The weight and number of fish removed at the end of the two sampling intervals includes those taken for stomach analysis.

Bottom Sampling

The 660 random samples from the two ponds were collected at the rate of 20 per pond per week during the period from the last week in April through the last week in August. This period corresponds with most of the active growing season for fish in Michigan.

All samples were collected using an Ekman dredge. The Ekman dredge, by taking smaller samples and larger numbers

TABLE 2
NUMBER AND WEIGHT IN POUNDS OF FISH RELEASED IN AND
REMOVED FROM PONDS 4 AND 5

		Bluegill	Pumpkinseed	Redear	Totals
Released in Pond 4	No.	1,935	933	60*	2,928
4/21/51	Wt.	84.0	40.0	1.8	125.8
Removed from Pond 4	No.	1,493	604	55	2,152
7/3/51	Wt.	140.0	51.5	3.7	195.2
Released in Pond 5	No.	845	590	52	1,487
7/9/51	Wt.	84.0	40.0	3.5	127.5
Removed from Pond 5	No.	644	545	44	1,233
9/9/51	Wt.	103.2	62.2	5.8	171.2

* Released 5/14/51

of them, gave a better coverage of the pond bottoms than would have been possible with a Petersen dredge. As each dredge sample was raised, it was swung quickly into a pail at water level. Later the pails, each containing one Ekman sample, were taken to shore where their contents were washed and concentrated in a 30-mesh screen and transferred to wide-mouth fruit jars for return to the laboratory.

Collection of Fish

Fish for stomach analysis determinations were collected with hook-and-line and by seining. Seventy-three pumpkinseeds, 121 bluegills, and 6 redear sunfish were collected.

These fish were weighed, sex determined, and measured immediately after capture and the stomachs, plus their contents, placed in alcohol. It was found that more efficient removal of the stomach contents could be facilitated by allowing the stomachs to harden in alcohol for a short period before they were opened. Immediate removal of the stomachs was necessary to stop digestive action on the stomach contents (Ball, 1948). An effort was made to procure fish of all sizes present in the population to obtain a more complete understanding of their use of available food. The effect of removal of these fish on the benthic fauna density comparisons discussed later is not considered serious since this loss was small compared with the total population in the ponds.

Laboratory Examination

Bottom samples

Bottom samples were examined soon after collection, and the organisms removed while still alive and active. Each sample was given an identification number and preserved separately in 80 per cent alcohol until time allowed identification and quantitative measurement of its contents.

Following division of the organisms into taxonomic groups, they were counted and placed on absorbent paper to remove excess liquid. Next, the volume of each group was determined by the liquid displacement method using a centrifuge

tube graduated to 0.1 cubic centimeter. Total volumes were recorded as each group was added to the tube, and the difference in the initial meniscus level and the last volumetric reading was taken as the total volume for the sample.

For comparison of these data with those of certain other investigators, 1 cc. of preserved volume can be considered equal to 1 gram of live weight in accordance with calculations made by Ball (1948).

Stomach analysis

A feeding habit investigation conducted as one phase of this problem had as its primary purpose a qualitative comparison of those bottom groups actually utilized by fish to a significant degree with those known to be present by bottom sampling. Consequently, only the taxonomic group and the number in each group were recorded. Many of the organisms were identified, with the aid of a binocular microscope and reference collection, from fragmentary remains.

DISCUSSION OF DREDGE SAMPLING DATA

A tabulation of the sampling data for all organisms collected by dredge in Ponds 4 and 5 is given in Tables 3 and 4. In these summaries the invertebrate groups were recorded by number and volume and by the percentage each comprised of the total number and total volume collected each month.

Trichoptera and planaria were significantly more abundant in Pond 5 than in Pond 4. The fingernail clam (Pisidium), while representing 12.2 per cent of the total volume of all organisms collected in Pond 5, was not present in Pond 4.

Midges were numerically dominant in the fauna of Pond 4 from the last week in April through the last week in June and represented 51.1 per cent of the total number of organisms collected during that period. In July and August, the groups present in greatest number were the mayflies Caenis sp. and Centroptilum spp. These two genera comprised 75.7 per cent of all organisms by number. The seasonal average tabulation for Pond 4 indicates the benthic groups in declining order of numerical importance to be Caenis sp., midges, Oligochaeta, Gastropoda, and Centroptilum spp. Volumetrically, the order was Oligochaeta, Gastropoda, Hexagenia sp., and Caenis sp.

The seasonal average for the two mayfly genera (Caenis and Centroptilum) in Pond 5 was 33.6 per cent of the total number and 8.6 per cent of the total volume of all organisms collected. They were more numerous than other faunistic

Table 3. Invertebrate fauna collected by dredge
sampling in Pond 4.

Collection date		April	May	June	July	August	Totals
No. of samples		20	80	80	80	80	340
Area of samples (sq. ft.)		5	20	20	20	20	85
Total No. of organisms		1565	1920	1854	4540	6900	16,779
No. organisms per sq. ft.		313	96	92	227	345	197.4
Total Vol. organisms (cc.)		21.21	74.36	54.13	42.55	50.91	243.16
Vol. organisms per sq. ft.		4.24	3.71	2.70	2.12	2.54	2.86
Chironomidae							
A		686	594	571	158	291	13.71
B		3.21	2.05	2.60	.62	1.33	4.03
Midge pupae							
A		203	59	26	10	30	1.95
B		.92	.19	.26	.04	.07	.56
Ceratopogonidae							
A		47	281	262	165	133	5.29
B		3.00	1.07	.83	.29	.28	1.10
Caenis							
A		.20	1.07	.64	.29	.28	1.10
B		10	108	60	2707	4614	44.59
Centroptilum							
A		.07	.56	.41	9.33	14.54	10.24
B		.....	.07	.31	489	851	8.25
Hexagenia							
A		26	105	36	2	5.55	3.98
B		3.71	19.93	4.73	3.76	.....	1.01
Anisoptera							
A		.....	1	.....	.....	.....	11.75
B		.....	.46	.01	.....	.....	.04
Zygoptera							
A		1	14	2	37	122	1.05
B		.02	.24	.09	.64	1.18	.89
Trichoptera							
A		.....	15	24	143	172	2.11
B		.....	.16	.27	90	123	2.42
Coleoptera							
A		.....	3	98	133	125	1.81
B		.....	.02	.57	.76	.83	.90
Tipulidae							
A		1	.....	.....	3	1	.03
B		.05	.....	.....	.03	.01	.04
Hemiptera							
A		.....	.....	2	.....	1	.02
B		.....	.....	.03	.....	.03	.02
Lepidoptera							
A		.....	.....	.....	.....	.....	.02
B		.....	.....	.01	.....	.....	trace
Hydracarina							
A		2	4	1	7	6	.12
B		.....	.....	.01	.....	.....	.01
Gastropoda							
A		13	84	411	615	489	9.61
B		1.94	20.64	15.18	12.64	11.23	25.35
Oligochaeta							
A		576	643	320	70	58	9.93
B		11.09	28.87	28.95	13.33	14.31	39.71
Planaria							
A		.....	.....	.....	1	.....	.01
B		.....	.....	.....	.01	.....	trace
Hirudinea							
A		.....	2	.....	.....	2	.02
B		.....	10	.....	.....	.01	.05

A Number of organisms and per cent of all organisms by number.
B Volume of organisms and per cent of all organisms by volume.

Table 4. Invertebrate fauna collected by dredge
sampling in Pond 5.

Collection date	May	June	July	August	Totals
No. of samples	80	80	80	80	320
Area of samples (sq. ft.)	20	20	20	20	80
Total No. of organisms	4970	6667	6470	4367	22,474
No. organisms per sq. ft.	248.50	333.3	323.5	218.3	280.9
Total Vol. organisms (cc.)	106.43	118.91	60.42	16.75	302.5
Vol. organisms per sq. ft.	5.32	5.94	3.02	.84	3.78
Chironomidae					
A	801	792	116	45	1,703
B	2.08	3.17	.56	.11	.66
Midge pupae					
A	96	55	15	5	.11
B	.30	.34	.01	.01	.06
Ceratopogonidae					
A	140	43	48	10	.23
B	.50	.15	.07	.01	.06
Caenis					
A	1151	1467	1007	2281	52.23
B	4.08	6.64	3.27	4.39	26.21
Centroptilum					
A	62	127	809	654	14.98
B	.70	.72	4.10	2.30	13.72
Hexagenia					
A	394	183	57	5	.11
B	36.27	37.54	11.82	1.08	6.45
Anisoptera					
A	2	.04	2	7	.16
B	.20	.13	.04	.13	.78
Zygoptera					
A	238	151	30	11	.25
B	4.26	4.56	.80	.03	.18
Trichoptera					
A	215	697	366	193	4.53
B	2.16	7.17	3.34	1.77	6.99
Coleoptera					
A	14	88	537	555	12.72
B	.08	.41	2.98	3.13	18.69
Tipulidae					
A	.....	1	.....	.....	.....
B	.....	.01	.....	.....	.....
Hemiptera					
A	.....	8	18	3	.07
B	.....	.02	.06	.01	.06
Lepidoptera					
A	2	.....	.....	.....	.....
B	.02	.02	.....	.....	.....
Hydracarina					
A	11	.....	.....	.....	.....
B	.....	.08	1	13	.30
Gastropoda					
A	486	844	2196	.01	.06
B	.....	.....	.....	.....	.....
Pelecypoda					
A	21.28	24.92	14.45	209	4.79
B	811	28.58	1042	1.03	6.15
Oligochaeta					
A	5.97	16.76	12.08	222	5.08
B	529	242	26	2.28	13.50
Planaria					
A	28.35	15.75	5.18	8	.18
B	18	46	171	.17	1.01
Mirudinea					
A	.18	.36	2.64	128	2.93
B	.....	.43	1.28	.73	4.35
	.....	10	29	13	.30
	.....	.16	.38	.16	.96

A Number of organisms and per cent of all organisms by number.
B Volume of organisms and per cent of all organisms by volume.

groupings throughout the season, excepting the month of July when mollusks were dominant. In Pond 5, the invertebrate groups in order of numerical significance were Caenis sp., Pelecypoda, Gastropoda, Chironomidae, and Centroptilum spp. On a volumetric basis the order was Hexagenia sp., Gastropoda, Oligochaeta, and Pelecypoda.

