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SURVIVAL, GROWTH AND FOOD OF 4-INCH WALLEYES IN PONDS WITH INVERTEBRATES, SUNFISHES OR MINNOWS [1]

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ABSTRACT

Survival, growth and food of 4-inch walleye fingerlings were studied for 2 years in experimental ponds containing either minnows, or sunfish, or only invertebrates. Survival, growth and production were best in the minnow ponds, intermediate in the ponds where the walleye were dependent on invertebrate foods, and poorest in the ponds containing stunted sunfish. Sunfish were eaten by walleyes, but they exerted a negative net effect by competing for invertebrates. Conversely, walleye predation did not significantly improve the growth of the sunfish population. Size of forage in relation to size of walleye was very critical to the process of food selection. Forage fish eaten by walleyes in these experiments were proportionately smaller than that reported for forage fish eaten by walleyes in Lake Erie. Results of the experiments imply that both the existing and the future food supply of natural lakes must be carefully evaluated before walleye fingerlings are stocked, if satisfactory results are to be obtained.

Introduction

Relatively few Michigan lakes support good walleye populations due to inadequate natural reproduction and recruitment. In the past, plantings of walleye fry or small fingerlings (2-4 inches long) established self-sustaining populations in only a few lakes and maintained small fisheries in only a few others (Schneider, 1969). Presumably, the failures resulted from high mortality of the hatchery fish within a few months of planting. In the future, it is anticipated that improved culture techniques will make it economically feasible to rear large numbers of walleyes to a

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relatively large size (4-8 inches long) in one growing season. Much better survival of, and returns from, the large fingerlings are anticipated (Klingbiel, 1971). At Pike Lake, Wisconsin, Mraz (1968) found that survival of walleyes (mostly native fish), which had reached a length of 6 to 7 inches in one year, was on the order of 50% during the following year. Survival of walleyes beyond the second year of life is typically excellent (Schneider, 1969).

Availability of food of the appropriate size and type is likely to be the most important determinant of growth and survival of planted fingerlings. Data of Parsons (1971) and Wolfert (1966) show, for example, that 6-inch walleyes prefer prey fish 2 inches long (range, 1.2 to 2.6 inches), and 4-inch walleyes prefer prey fish 1.5 inches long (range, 1.0 to 2.0 inches). Parsons suggests that the species of prey is not so important as its size--robust fishes (shad and alewife) found in walleye stomachs were as long as slim fishes (perch and minnows). Possibly then, sunfishes would be as suitable for walleye forage as perch or minnows of the same length. Walleyes are known to eat sunfishes, but the literature suggests that they are only a minor component of the diet. To a large extent this is because sunfishes are not abundant in the same types of lakes where walleyes are abundant; in addition it is likely that they are not a preferred food item. The question remains, however, as to whether walleyes will survive and grow on sunfishes if they are the primary food available. Since small, stunted sunfish predominate in the fish populations of many Michigan lakes and, potentially, are a large forage resource, this question merits more study. Conversely it is hoped that walleye predation will result in improved growth of the sunfish populations.

The primary objective of this study was to determine the effect of food type--sunfish, minnows and invertebrates--on the survival, growth and food habits of 4-inch fingerling walleyes (Stizostedion vitreum) planted in ponds for 1 year (autumn of age 0 to autumn of age I). Secondary objectives were to assess (1) over-winter mortality of walleyes caused by the rigors of transporting, handling, and adapting from artificial hatchery food to natural pond foods; (2) size of prey actually consumed in relation to size of walleye; and (3) impact of walleye predation on the abundance and growth of prey fish.

Methods

Experiments were conducted in ponds at the Saline Fisheries Research Station during 1972-73 (series A) and 1973-74 (series B). Each experiment began in October with the stocking of young-of-the-year walleyes and forage fish, and terminated in late September to early October of the following year when the ponds were drained. Three forage types were considered: (1) invertebrates (mainly crayfish, Orconectes virilis), (2) sunfishes (mainly bluegill, Lepomis macrochirus; also some green sunfish (L. cyanellus) and pumpkinseed (L. gibbosus), and (3) minnows (fathead, Pimephales promelas). The invertebrates were produced naturally in all ponds; the forage fish were stocked initially and were supplemented later by natural reproduction.