Groups included in the bottom sampling data but contributing little to the seasonal totals in either pond were Odonata, Tipulidae, Lepidoptera, and Hydracarina. The percentage composition of the total bottom fauna represented by each major invertebrate group is presented graphically in Figures 2 and 3. This is done by number and volume for both ponds.

The unnatural situation created by drainage of the ponds and subsequent transfer of the fish from one pond to the other was reflected in the numbers and volume of the bottom organisms present. Consequently, comparisons concerning abundance and importance of the bottom organisms in the two ponds on a monthly or summer average basis must take these factors into account. Also, comparisons among the different groupings on a percentage of total volume basis are difficult, because the large volume groups (Gastropoda, Oligochaeta, and Pelecypoda) tend to preclude the quantitative values of other organisms more important as fish foods.

Figure 2. Percentage composition of benthic fauna by
number and volume---Pond 4.

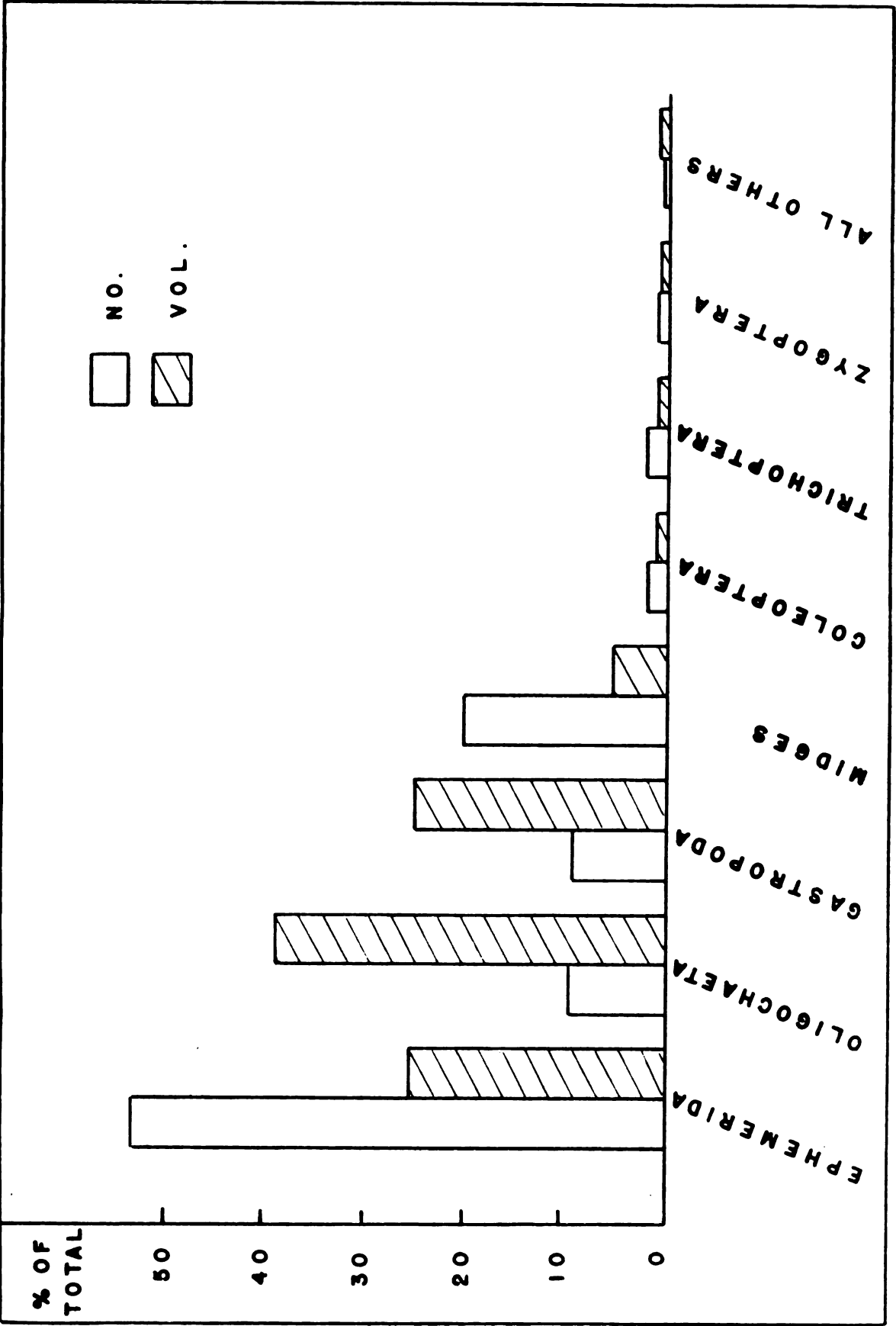
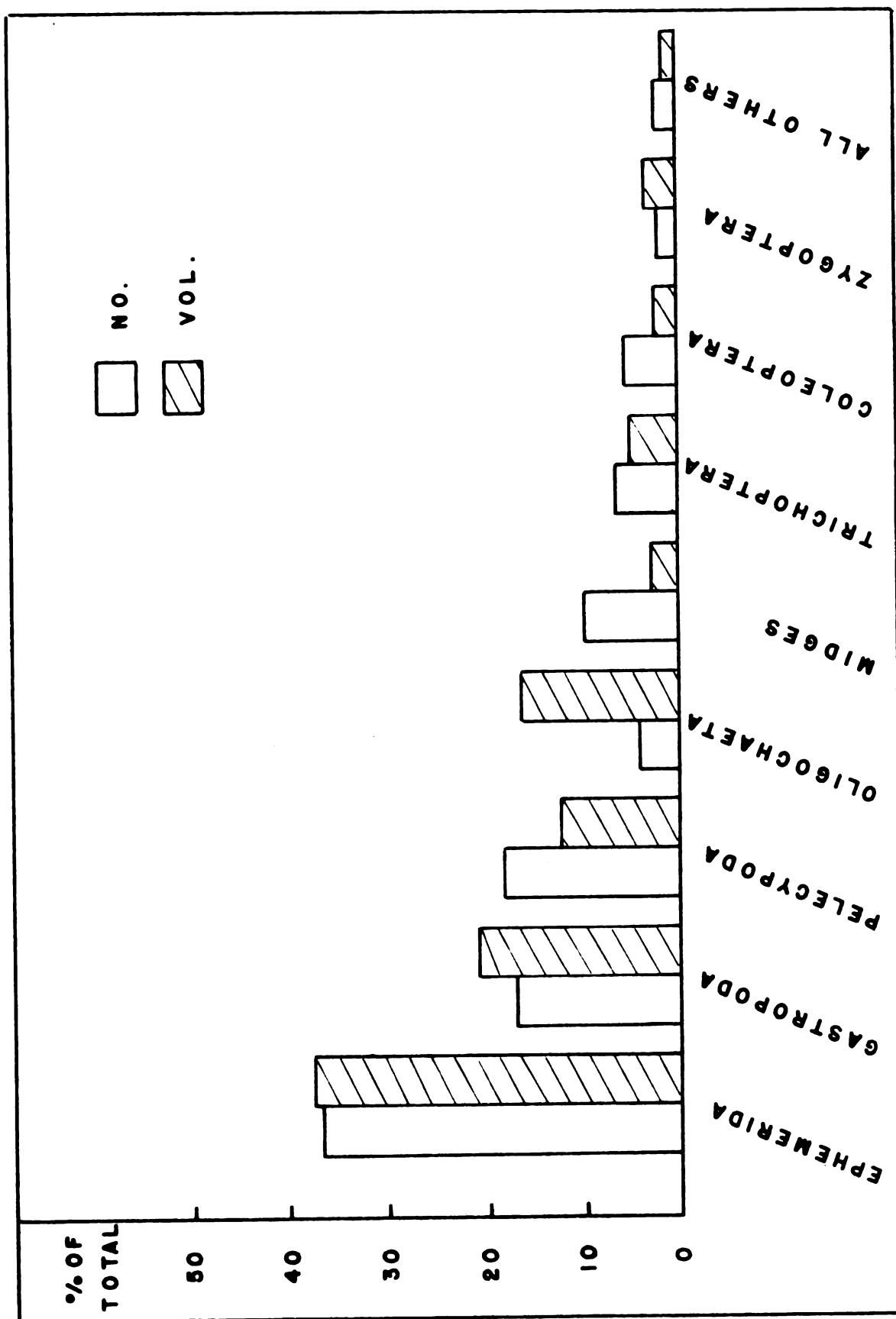


Figure 3. Percentage composition of benthic fauna by
number and volume---Pond 5.



EFFECT OF FISH PREDATION

The response of invertebrate fauna to the introduction and removal of a fish population closely dependent upon it is presented graphically in Figures 4, 5, 6, and 7. Figures 4 and 5 show the variations in total number and total volume per square foot of all organisms collected by dredge sampling during a 17 week period beginning April 24.

In Figure 4 certain systematic groups e.g. Hexagenia sp., oligochaetes, leeches, and large snails, because of their greater volume, assume a dominant position over the groups more important as fish foods. Because of the large percentage of the total volume represented by even a small number of these individuals, the weekly volumetric fluctuations in Figure 4 are probably due more to sampling dissimilarities than predation by fish, insect emergence and mortality, and other factors. However, these same groups helped to stabilize the curves in the plot of total number per square foot (Figure 5) since they were less subject to fish predation, emergences, and mortality upon drainage of the ponds.

To present a more accurate representation of the relationship of a fish population to fluctuations in its food supply, the graphs were replotted omitting the leeches, oligochaetes, Hexagenia sp., and snails greater than 2 mm. in diameter. The 2 mm. measurement represents the largest diameter of any snail found in the fish stomachs analyzed.