Ponds 8, 9, 10, 14, 15, and 16 were used. They are similar in size (0.53 to 0.70 acre), depth (maximum about 6 feet) and productivity. Ponds 8, 9 and 10 are turbid and free of higher vegetation, whereas ponds 14, 15 and 16 are less turbid and have stands of cattails (Typha latifolia). Any effect this difference may have had was eliminated by cross-classifying in the experimental design. As it turned out, no effect on the results could be detected. Records from a typical pond (No. 8) show that surface waters reached temperatures as high as 91 F during the study, but bottom waters never exceeded 82 F--and usually averaged 10° less--due to small inflows of cool water from the supply reservoir. The ponds are highly productive and support large populations of fish, crayfish, insects and zooplankton.

Fingerling walleyes, which had been reared on pelleted food at Wolf Lake Hatchery, were stocked in each pond at the rate of 100 per acre. They averaged 4.0 inches long (range, 3.2 to 4.9) in the series A experiments and 4.2 inches long (range, 3.2 to 6.0) in the series B experiments.

In the series A experiments, ponds 8 and 14 were stocked with minnows averaging 1.9 inches (range, 0.6 to 3.5), and ponds 10 and 15 were planted with fingerling sunfish averaging 1.8 inches (range, 1.1 to 3.2). The stocking rate was 100 pounds per acre.

In the series B experiments, ponds 10 and 15 were planted with minnows averaging 1.2 inches (range, 0.8 to 2.6) at the rate of 100 pounds per acre. In addition, small sunfish were unintentionally introduced at the rate of 13 pounds per acre into pond 10, and pond 15 became contaminated with a few green sunfish. Ponds 8 and 14 were stocked with sunfishes 1.4 inches long (range, 0.7-4.0) at the rates of 85 and 75 pounds per acre, respectively. Ponds 9 and 16 received no forage fish, and served as controls; in these ponds the walleyes were wholly dependent on the native invertebrates for food.

In both series of experiments, 13 adult (5- to 7-inch) bluegills were added to each sunfish pond the following spring. This was done so that the recruitment process of natural sunfish populations could be simulated. The sex ratio of the adult bluegills was approximately 1:1 in each pond, as determined by autopsies at the end of the experiment.

Mark-and-recapture estimates of walleyes were conducted in one pond with each food type (8B, 9B, 10B) in the spring of 1974 to determine mortality in the initial period following stocking. A 50-foot bag seine was used to capture the walleyes. Part of the caudal fin was clipped for identification purposes. The Bailey modification of the Petersen formula was used to calculate the estimates (Ricker, 1975).

Most of the experimental ponds were sampled periodically during the growing season with bag seines of 1/4-inch and 3/8-inch stretched-mesh, to determine the size of walleyes and forage present, and to provide specimens for a study of walleye food habits. The stomachs of 119 walleyes were examined in all. Food items were identified as precisely as possible and their lengths were estimated; then they were blot-dried and weighed to 0.1 mg. No walleyes were removed from experimental ponds 14B, 15B, and 16B; 10% were removed from 15A; and 25 to 38% were removed from the other experimental ponds.

All fish were collected and measured when the ponds were drained dry at the end of each experiment. The biomass figures obtained for crayfish are minimum estimates of their true abundance because many crayfish remained in the pond basins. In the tabulations, small, young-of-the-year crayfish were separated from adults which were too large to serve as walleye forage.

Results

Natural mortality

Annual natural mortality of walleyes was lowest (20.6%) in the ponds containing minnows, highest (46.8%) in the ponds containing only sunfish, and intermediate (27.3%) in the invertebrate-only ponds (Table 1). Among the minnow ponds, the highest mortality took place in the one (10B) containing some sunfish. There was no evidence that natural mortality was related to walleye density, as influenced by amount of sampling.

The mark-and-recapture estimates, in April, and the final census figures, in October, suggest that most of the natural mortality occurred within 6 months of stocking and that relatively little loss--other than due to sampling--took place later, during the growing season. Based on the point estimates for three ponds, 68 to 91% of the annual natural mortality (18 to 32% of the number planted) was associated with handling and adaptation to the new environment, or with over-winter conditions. Confidence limits on these estimates are sufficiently broad, however, due to small numbers, to allow for the possibility that all mortality could have occurred during the growing season. In any event, dead walleyes were not observed, either after stocking, or at any other time.

Growth

Growth of walleyes was related to forage type and to walleye density--walleye density being a function of natural and sampling mortality (Fig. 1). In the A experiment, at a comparable density of 40 walleyes per acre at the end of the year, mean weight of walleyes would average (based on Fig. 1) about 250 g in minnow ponds compared to only

140 g in sunfish ponds. In the B experiment, at a comparable density of 40 walleyes per acre, mean weight would also be higher in minnow ponds (370 g) than in sunfish ponds (190 g) or invertebrate-only ponds (230 g). Walleyes in Pond 14B, which was stocked with sunfish at three-fourths the usual rate, grew better than expected, reaching 251 g. Better growth of walleyes in the minnow ponds of experiment B, compared to the minnow ponds of experiment A, is attributed to the presence of some sunfish forage and to the smaller size of the minnows in the former.

Growth in the experimental ponds was good compared to natural populations of walleyes. The state average length of 9.5 inches for the second year of life (Laarman, 1963) was usually reached by walleyes in the sunfish ponds, and greatly exceeded by walleyes in all other ponds (Table 2).

Production

Gains in biomass due to growth exceeded losses due to natural mortality, resulting in a positive net production of walleyes for the year. Since most of the natural mortality was prior to the growing season, net production can be approximated by adding the pounds of walleyes harvested at the end of the experiments to the pounds sampled during the study, and subtracting the poundage stocked.

Net production, like growth, was related to both food type and walleye density (Fig. 2); however, net production was positively related to density, whereas individual growth was negatively related to density. In experiment A, at a comparable density of 40 walleyes per acre at the end of the year, net production in pounds per acre per year would be about 24 in minnow ponds and only 10 in sunfish ponds. In experiment B, comparable figures would be 37 in minnow ponds, 22 in invertebrate ponds and 16 in sunfish ponds. Production in ponds 10B, 15B and 14B was relatively high for the reasons cited in the section on growth.

Food habits and food availability

The diet of walleyes generally reflected the type of food available, species preference, and the size of food in relation to size of walleye. In the ponds without forage fish, walleyes ate mainly midges and cladocerans ("other" in Table 3) in the early spring, and crayfish the rest of the year. Midges and cladocerans were a negligible part of the diet in all other ponds, but crayfish were important in some. Young crayfish first became available in late May. An ample supply of small crayfish was left in the invertebrate-only ponds when the experiment terminated in October (Table 4).

Minnows were the predominant spring food in ponds in which they were abundant (Table 3). By late summer the minnows had been depleted and the walleyes fed more on crayfish or, in the case of pond 10B, on sunfish (Tables 3 and 4). It can be seen in Figure 3 that the walleyes had also out-grown the surviving minnows. Actually the average size of the minnows declined some, due in part, to recruitment of young. Most sunfish, on the other hand, remained within the preferred food size range. Even so, the walleyes fed on the smallest sunfish available (Fig. 3).

In the ponds containing large numbers of sunfish, the walleyes fed mainly on them (Table 3). A few very small crayfish were consumed when they first became available but none were eaten later in the year. No young crayfish were taken in seines or when the ponds were drained, indicating that crayfish were unavailable then (Table 4). Growth and survival of walleyes were poorest in these ponds in spite of an over-abundance of sunfish within the preferred size range throughout the year (Fig. 3).