Figure 4. Variation in total volume of benthic
organisms per square foot.

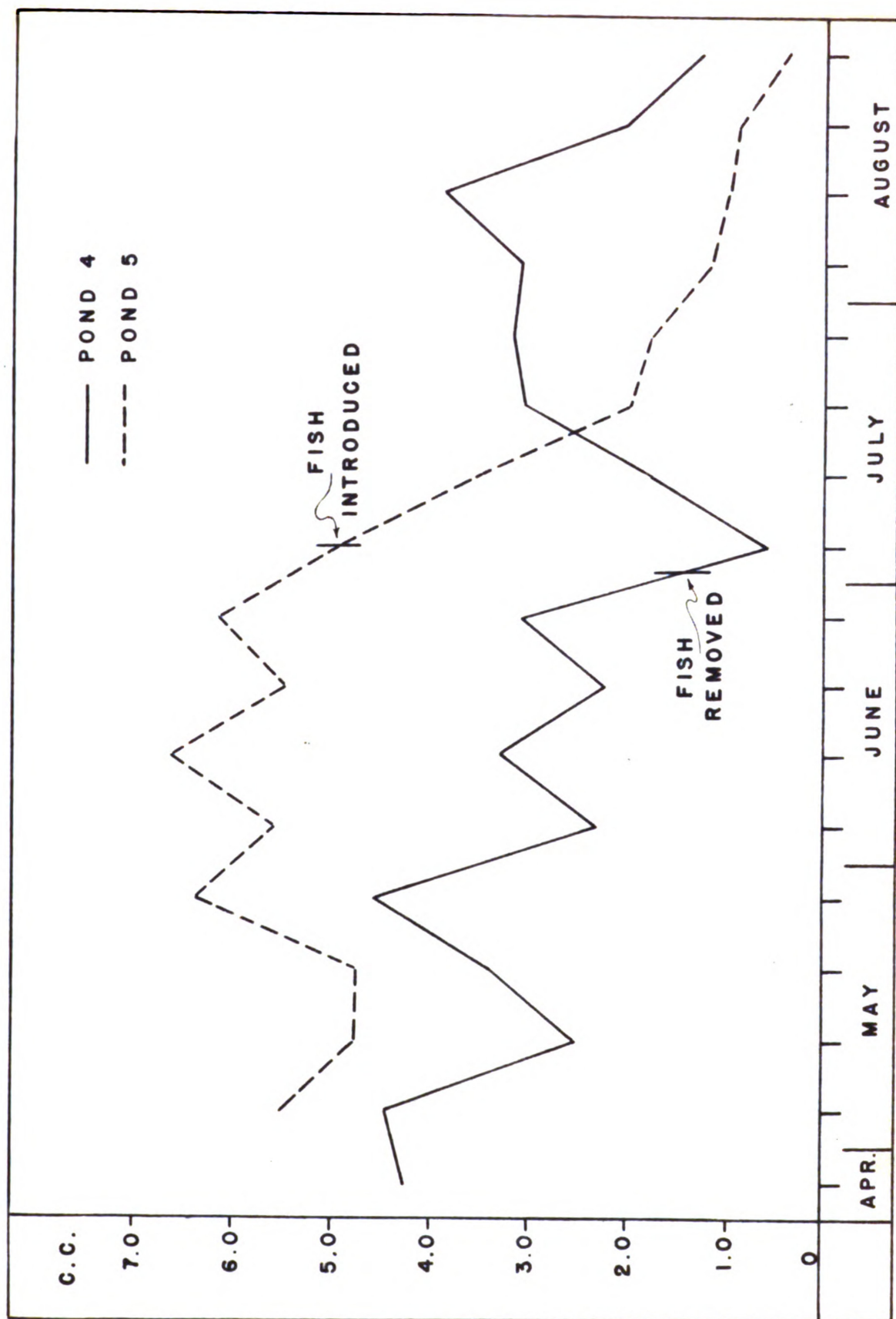
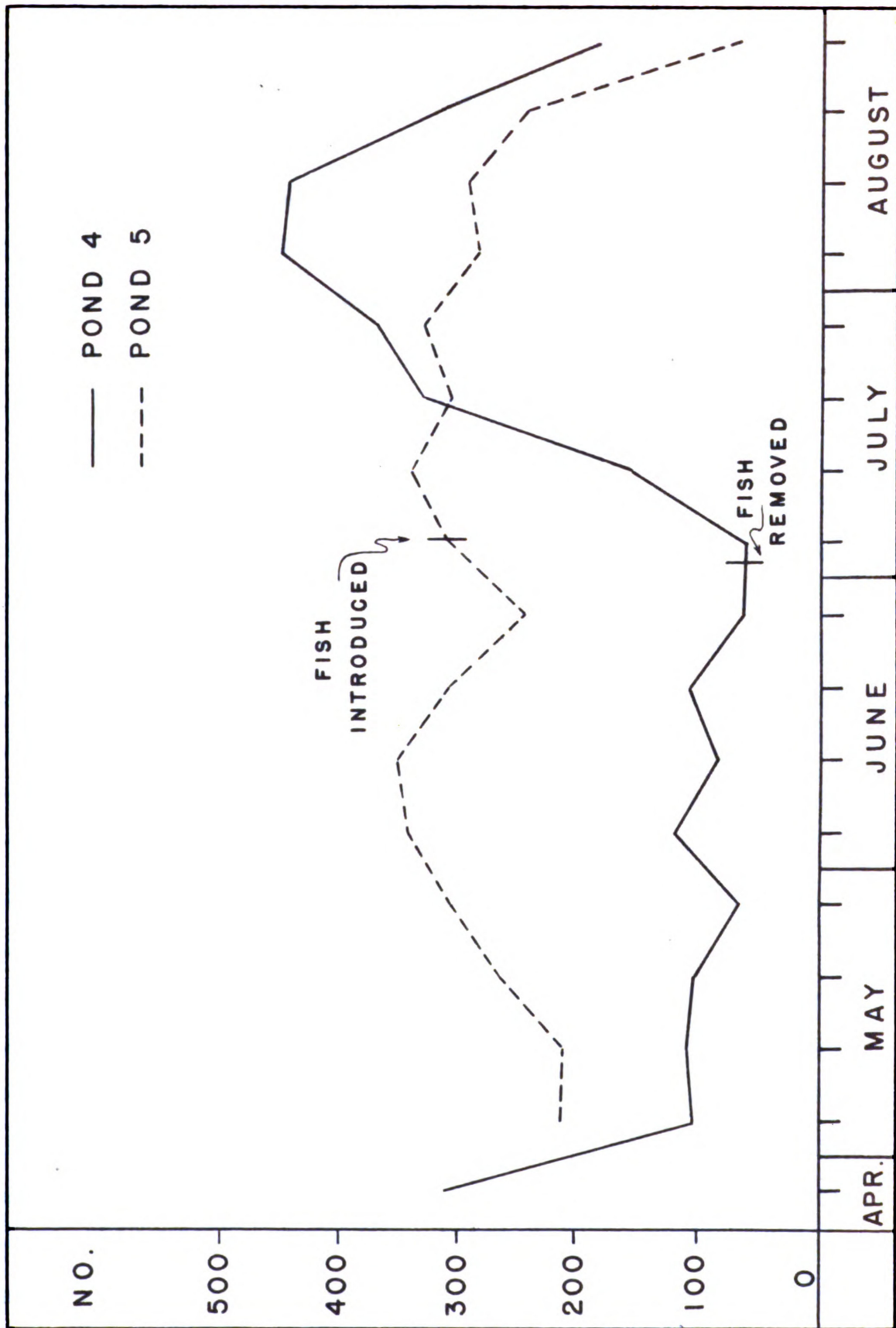


Figure 5. Variation in total number of benthic organisms per square foot.



These corrected quantitative values are depicted in Figures 6 and 7. The curves of number and volume in the two figures are very similar.

Hexagenia sp. and the oligochaetes together constituted less than 1.0 per cent of the total number of organisms in the stomachs analyzed, and no leeches were found. This observation confirms results reported by (Howell, 1942; Funk, 1942; Ball, 1948; Patriarche and Ball, 1949).

Seasonal fluctuations of invertebrate populations, and the effects of removal of a fish population upon the bottom organisms in a natural lake have already been studied by Ball and Hayne (1952). Their data from Third Sister Lake in Michigan showed a definite cycle of seasonal abundance and scarcity of benthic organisms over a three year period with the maximum occurring in early winter followed by a decline until a minimum is reached in early summer. Then in latter July or early August the population began its rise toward a new peak. A similar population cycle has been reported by Deevey (1941) and Lyman (1943).

The study of Ball and Hayne (1952) shows further that the normal seasonal population cycle, when released from predation by fish, did not reach so low a point as during the preceding year, and the upturn in volume of organisms per unit area of bottom was much sharper than during the preceding year. The preceding year referred to was the year 1940 when a fish population, 85 per cent of which was estimated to be

directly dependant upon the invertebrate fauna, was present.

In this study no comparative data are available to give the benthic density in the ponds for previous years, with and without fish, as was done above. However, a situation analogous to the one described by Ball and Hayne is seen in the sharp, upward population trend exhibited by the invertebrates in Pond 4 when they, like those in Third Sister Lake, were relieved of fish predation.

A rapid population decline in Pond 5, under the influence of actively foraging fish, gradually reduced the invertebrate population from a high of 2.01 cc. and 270 organisms per square foot the first week in July to a low of 0.34 cc. and 81 organisms the last week of August when sampling was terminated. Patriarche and Ball (1949), also working at the Wolf Lake Hatchery with four similar ponds and the same faunistic groups, recorded the same downward tendencies at this time and approximately the same reasons for their occurrence. The population decline in Pond 5 is directly opposed to the annual upturn occurring at this time as reported by Ball and Hayne, Deevey and Lyman. However, the decline is not an unnatural one for the following reasons.

Patriarche and Ball attributed this deviation to (1) the effects of predation by large numbers of young bluegills, and (2) the emergence of numerically dominant midges. An examination of the data for Pond 5 illustrates the same cause and effect; the variation from the normal here being due to

predation by large numbers of young and adult sunfish and emergence of numerically dominant mayflies.

A more specific discussion of the fluctuations in benthic fauna abundance and reasons for their occurrence follows. The numerical and volumetric values used have been corrected for oligochaetes, Hexagenia sp., leeches, and snails greater than 2 mm. in diameter.

Pond 4

Bottom fauna were at a relative high of 1.02 cc. and 191 organisms per square foot (Figures 6 and 7) when bottom sampling began on April 21 but dropped to 0.21 cc. and 43 organisms one week after the fish were introduced. It is possible that this decrease was greater than would have occurred normally since the fish had been held for 18 days without food prior to their release. Moore (1941), working with green sunfish (Lepomis cyanellus) that had been starved for a period of five weeks, concluded that these fish after being returned to their normal laboratory diet ingested considerably more food and gained weight at almost twice the normal rate of comparable unstarved individuals.

Midges were the most important insect group present, both numerically and volumetrically, at the beginning of the sampling period, and early emergences were partly responsible for the early downward trend. Further evidence of en-

Figure 6. Variation in volume per square foot of important fish food organisms. (Oligochaetes, leeches, Hexagenia sp., and large snails omitted.)

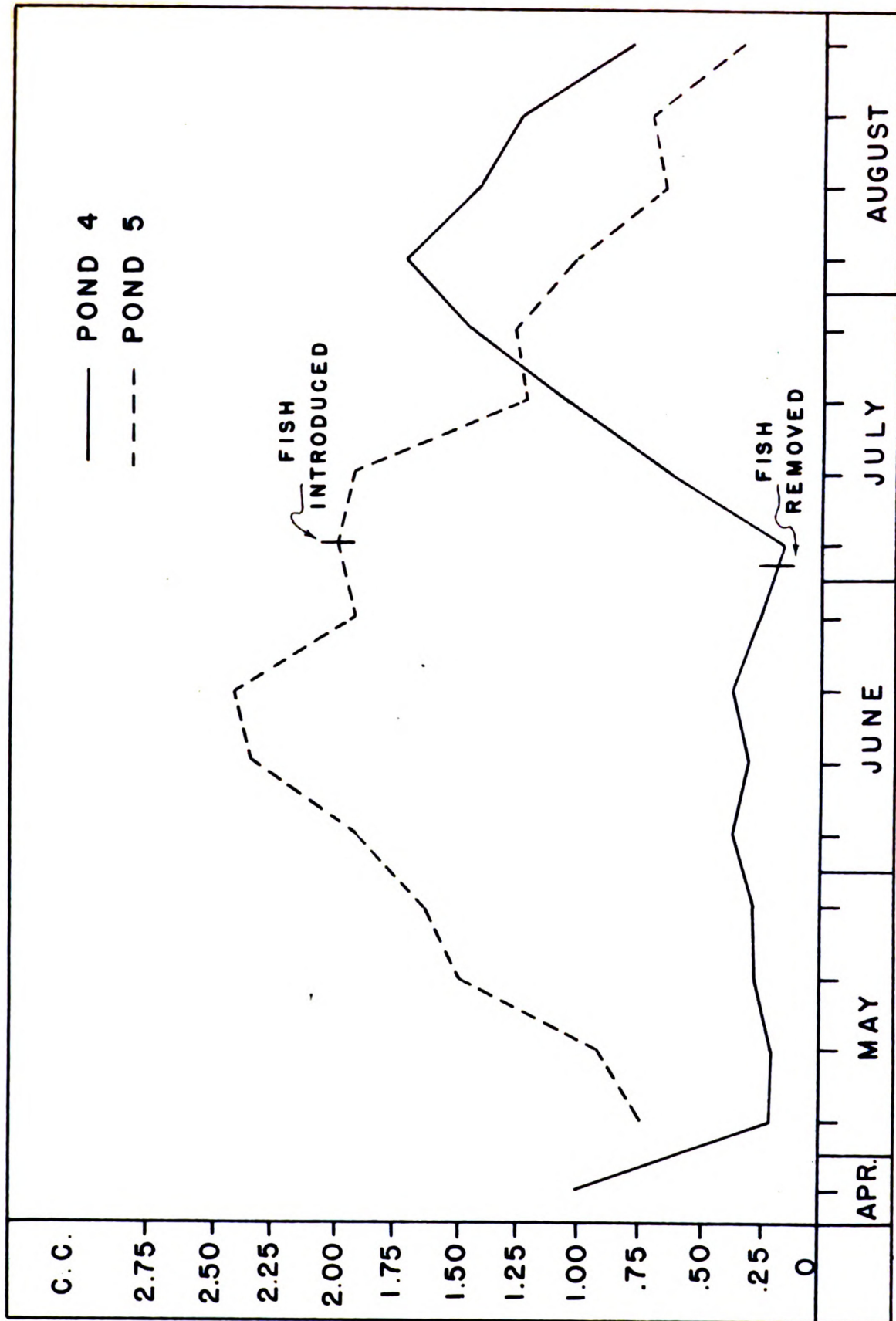
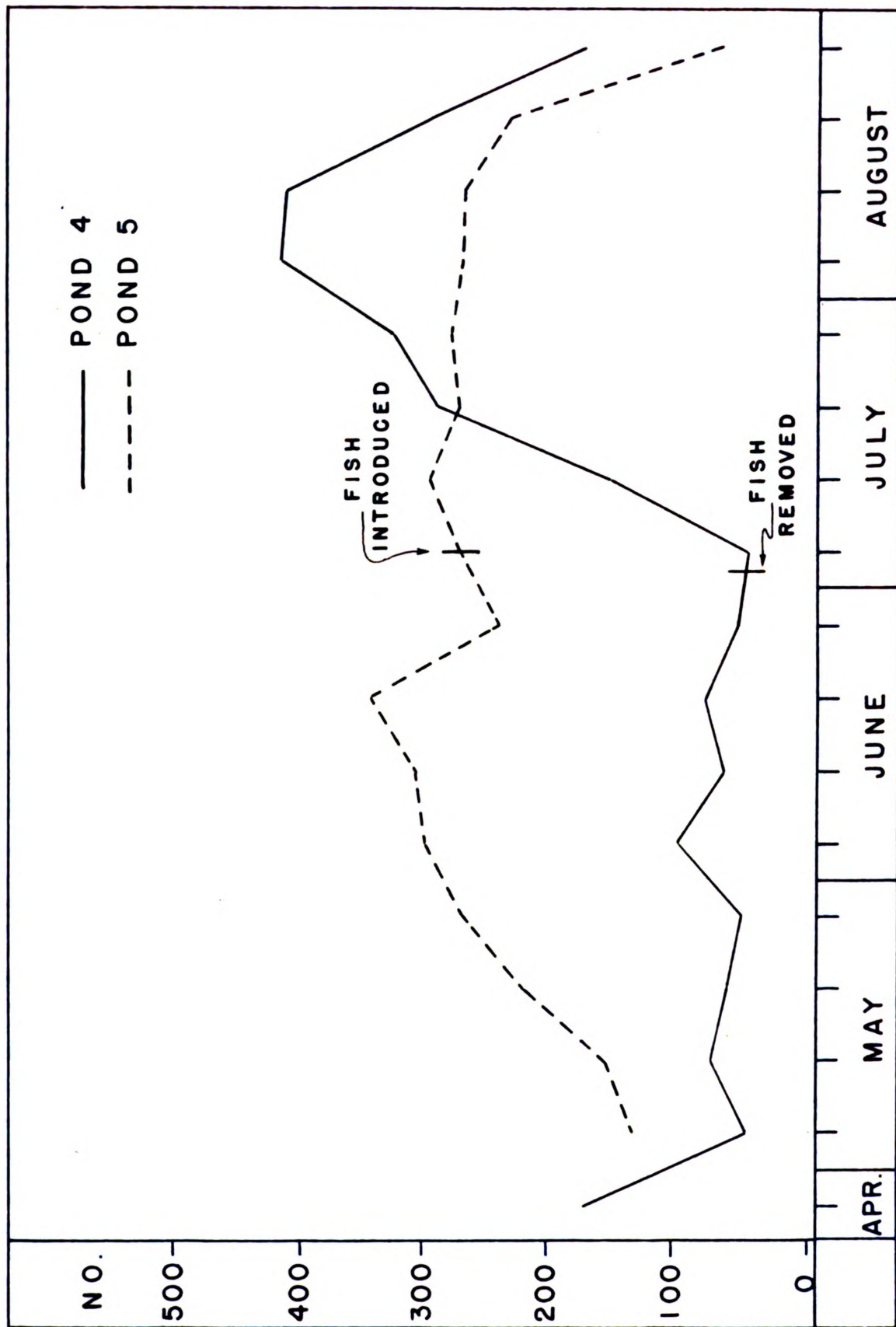


Figure 7. Variation in number per square foot of important fish food organisms. (Oligochaetes, leeches, Hexagenia sp., and large snails omitted.)



suing emergences during this period is seen in the relatively large numbers of midge pupae collected.

Following this decline the first week of sampling, the standing crop of available organisms did not fall below a fairly stable average of 63 organisms and 0.28 cc. per square foot during May and June. Recorded fluctuations during this period were probably due to insect emergences and sampling inaccuracies. Midges remained the dominant group throughout May and June and comprised 70.8 per cent by number and 60.1 per cent by volume of all organisms known to be important in the diet of the fish present.