Discussion

It is clear that minnows enhanced walleye growth and survival, and that dense populations of sunfish had a negative effect. The interactions among walleyes, forage fish, and native populations of crayfish and other invertebrates were complex, however. These ponds have a high level of natural fertility, producing up to 66 pounds per acre of yearling walleyes on an invertebrate diet alone. Addition of fathead minnows improved the growth and survival of walleyes, but to a lesser extent than expected. Apparently the positive effect of minnows as walleye forage was partially offset by their negative effect as competitors for zooplankton and insects during winter and spring. In summer, production of young-of-the-year crayfish buoyed the diet after the minnow population had been depleted by walleye predation (and by natural mortality).

Experimental ponds with large populations of minnows plus small numbers of sunfish were the best producers of walleyes because food of the proper size was always available. The initial size of the minnows in these ponds was smaller (1.2 inches) than in the minnow-only ponds (1.9 inches)--and apparently more suitable for forage, despite the fact that no less than 86% of the minnows were in the preferred range defined by Parsons. Small crayfish and sunfish were utilized after the walleyes had depleted and out-grown the minnows.

Addition of large numbers of sunfish to the pond system had a negative net effect on walleye production. Zooplankton, insects and crayfish were greatly reduced by the sunfishes. Only in the two ponds which had been stocked with a lower density of sunfish was there some survival of young crayfish (Table 4). Also, the dense population of fingerling sunfish repressed sunfish reproduction in the ponds, as they often do in "stunted" sunfish lakes (Beyerle and Williams, 1972). Only in the pond stocked at the lowest rate (14B) was there some survival of young-of-the-year sunfish (Table 4). Higher walleye production in this pond was correlated with increased reproduction of both crayfish and sunfish.

The survival and growth of walleye fingerlings stocked in the ponds with slow-growing sunfish could have been considered satisfactory from the point of view of the fisheries manager. It is likely, however, that similar results could be achieved in only a few, carefully selected, stunted sunfish lakes. Growth of sunfish was about 1 inch per year in the high-density sunfish ponds--a slow rate, but a rate higher than that of stunted sunfish populations in many natural lakes. Greater sunfish densities, relative to limnological productivity, may be expected to exert a greater negative effect on the invertebrate populations and a correspondingly greater negative effect on planted walleyes. In order to routinely achieve satisfactory production from 4-inch walleye fingerlings stocked on top of stunted sunfish, both the existing and the future food supply must be carefully evaluated. Not only must there be an abundance of food of the right size available immediately, but also, the density of sunfish must be low enough so that alternative foods--such as insects, minnows, and young-of-the-year crayfish, sunfish or perch--will be available later in the year. Few of our problem sunfish lakes meet these criteria. A typical pattern for these lakes is the formation of one dominant year class, which depletes the supply of alternative foods and soon grows too large to serve as forage, followed by several extremely weak year classes which would not provide adequate forage. Some walleye production can be expected as long as the dominant year class can be used as forage. On the other hand, walleye predation cannot be expected to effectively control the dominant year class and restore population balance. In the ponds, growth of sunfish was unsatisfactory in spite of predation by relatively large populations of walleyes.

The relationship between length of walleye and length of food reported by Parsons (1971), was used throughout this paper to predict the availability of forage fish to walleye predation. This relationship was developed in years when a large variety of forage was available to the walleyes in Lake Erie and, presumably, reflects food preference rather than availability. The relationship between walleye size and prey size observed in the ponds is presented in Figure 4. In the ponds the tendency was for walleyes to eat slightly smaller fish. For minnows, this does not necessarily reflect preference, as large minnows were not available when the walleyes were large. On the other hand, the minnows eaten were often the smallest available (Fig. 3). For sunfish the graph is a valid indication of a preference for smaller sizes. Substantiation is provided by the selection of the smaller sunfish from those available (Fig. 3) and more rapid spring growth of walleyes in ponds stocked with smaller sunfish. For 4-inch walleyes the preferred sunfish was about 1 inch long. This was about 0.5 inch shorter than the preferred size of forage fish given by Parsons.