The rapid increase of insect fauna in Pond 4, when relieved of fish predation is most apparent in the two mayfly genera (Caenis sp. and Centroptilum spp.) as the eggs from earlier oviposition and those instars previously too small to be retained during screening of the samples developed. These two genera alone rose from 11 organisms and 0.07 cc. per square foot the first week in July to 358 organisms and 1.36 cc. the first week in August. This upward trend continued until a large hatch of Caenis sp. the night of August 3 and a second hatch on August 10 sharply reduced their numbers. Further nocturnal emergences of Centroptilum spp. occurring on August 13, 15, and 20 hastened the decline so apparent in Figures 6 and 7. Small hatches of mayflies were common throughout August, but those taking place on the specific dates just mentioned were sufficiently large to form windrows

along the lee margins of the ponds.

Increases in the numbers of Zygoptera, Trichoptera, and Coleoptera were also important in the population upturn of July and early August. The total quantity of organisms available as fish food increased from 43 organisms and 0.17 cc. to 416 organisms and 1.69 cc. per square foot during this period.

Pond 5

Pond 5 was drained and allowed to remain nearly empty for three days prior to its filling on April 26. Repopulation occurred quickly and increasing numbers of Ephemera, Pelecypoda, and Trichoptera offset the loss by emergence of midges and Zygoptera, resulting in a continuous increase from 129 organisms and 0.73 cc. per square foot the first week of May to a maximum of 341 organisms and 2.46 cc. per square foot the third week of June. Insect emergences were beginning to have their effect, and a sharp decline, both in numbers and volume, occurred during the fourth week in June. Plotted on semi-logarithmic paper a similar geometric rate of decline is evident for both ponds at this time. It is indicated that the influence causing this downward trend was equally active in both situations thereby reducing the possibility that the smaller quantity of organisms collected was a sampling disparity.

The effect of the fish population upon the benthic organisms in Pond 5 is best seen in the abruptly declining quantitative volume (Figures 4 and 6). Emergences of Zygoptera and Trichoptera, plus increased utilization of fingernail clams and snails by foraging pumpkinseeds and redear sunfish, contributed most to the population reduction of July and early August. More important in the decline were the large numbers of small snails that appeared in the samples the latter part of the summer. Although snails were instrumental in upholding the numerical curve illustrated by Figure 7, they represented a much smaller percentage of the total volume than they had previously. A marked reduction in all groups except the Coleoptera occurred during the month of August.

In spite of fish predation introduced the first week of July there was no immediate decrease in the numbers of bottom fauna. An increase in Coleoptera, Ephemera, and Gastropoda overcame any significant decline due to emergence of other insect groups and the effect of fish utilization. Consequently, the number of organisms was maintained at a nearly constant level of 273 per square foot until the third week of August. At this time, the large Caenis sp. and Centrop-tilum spp. hatches previously mentioned for Pond 4 resulted in a very rapid quantitative decline. These hatches occurred during the same general period but never in both ponds on the same night. Emergence periods usually alternated between

ponds and at two to five day intervals.

In summary, the volume of available benthic fauna in Pond 5 without the limiting effect of fish predation increased steadily from 0.73 cc. per square foot the first week in May to a maximum of 2.46 cc. the third week of June. Then, when exposed to predation by fish, the benthic population declined from 2.01 cc. the first week of July to 0.34 cc. the last week in August.

It should be reiterated that numerical values used in this section and the one previous represent only those organisms important in the diet of the fish.

FEEDING HABIT INVESTIGATION

Many studies of the feeding habits of bluegills and pumpkinseeds in natural waters have been made (Baker, 1916; Pearse, 1918; Leonard, 1940; McCormick, 1940; Funk, 1942; Moffett and Hunt, 1945; Ball, 1948; Ball and Tanner, 1951; Morgan, 1951). The food analysis considered here differs from most of those made previously since it concerns food consumed in two, small, artificial ponds.

A total of 200 fish of the three species present in the ponds were collected between May 6 and August 26. The 73 pumpkinseed stomachs were from fish ranging in length between 2.5 and 6.2 inches (total length) and having an average length of 4.8 inches. The bluegills were larger, averaging 5.3 inches and were from 3.5 to 7.4 inches in length. Six redear sunfish, having an average length of 4.9 inches, were included in the study. Of the total number of stomachs examined, only 14 were empty. A summary of the data concerning the fish used in the food study is given in Table 5.

Table 6 represents a tabulation of the stomach analysis data for the pumpkinseed sunfish and bluegills and lists each food grouping as the percentage it represents of the total number of organisms and by the percentage of stomachs containing each group. An examination of the redear sunfish stomachs showed their feeding habits to be similar to those of the pumpkinseed and bluegill excepting a decidedly greater

TABLE 5
DATA CONCERNING FISH REMOVED FOR STOMACH ANALYSIS

	Pumpkinseed	Bluegill	Redear
Number of fish	73	121	6
Length range (in.)	2.5-6.2	3.5-7.4	4.3-5.4
Average length (in.)	4.87	5.36	4.92
Weight range (gms.)	6-98	11-151	26-60
Average weight (gms.)	48.2	53.9	41.0
Total weight (pounds)	7.7	14.3	0.4

usage of snails and fingernail clams (Pisidium). These two groups comprised 43.5 and 11.4 per cent, respectively, of the stomach contents.

The stomach analysis data from fish of all sizes are combined in one table since no significant differences could be determined among the organisms utilized by the various size classes. The only important difference observed among the different size groups lay in the larger number of ostra-cods consumed by the smaller fish.

Vegetation consumed as food refers to fragments of filamentous algae, Chara, and in a few instances sago pondweed, (Potamogeton pectinatus). Included under terrestrial insects are small numbers of adult wasps, ants, and beetles. Organic debris includes animal matter in such an advanced state of

Table 6. Food of adult pumpkinseed sunfish and bluegills from Ponds 4 and 5. (Unless otherwise indicated, all aquatic insects listed are immature stages.)

Number of stomachs Number empty stomachs Total number organisms Organisms per stomach	Pumpkinseed sunfish		Bluegills	
	73 5 2,517 34.5		121 9 10,177 45.6	
Fish food organisms	Percent organisms by number	Percent stomachs containing organism	Percent organisms by number	Percent stomachs containing organism
Aquatic insects				
Midges				
Chironomidae	27.48	60.27	24.87	26.00
Ceratopogonidae	7.35	46.58	3.10	23.76
Midge pupae	1.07	19.18	.17	6.73
Midge adults	.32	9.59	.19	5.83
Ephemera				
Caenis	11.36	34.25	3.86	20.63
Caenis adults	.08	1.37	.37	5.38
Centroptilum	3.50	31.51	5.15	25.11
Centroptilum adults	.04	1.37	.16	4.48
Hexagenia	.16	4.11	.04	1.79
Odonata				
Anisoptera	.04	1.37	.08	.90
Zygoptera	.....	.....	.20	5.83
Zygoptera adults	.08	2.74	.25	.90
Hemiptera				
Corixidae	.12	4.11	.28	3.14
Corixidae adults	.....	.....	.01	.45
Coleoptera				
Haliplidae	4.37	45.21	.84	13.00
Haliplidae adults	.12	2.74	.03	.90
Trichoptera	.52	4.11	.10	3.59
Lepidoptera	.36	1.37	.....	.....
Crustacea				
Cladocera	23.08	42.47	55.26	27.80
Ostracoda	.32	8.22	.37	5.38
Decapoda	.04	1.37	.06	2.24
Hydracarina	.20	5.48	.52	8.97
Gastropoda	17.48	54.79	2.80	16.59
Pelecypoda	.36	4.11	.61	2.24
Oligochaeta	.08	2.74	.01	.45
Nematoda	1.43	24.66	.54	11.21
Terrestrial insects	.04	1.37	.04	1.79
Vegetation	.....	30.14	.....	18.38
Organic debris	.....	34.25	.....	22.42
Inorganic debris	.....	15.07	.....	1.79

decomposition or of such a fragmentary nature as to make it unidentifiable. Inorganic debris refers to grains of sand which were probably picked up accidentally.

The large aquatic earthworms, smaller tubificids, and burrowing mayflies, Hexagenia sp., were relatively unimportant as fish foods, because their burrowing habit made them unavailable to the fish. These groups combined represented only 0.24 per cent of the pumpkinseed diet and 0.05 per cent of the bluegill diet.

The use of Odonata and Trichoptera as fish food was slight but in proportion to presence of the two groups in the bottom samples.

Representatives of the order Hemiptera were common along the margins of both ponds during the latter part of the summer. Members of the families Gerridae, Notonectidae, and Corixidae were all numerous, but only nymphal and adult Corixids were present in the stomachs. This preference has been noted by Leonard and Leonard (1949) in their work with trout and is probably related to the piercing bite and characteristic odor some of the bugs possess. The Corixidae have neither of these offensive qualities and consequently would seem to be a more desirable food item.

The feeding habits of the pumpkinseeds and bluegills in the ponds were generally similar except for a greater utilization of snails and beetle larvae by the pumpkinseeds.

A more detailed account of the dietary components in the

pumpkinseed and bluegill stomachs follows.

Pumpkinseed Sunfish

Midges constituted the principal item in the pumpkinseed sunfish diet and composed 36.2 per cent of the total number of organisms in the stomachs. The Chironomidae were present in 60.2 per cent and the Ceratopogonidae in 46.5 per cent of the stomachs examined.

The planktonic crustacean, Daphnia, was second in numerical importance, representing 23.0 per cent of the total number of organisms and was found in 42.4 per cent of the stomachs collected. The small creeping mayfly, Caenis sp., was especially susceptible to capture by the fish during its transformation periods and ranked fourth by numbers while appearing in approximately one-third of the stomachs.

Snails made up 17.4 per cent and appeared in more than one-half of the stomachs, which would indicate them to be a preferred food. Centroptilum spp. and the Haliplidae were nearly equal in importance, comprising 3.5 and 4.3 per cent of the total number. Even though their rate of incidence was low, they were present in 31.5 and 45.2 per cent of the fish. The selection of snails and hard-bodied insects e.g. Haliphus and Peltodytes spp. is characteristic of the pumpkinseed as evinced by other investigations (Baker, 1916; Funk, 1942; Ball, 1948; Ball and Tanner, 1951). This utilization did not extend to the fingernail clam (Pisidium).

The dietary habit of the pumpkinseeds varied from the results recorded by McCormick (1940), Ball (1948), Ball and Tanner (1951), due to the presence of vegetation, chiefly Chara, in 30.1 per cent of the stomachs as compared to only 18.3 per cent for the bluegills. Chara composed more than half of the contents of those stomachs containing it, precluding the possibility that it may have been taken accidentally. Furthermore, there appeared to be no direct relationship between incidence of the Chara and quantity of food available as the season progressed. It is probable that the food supply never did reach a critical low necessitating the substitution of plant material for aquatic insects in the diet of the fish.

Bluegills

The small size and large number of Cladocera present in those stomachs containing them tend to magnify their numerical importance. Bluegills taking cladocerans fed on them almost to the exclusion of other foods. Although no quantitative determinations were made of the zooplankton in the ponds, few cladocerans were noted by visual observations. However, they formed the largest percentage of organisms by number (55.2) and also ranked first in frequency of occurrence among the stomachs analyzed.

Chironomidae were second in importance, constituting a

numerical percentage of 24.8 and present in 26.0 per cent of the stomachs. Computed on a numerical basis, midge larvae were the dominant organisms in the stomachs examined during the early part of the sampling period, and zooplankters were of principal importance the latter portion of the experiment. Further, during the spring and early summer, midges were as numerous in some stomachs as zooplankters were in others later on. For this reason, no attempt was made to correct for the dominating influence of these two systematic categories upon the remaining food groupings. This dominating tendency should be remembered when interpreting the percentage composition by number tabulation since percentages assigned to other food groupings are subsequently lower. Relative values or the order of importance among the various dietary groups remain unchanged.

Other groups of importance in descending order of frequency were the mayfly (Centroptilum spp.), the creeping mayfly (Caenis sp.), Ceratopogonidae and Gastropoda. These groups were taken by fish in nearly equal numbers.

Hydracarina and Ostracoda were eaten consistently during the sampling period but in comparatively small quantities.

Only one stomach (bluegill) contained sunfish fry and this item was not entered in the food organism tabulation.

In nearly all of the stomachs containing Chara, it composed more than one-third of the contents. Filamentous algae was present as infrequent fragments, occurred in only

5 per cent of the stomachs, and may have been taken incidentally while feeding.

Oligochaetes and Hexagenia sp. were also of negligible importance in the bluegill diet, being responsible for only 0.05 per cent of the total number of organisms consumed.

FORAGE RATIO DISCUSSION

The relationship of the organisms found in the stomachs of a fish population to the fauna found in the fishes' environment is a complicated one. The most widely used approach to an estimate of the existing quantity of food organisms represented by an aquatic fauna is the "measure of food preference" by Hess and Rainwater (1939). This was referred to as "forage ratio" by Hess and Swartz (1940) and was defined by them as the ratio of the percentage which a given kind of organism makes up of the total stomach contents to the percentage which this same organism makes up of the total population of organisms in the fish's environment. They explained further that where a group of organisms has a forage ratio significantly different from one, it should be the result of either a difference in availability or a difference in preference.

Leonard (1942) questioned the use of "preference" to describe the degree of utilization of organisms by fish. He suggested that forage ratio be used as a method for measuring availability instead of preference.

Allen (1942) renamed forage ratio "availability factor" but recognized the possibility of selection or preference on the part of the fish.

Regardless of the name given the ratio of the percentage occurrence of items in the stomach contents to their percen-

tage occurrence in the bottom samples, it has some useful applications.

Surber (1941) used the methods of Hess and Swartz for forage ratio and effective food grade determinations in his work with smallmouth bass streams.

Patriarche and Ball (1949) compared availability factors (using numerical data) for organisms in fertilized and unfertilized ponds and their use by young-of-the-year bluegills.

Ball and Tanner (1951) utilized forage ratio to point out the intermediate nature of food selection by pumpkinseed x bluegill hybrids as compared to food used by their parent species.

Ball (1948) compared variation in forage ratio values of five benthic groups over a 3 year period in a natural lake. It is evident from his investigation that values assigned to food groupings will vary from year to year in the same body of water. His data also show a wide disparity in forage ratios computed from volumetric determinations and those calculated from numerical data. However, it remains an open question as to which gives the most accurate values for relating food consumed to forage available.

Leonard (1949) favored the use of numbers and frequency of occurrence in the stomachs rather than volume for recording food data. He included volume measurements to facilitate comparison with other published reports. Allen (1942) stated that availability factors determined from volumetric, gravi-

metric, or numerical observations can be used interchangeably with reasonable accuracy. Hess and Swartz (1940) used numbers for their computations of forage ratio and food grade values of bottom fauna groups as related to their occurrence in the diet of black-nose dace. They state that the use of weight or volume might be preferable for these determinations.

Uneven distribution of the bottom fauna and other forage organisms has been cited as a principal source of error in comparing densities of different faunas present in streams (Surber, 1941; Allen, 1942). Fortunately, the pond bottoms sampled in this investigation provided a nearly uniform environment for benthic fauna, and wide differences in number and volume among the bottom samples did not occur.

The occurrence of seasonal variations in population density among the important food organisms is a well recognized fact. To minimize the error these fluctuations might introduce in availability factor determinations, Allen suggested that faunistic collections be taken throughout the year instead of at one season. Since the primary use of forage ratio concerns the nutritional benefit a fish receives from organisms in its environment, it would seem that these determinations would be more useful if made during the active feeding and growing season of the fish. The reduced rate of digestion and assimilation during the winter period is well established (Markus, 1932; Leonard, 1942), and forage ratios determined during this period of reduced metabolic activity

would neither be useful nor correct.

Forage ratio is used in this study to compare the utilization of various food items as they vary in quantity throughout a summer. For this comparison the important fish food groups, as determined from the stomach analysis data, were recalculated on the basis of their representing 100 per cent of the stomach contents. The corresponding groups among the bottom fauna were revised in like manner.

Tables 7 and 8 present this variation for the pumpkinseed sunfish and bluegill from May through August and give the average forage ratio values and their components for the 4 month period. It should be remembered that the sampling data listed under May and June were collected while the fish population was present in Pond 4. The data under July and August were taken after transfer of the fish to Pond 5.

Midges consistently represented a greater percentage of the total stomach contents than their relative abundance among the bottom samples would indicate. This increased rate of utilization, probably a food preference, is apparent for both species of fish throughout the sampling period.

The large number of Ephemera present in Pond 5 during July and August is reflected in their increased usage by both species of fish.

The Odonata formed an important dietary item for the bluegills in comparison to their small numbers available.

A reduced utilization of coleoptera larvae is indicated for the pumpkinseed sunfish after transfer to Pond 5 where more available and/or desirable foods were present.

TABLE 7

COMPARISON OF FOOD UTILIZED BY PUMPKINSEED SUNFISH
WITH THE VARIATION IN FOODS AVAILABLE

Food groups		Pond 4		Pond 5		Average
		May	June	July	August	
Midges	A	78.24	57.50	3.48	1.51	35.18
	B	96.02	52.39	26.95	3.03	44.59
	C	1.22	.91	7.74	2.00	1.26
Ephemera	A	10.78	6.49	35.30	73.78	31.58
	B	.18	2.87	28.32	60.33	22.92
	C	.01	.44	.80	.81	.72
Gastropoda	A	7.88	27.51	42.69	5.25	20.83
	B	3.44	27.04	36.72	33.33	25.13
	C	.43	.98	.86	6.34	1.20
Coleoptera	A	.28	6.56	10.44	13.95	7.80
	B	.36	17.70	5.08	2.75	.64
	C	1.28	2.69	.48	.19	.08
Trichoptera	A	1.41	1.61	7.12	4.98	3.75
	B	.....	.....	2.34	.28	1.31
	C	.....	.....	.32	.05	.34
Odonata	A	1.41	.20	.62	.45	.67
	B	.....	.....	.....	.....	.....
	C	.....	.....	.....	.....	.....
Hemiptera	A	.....	.13	.35	.08	.18
	B	.....	.....	.59	.28	.43
	C	.....	.....	1.68	3.50	2.38

A -- Per cent in bottom samples by number.

B -- Per cent in stomach samples by number.

C -- Forage ratio.

TABLE 8

COMPARISON OF FOOD UTILIZED BY BLUEGILLS WITH
THE VARIATION IN FOODS AVAILABLE

Food groups		Pond 4		Pond 5		Average
		May	June	July	August	
Midges	A	78.24	57.50	3.48	1.51	35.18
	B	98.47	89.73	18.11	7.10	53.35
	C	1.25	1.56	5.20	4.70	1.51
Ephemera	A	10.78	6.49	35.30	73.78	31.58
	B	.45	6.12	38.86	81.79	31.80
	C	.04	.94	1.10	1.10	1.00
Gastropoda	A	7.88	27.51	42.69	5.25	20.83
	B	.80	1.79	27.58	7.09	9.31
	C	.10	.06	.64	1.35	.44
Coleoptera	A	.28	6.56	10.44	13.95	7.80
	B	.....	1.22	8.22	2.14	3.86
	C	.....	.18	.78	.15	.49
Trichoptera	A	1.41	1.61	7.12	4.98	3.75
	B	.11	.19	.14	1.08	.38
	C	.07	.11	.01	.21	.10
Odonata	A	1.41	.20	.62	.45	.67
	B	.17	.85	2.51	.80	1.08
	C	.12	4.25	4.04	1.77	1.61
Hemiptera	A	.....	.13	.35	.08	.18
	B	.....	.09	4.60	.....	2.34
	C	.....	.69	13.14	.....	13.00

A -- Per cent in bottom samples by number.

B -- Per cent in stomach samples by number.

C -- Forage ratio.