Parsons suggested that walleyes select prey fish on the basis of length regardless of species (with the exception of trout-perch which were not eaten at all). His data did not include sunfish, as they are rare in Lake Erie. Sheepshead and white bass, the only abundant species with spiny fin rays and a robust shape (like sunfish), were rarely eaten; however, in Lake Winnebago, Wisconsin, these species are important foods of the walleye (Priegel, 1963). There are only three reports of natural populations in which bluegill, pumpkinseed, crappie or rock bass were a significant part of the walleye diet (but then only 5 to 17%), namely: in the Muskegon River impoundments (Eschmeyer, 1950); in Oneida Lake, New York (Raney and Lachner, 1942)--young only; and in Norris Reservoir, Tennessee (Dendy, 1946). Throughout most of its range the walleye is heavily dependent upon yellow perch and soft-rayed species.

Table 1.--Natural mortality rate (percent) of walleyes in relation to forage type

Pond number	Forage type: Minnow	Sunfish	Invertebrate
8A, B	14.5	26.7	....
9B	....	....	23.0
10B, A	35.0	64.5	....
14A, B	12.4	58.8	....
15B, A	20.6	37.1	....
16B	....	....	31.6
Mean	20.6	46.8	27.3

Table 2.--Number and pounds of walleyes recovered at the end of the experiments, with mean length of walleyes and the estimated preferred size range (PSR)[1] for forage fish

Forage type and pond number	Number per acre	Pounds per acre	Length (inches)	PSR (inches)
Invertebrate				
9B	41	21	11.6	2.0-4.8
16B	66	32	11.4	2.0-4.7
Sunfish				
10A	11	5	10.8	1.8-4.5
15A	53	14	9.2	1.3-4.5
8B	40	12	9.4	1.2-4.9
14B	40	22	12.0	2.1-5.0
Minnow				
8A	55	27	11.7	2.2-4.7
14A	36	20	11.9	2.1-4.8
10B	31	27	13.7	2.5-5.4
15B	77	43	12.2	2.2-5.0

[1] Preferred size range based on Figure 1 of Parsons (1971), and the smallest and largest walleyes present in each pond.

Table 3.--Food habits of yearling walleyes by pond type and season, expressed as percent frequency of occurrence, and percent composition by weight

Forage type and pond number	Season	Sample size N	Items in stomachs: Empty	Minnow	Sunfish	Fish (sp)[1]	Crayfish	Other
Frequency of occurrence (percent)								
Invertebrate	Spring	10	10	..	..	..	40	70
9B	Summer	10	..	..	..	..	80	40
Minnow	Spring	29	21	34	10	31	7	24
8A, 14A	Summer	10	20	30	..	30	20	..
Minnow and	Spring	10	..	70	..	20	20	20
sunfish	Summer	10	..	70	30	30	10	..
10B								
Sunfish	Spring	28	25	..	39	25	29	7
8B, 10A, 15A	Summer	12	42	..	50	..	..	8
Composition by weight (percent)								
Invertebrate	Spring	10	..	0	0	0	44	56
9B	Summer	10	..	0	0	0	98	2
Minnow	Spring	29	..	73	11	13	tr*	2
8A, 14A	Summer	10	..	39	0	14	47	0
Minnow and	Spring	10	..	84	0	11	1	4
sunfish	Summer	10	..	47	47	4	2	0
10B								
Sunfish	Spring	28	..	0	74	11	13	2
8B, 10A, 15A	Summer	12	..	0	100	0	0	tr*

[1] Fish (sp) means fish species unidentified.

* tr = trace, or less than 0.5%.

Table 4.--Summary of the pounds of forage fish per acre and crayfish per acre recovered at the end of the experiments, in relation to the estimated preferred size range (PSR) for the walleyes present (see Table 2)

Forage type and pond number	Forage fish (pounds per acre)				Crayfish (pounds per acre)		
	Total	<PSR	in PSR	>PSR	Total	Smaller	Larger
Invertebrate							
9B	0	0	0	0	120	64	56
16B	0	0	0	0	48	31	17
Sunfish							
10A	185	0	184	1	1	0	1
15A	172	0	156	16	11	0	11
8B	95	tr *	94	2	100	tr*	100
14B	128	34	91	4	125	tr*	125
Minnow							
8A	18	16	2	0	41	tr*	41
14A	62	60	2	0	tr*	tr*	tr*
10B	48 [a]	35	13	0	16	10	6
15B	20 [b]	20	0	0	191	164	27

[a] In pond 10B, 37 pounds per acre of sunfish were also recovered--3 pounds were smaller than the PSR, 26 pounds were in the PSR, and 8 pounds were larger than the PSR.