YIELD OF BOTTOM FAUNA AND FISH

An outline for a study of fish and fish food production is presented by Ricker (1946) using a critical analysis of existing literature to formulate proposed principles and methods. Such an understanding of the complexities of the production at various trophic levels would be helpful in the intelligent manipulation of factors leading to increases in yield at any one and subsequently in all succeeding trophic levels. The many interrelated phases of the productivity investigation proposed by Ricker include a consideration of the annual net production of food organisms, the fraction of existing organisms actually consumed by fish, factors affecting amount and rate of feeding by fishes, and the conversion of food to fish flesh.

Because of the many complexities involved in production studies, wide use has been made of the more easily determined relationship between summer standing crop of benthos and the weight of fish produced from it (Meehean, 1936; Howell, 1941; Smith, 1947; Ball, 1948). Meehean and Howell compared the effect of fertilizer on production in southern ponds. The work of Smith and of Ball was conducted on natural lakes in Nova Scotia and Michigan, respectively. The standing crop figure is a useful one since it represents the excess of food material produced over the material destroyed by the many factors acting to limit its magnitude. Standing crop is, there-

fore, a measure of end result or food present at a given time while production gives the amount entering the aquatic area per unit time (Clarke, 1946).

No direct comparison exists between southern ponds, natural lakes, and the shallow Wolf Lake Hatchery ponds because of the diverse nature of these waters. Nevertheless, it is interesting to note that the total standing crop of benthic organisms in pounds per acre was considerably higher in the two Wolf Lake ponds than in the southern bodies of water and northern lakes just mentioned. However, when those systematic groups not utilized by the fish are eliminated from the total standing crop average, the resulting quantity is less than that reported by the other workers except Smith (1947).

Data concerning fish growth in Ponds 4 and 5 are limited to short periods of time because of the manner in which the experiment was conducted. The following conclusions relating standing crop of food organisms to yield of fish are made with the objective of contributing to the meager store of information dealing with this subject.

The 124 pounds of bluegills and pumpkinseed sunfish released in Pond 4 on April 21 increased in weight to 191.5 pounds by July 3 when they were removed for weighing and transfer to Pond 5. Net increase for the 10 week period was 67.5 pounds or a net gain of 6.4 pounds per week. The average standing crop of important fish food organisms

during the period was 0.36 cc. per square foot or approximately 34.5 pounds per acre.

On July 9 the same weight of each species originally released in Pond 4 (124 pounds) was transferred to Pond 5. In addition, 3.5 pounds of redear sunfish were transferred. A net gain of 41.4 pounds, or 5.2 pounds per week, occurred by September 9 when 171.2 pounds of fish were removed and weighed. These fish had available a benthic fauna averaging 1.15 cc. per square foot or approximately 110.4 pounds per acre for the 8 week periods.

The standing crop average of 0.28 cc. per square foot for the May-June period represents a fairly stable average food level (Figure 6) and was supporting 195.2 pounds of sunfish per acre the first week in July. This poundage includes 3.7 pounds of redear sunfish.

Using data available for the May-June interval, it is possible to compute the ratio of food conversion in Pond 4. Only during this period can direct comparisons be made between the two ponds beginning with the same approximate food level.

To calculate this conversion ratio, the following assumptions must be made.

- (1) The two ponds were alike in production of fish food organisms.

- (2) The difference between the average bottom fauna abundance values in the two bodies of water was directly

attributable to fish utilization.

(3) The rate of food production or "turnover" was not appreciably different in the two ponds.

The similarity of the two ponds as to morphometry, water supply, bottom type, and benthic populations has been discussed under pond description.

The numbers of organisms entering the size range usable by the fish in Pond 4 were also responsible for the increased abundance of food organisms in Pond 5. Consequently, this difference in food levels should equal approximately the quantity of benthic fauna necessary to produce the recorded increase in fish poundage.

Although there were many more organisms in Pond 5, most were insect larvae or nymphs and not of a stage of maturity to add their progeny to the available food supply during the short 2 month period.

If the foregoing assumptions are tenable then volume of the standing crop of food organisms for Pond 5 during May and June (1.66 cc. per square foot) minus the average volume in Pond 4 (0.28 cc. per square foot) equals 1.38 cc. per square foot or the quantity of food utilized by the fish. This volume in cubic centimeters can be converted to grams within reasonable limits of error by using the conversion factor 1 cc. preserved volume = 1 gram live weight (Ball, 1948). Consequently, 1.38 grams per square foot x 43,560 square feet in one acre equals 132.5 pounds per acre of those bottom

fauna known to be important in the fish diet. Further, the 132.5 pounds of bottom fauna per acre divided by the net poundage gained by the fish (69.4 pounds) represents a food conversion ratio of 1.9. Stated differently, it took 1.9 pounds of bottom organisms to produce one pound of fish flesh.

TABLE 9
DATA FOR CALCULATION OF CONVERSION RATIO

Food level in Pond 5	159.4	pounds/acre
Food level in Pond 4	26.9	"
Difference in levels	132.5	"
Weight of fish removed	195.2	"
Weight of fish released	125.8	"
Increase in weight	69.4	"
Conversion ratio	$\frac{132.5}{69.4} = 1.9$ pounds	

The conversion ratio obtained by this method is probably low because the importance of planktonic forms in the stomachs, while low volumetrically, was not accounted for as available food. Also, the added value of plant material in the diet is not known. A factor acting to lower the benthic abundance level in Pond 5 might be the effect of midge emergences. These hatches would be more important in the Pond 5

food level because of the larger number of individuals present there.

Moore (1941) fed beef and beef liver to a specimen of green sunfish (Lepomis cyanellus) for a 6 week period and obtained a food conversion ratio of 1.9. Ratios for other green sunfish, bluegills (Lepomis macrochirus), yellow perch (Perca flavescens), and a pumpkinseed sunfish (Lepomis gibbosus) ranged from 2.3 to 5.7. The work of Titcomb, Cobb, Crowell, and McCay (1929) shows that brook trout require from 1.1 to 3.8 units of dry food to produce one unit increase in body weight.

Although the estimate of food ingested to effect the observed increase in weight is probably conservative, the technique is a suggested method for determining this ratio under natural conditions rather than in the highly artificial situation created by confinement of the fish in aquaria or hatchery ponds.

The standard error of the weekly average volume of organisms per square foot was calculated for each of the ponds (Table 10). Two standard errors were then plotted on either side of the weekly mean and connected by narrow lines as illustrated in Figure 8. Since the weekly volumes per square foot (connected by heavy lines) each represent an average of 20 samples representative of the benthic population in the ponds, the probability that the true population mean falls within the limits indicated is 95.45 per cent.

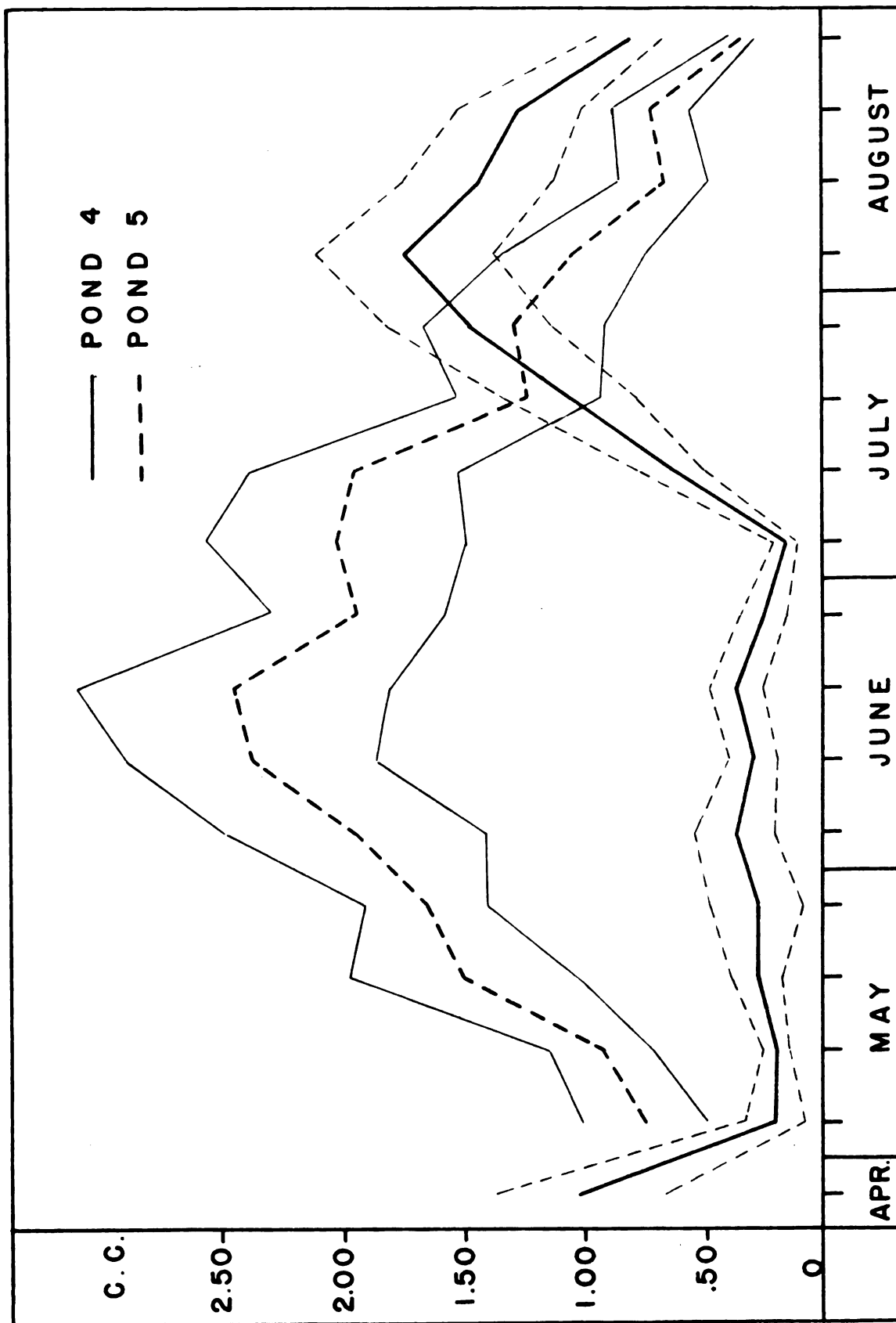
TABLE 10

TABLE SHOWING AVERAGE VOLUME OF BENTHIC ORGANISMS
PER SQUARE FOOT AND STANDARD ERROR

Week	Pond 4		Pond 5	
	Mean vol.	Stan. error	Mean vol.	Stan. error
April 4	1.02	.1940		
May 1	.21	.0540	.73	.1376
2	.20	.0284	.91	.1020
3	.27	.0484	1.50	.2396
4	.28	.1032	1.65	.1252
June 1	.37	.0820	1.89	.2676
2	.30	.0528	2.37	.2604
3	.38	.0616	2.46	.3224
4	.25	.0580	1.85	.1884
July 1	.17	.0268	2.01	.2740
2	.63	.0764	1.92	.2196
3	1.06	.1412	1.23	.1540
4	1.47	.1704	1.27	.1920
August 1	1.70	.1912	1.02	.1456
2	1.42	.1556	.67	.0940
3	1.25	.1244	.72	.0808
4	.79	.0704	.35	.0296

Figure 8 is essentially a modification of the graphical method of Dice and Leraas (1936) and may be used for comparing mean weekly values within and between the two ponds. Where the two standard error limits do not overlap, the difference between the mean values are significant at approximately the one per cent level. Overlapping limits imply that there is no significant difference between average weekly volumes of organisms per square foot. A further analysis of these differences is possible through use of a standard "t" test.

Figure 8. Confidence limits (at approximately the 5 per cent level)
within which the true mean lies.



SUMMARY

1. The standing crop of benthos in two paired ponds was compared at weekly intervals following the introduction of a fish population into one of them. A benthic abundance level approaching a balance between food organisms consumed and those entering a size range usable by the fish was reached less than one week after release of the fish. The number and volume of bottom fauna increased steadily in the pond without fish during this period.
2. Upon transfer of the fish to the other of the matched ponds in midsummer, two directly opposed trends occurred. The benthic population relieved of fish predation increased in volume per square foot 7.3 times within 5 weeks until checked by heavy mayfly emergences. Meanwhile, the pond subjected to predation declined steadily in benthic abundance until it reached a point approximating the food level previously recorded for the other pond when it held fish.
3. The benthic groups of consequence in the bluegill and pumpkinseed sunfish diet comprised only 24.1 and 37.0 per cent by volume of the total invertebrate fauna collected by dredge sampling. By number, the percentages were 82.7 and 86.1, respectively, of the total. Obviously, any study relating fish yield to their food supply must con-

sider these variations in organisms present, available, and consumed.

4. Analysis of bluegill and pumpkinseed stomachs showed their dietary habits to be similar excepting a greater usage of snails and hard-bodied insects by the pumpkinseeds. It is indicated that midges were a preferred food of both species as evinced by the proportionately greater incidence of this item in the diet than in the available food supply. Other food groups were generally taken in relation to the quantity available.
5. The percentage composition of various groupings making up the total bottom fauna population changed considerably as the season progressed. This variation, due primarily to insect emergences and development, was also evident in the composition of organisms represented in the bluegill and pumpkinseed sunfish diets.
6. A correlation between average standing crop of fish food organisms and the weight of fish produced from it can be made for the first half of this investigation. Food consumption balanced supply at the average level of 34.5 pounds of fish food organisms per acre during this 10 week period and gain by the fish equaled 54 per cent of their original weight (69.4 pounds).
7. The efficiency of food conversion was also calculated for

the first sampling period, using the difference in average food levels in the two ponds as the amount of food ingested to produce the increased weight of fish obtained. The conversion ratio obtained was 1.9.

LITERATURE CITED

- Allen, K. Radway
 1942 Comparison of bottom faunas as sources of available fish food. Trans. Am. Fish. Soc., 1941, 71: 275-283.
- Baker, Frank C.
 1916 The relation of mollusks to fish in Oneida Lake. Tech. Publ. 4, N. Y. State Coll. Forestry, 16: 1-366
- Ball, Robert C.
 1948 Relationship between available fish food, feeding habits of fish and total fish production in a Michigan lake. Tech. Bull. 206, Michigan State College Agr. Exp. Sta., March, 1948.
- 1949 Experimental use of fertilizer in the production of fish-food organisms and fish. Tech. Bull. 210, Michigan State College Agr. Exp. Sta., March, 1949.
- and Howard A. Tanner
 1951 The biological effects of fertilizer on a warm-water lake. Tech. Bull. 223, Michigan State College Agr. Exp. Sta., April, 1951.
- and Don W. Hayne
 1952 Effects of the removal of the fish populations on the fish-food organisms of a lake. Ecology (in press).
- Clarke, George L.
 1946 Dynamics of production in a marine area. Ecol. Monog. 16: 321-335.
- Deevey, Edward S.
 1941 Limnological studies in Connecticut. VI. The quantity and composition of the bottom fauna of thirty-six Connecticut and New York lakes. Ecol. Monog. 11(4): 413-455.
- Dice, Lee R. and Harold J. Leraas
 1936 A graphic method for comparing several sets of measurements. Contrib. Lab. Vert. Gen. Univ. Mich., 3: 1-3.

- Funk, John
 1942 The food of bluegills, perch, and pumpkinseeds from Wintergreen Lake, Michigan, for 1935-1938. Unpublished Report No. 790, Michigan Inst. for Fish. Res., June, 1942.
- Hess, A. D. and J. H. Reinwater
 1939 A method for measuring the food preference of trout. Copeia No. 3, Sept. 9, 1939: 154-157.
- and Albert Swartz
 1940 The forage ratio and its use in determining the food grade of streams. Trans. Fifth N. A. Wildlife Conf. 162-164.
- Hogan, Joe
 1949 The control of aquatic plants with fertilizers in rearing ponds at the Lonoke Hatchery, Arkansas. Trans. Am. Fish. Soc., 1946, 76: 183-189.
- Howell, Henry H.
 1942 Bottom organisms in fertilized and unfertilized ponds in Alabama. Trans. Am. Fish. Soc., 1941, 71: 165-179.
- Leonard, Justin W.
 1940 Further observations on the feeding habits of the Montana grayling (Thymallus montanus) and the bluegill (Lepomis macrochirus) in Ford Lake, Michigan. Trans. Am. Fish. Soc., 1939, 69: 244-256.
- 1942 Some observations on the winter feeding habits of brook trout fingerlings in relation to natural food organisms present. Trans. Am. Fish. Soc., 1941, 71: 220-227.
- and F. A. Leonard
 1949 An analysis of the feeding habits of rainbow trout and lake trout in Birch Lake, Cass County, Michigan. Trans. Am. Fish. Soc., 1946, 76: 301-314.
- Lyman, F. Earle
 1943 A pre-impoundment bottom fauna study of Watts Bar Reservoir area (Tennessee). Trans. Am. Fish. Soc., 1942, 72: 52-62.
- Markus, Henry C.
 1932 The extent to which temperature changes influence food consumption in largemouth bass (Huro floridana). Trans. Am. Fish. Soc., 1932, 62: 202-210.

- McCormick, E. M.
 1940 The study of some Reelfoot Lake fishes. Jour. Tenn. Acad. Sci., 10: 65-75.
- Meehean, O. Lloyd
 1936 Some factors controlling largemouth bass production. U. S. Bur. Fish., Prog. Fish. Cult., 16: 1-6.
- Moffett, J. W. and Burton P. Hunt
 1945 Winter feeding habits of bluegills and perch in Cedar Lake, Washtenaw County, Michigan. Trans. Am. Fish. Soc., 1943, 73: 231-242.
- Moore, Walter G.
 1941 Studies on the feeding habits of fishes. Ecology 22(1): 91-96.
- Morgan, George D.
 1951 The life history of the bluegill sunfish, Lepomis macrochirus, of Buckeye Lake (Ohio). Denison Univ. Bull., Jour. Scientific Labs., 42(4): 21-59.
- Patriarche, Mercer H. and Robert C. Ball
 1949 An analysis of the bottom fauna production in fertilized and unfertilized ponds and its utilization by young-of-the-year fish. Tech. Bull. 207, Michigan State College Agr. Exp. Sta., May, 1949.
- Pearse, A. S.
 1918 The food of the shore fishes of certain Wisconsin lakes. U. S. Bur. Fish. Bull., 35: 247-292.
- Ricker, William E.
 1946 Production and utilization of fish populations. - Ecol. Monog. 16: 373-391.
- Smith, E. V. and H. S. Swingle
 1942 The use of fertilizer for controlling several submerged aquatic plants in ponds. Trans. Am. Fish. Soc., 1941, 71: 94-101.
- Smith, M. W.
 1947 Food of killifish and white perch in relation to supply. J. Fish. Res. Bd. Can. 7(1), 22-34.
- Surber, Eugene W.
 1941 A quantitative study of the food of the smallmouth black bass, (Micropterus dolomieu), in three eastern streams. Trans. Am. Fish. Soc., 1940, 70: 311-334.

- Surber, Eugene W.
1945 The effects of various fertilizers on plant growths and their probable influence on the production of smallmouth black bass in hard-water ponds. Trans. Am. Fish. Soc., 1943, 73: 377-393.
- Swingle H. S. and E. V. Smith
1950 Management of farm fish ponds. Ala. Poly. Inst. Agr. Exp. Sta. Bull. 254, 1950: 1-23.
- Titcomb, J. W., Cobb, E. W., Crowell, M. F. and C. M. McCay
1929 The relative value of plant and animal by-products as feeds for brook trout and the basic nutritional requirements of brook trout in terms of proteins, carbohydrates, vitamins, inorganic elements, and roughage. Trans. Am. Fish. Soc., 1929, 59: 126-145.

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