[b] In pond 15B, 16 pounds per acre of sunfish were also recovered--6 pounds were smaller than the PSR, 0 pound was in the PSR, and 10 pounds were larger than the PSR.

* tr = trace, <0.05%.

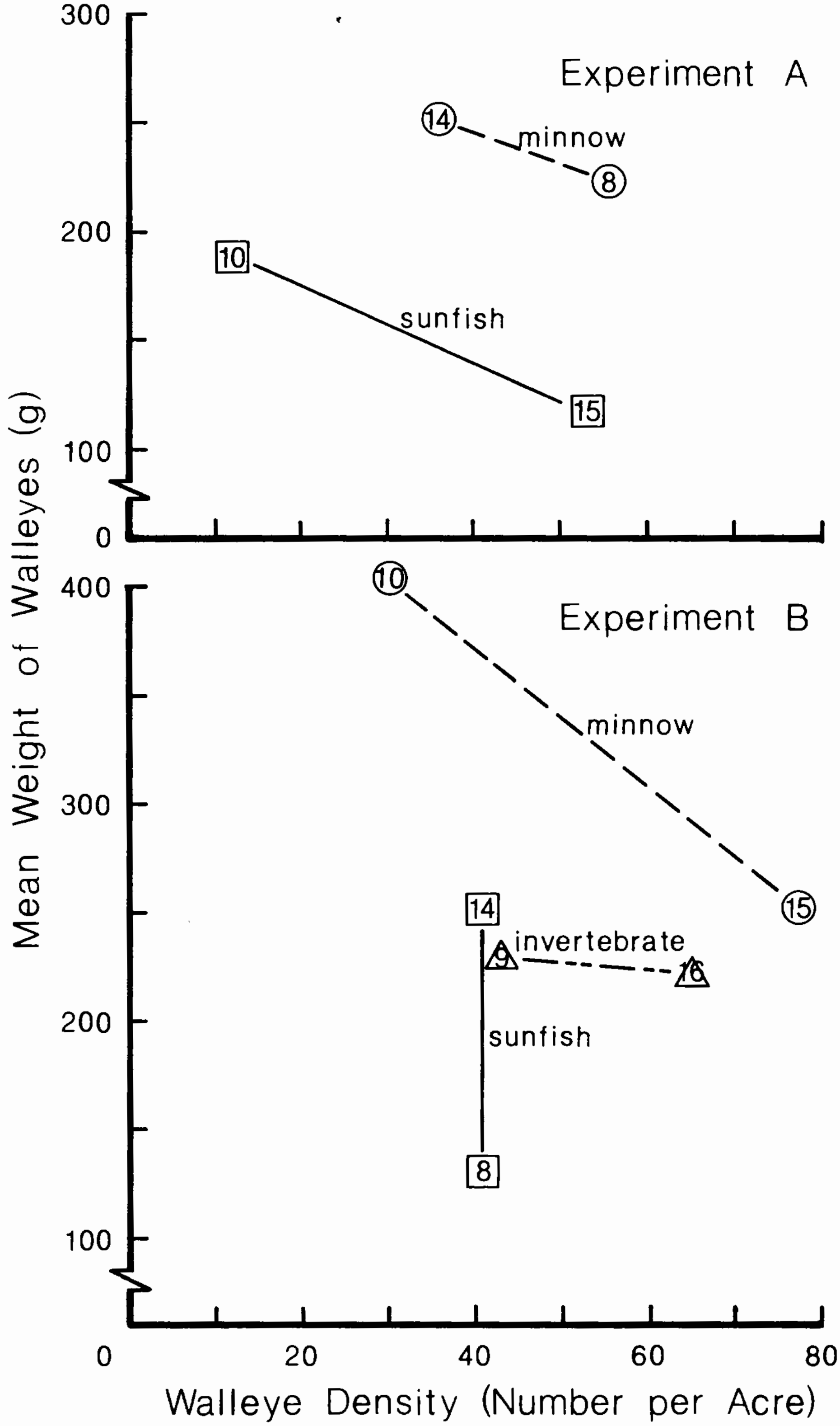

Figure 1.--Final mean weight of walleyes related to walleye density at the end of experiments A and B, and to forage type. Pond numbers are inside the symbols.

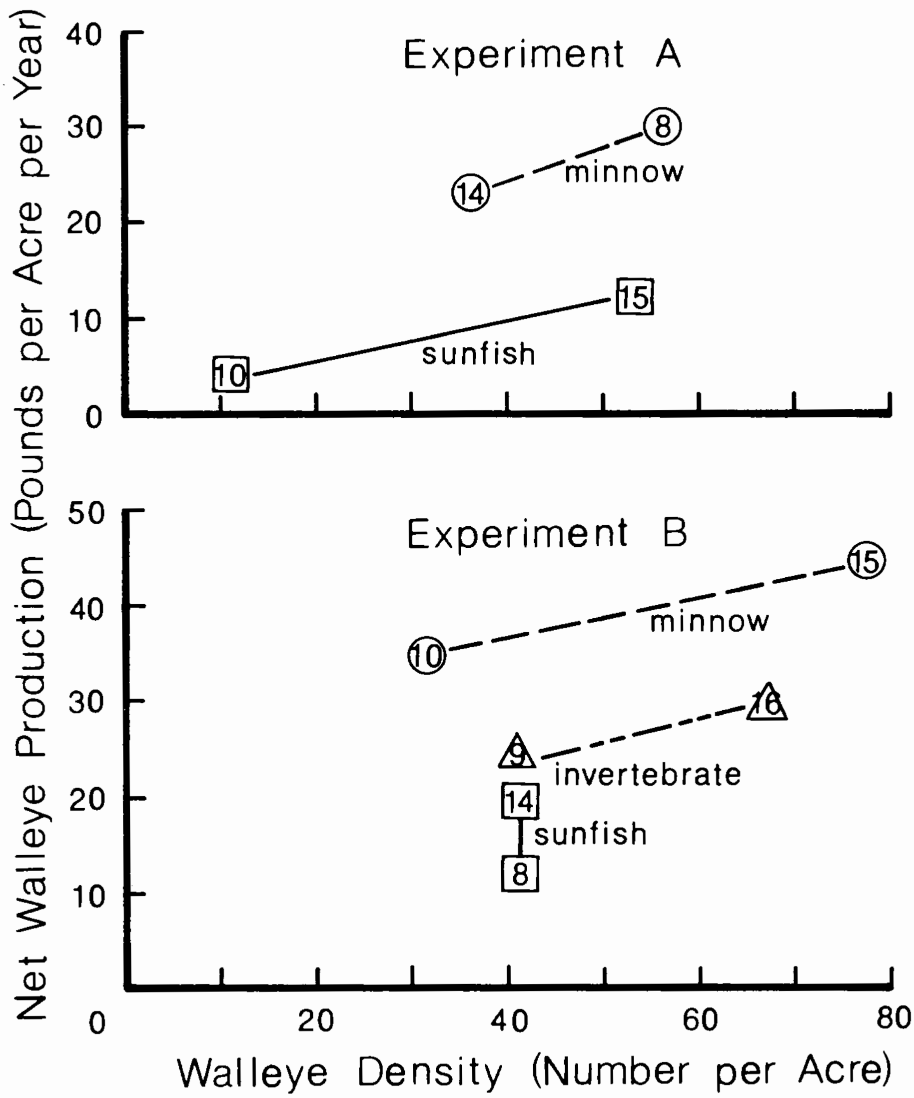

Figure 2.--Net walleye production in relation to walleye density at the end of experiments A and B, and to forage type. Pond numbers are inside the symbols.

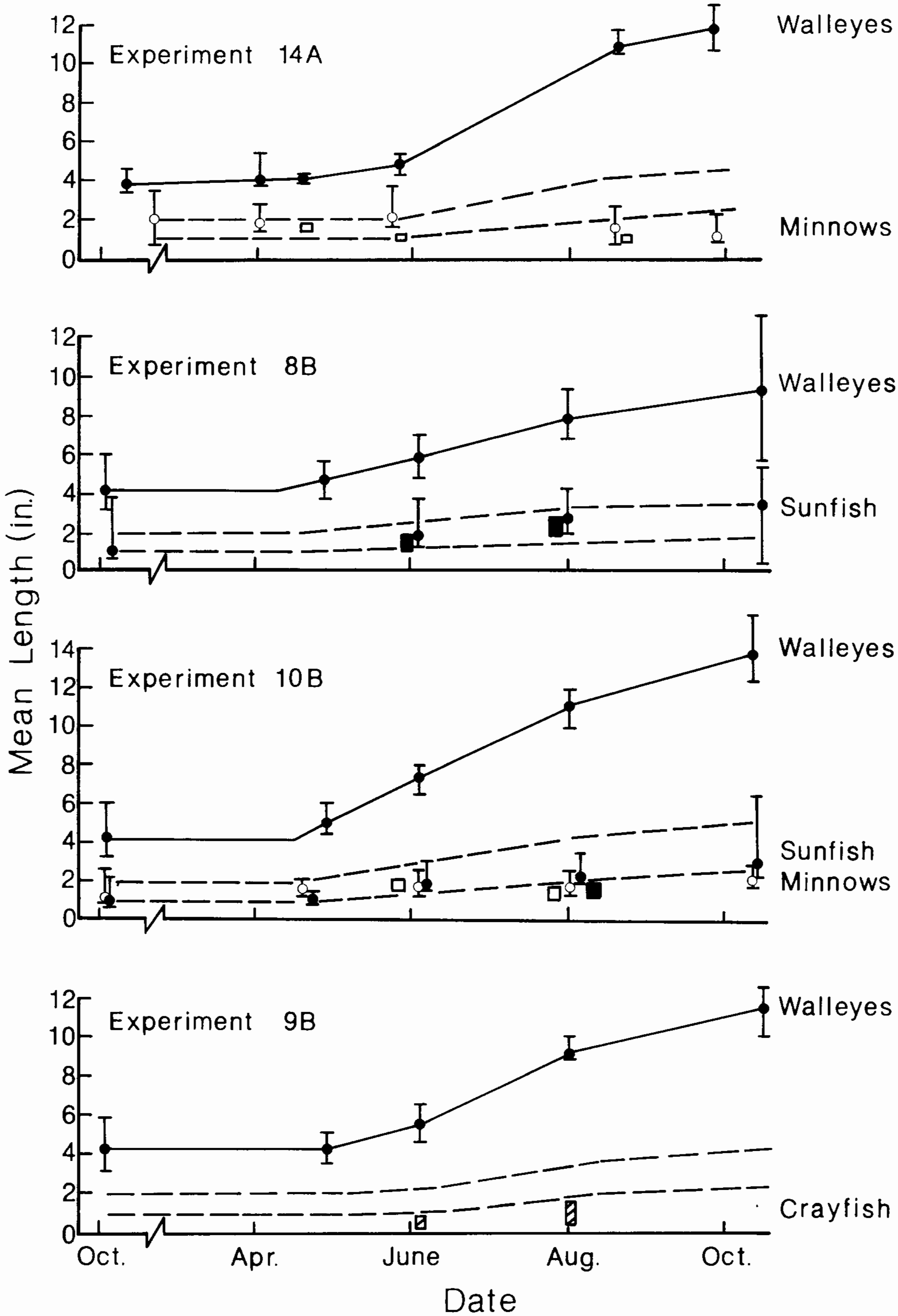

Figure 3.--Seasonal changes in mean size and size range of walleyes [—╪—], minnows [⚲] and sunfish [⚲] present in typical experimental ponds; in preferred size range of forage [⌶ ⌶] (derived from mean size of walleyes present and Figure 1 of Parsons, 1971); and in size range of minnows [□], sunfish [■] and crayfish [▨] eaten by walleyes.

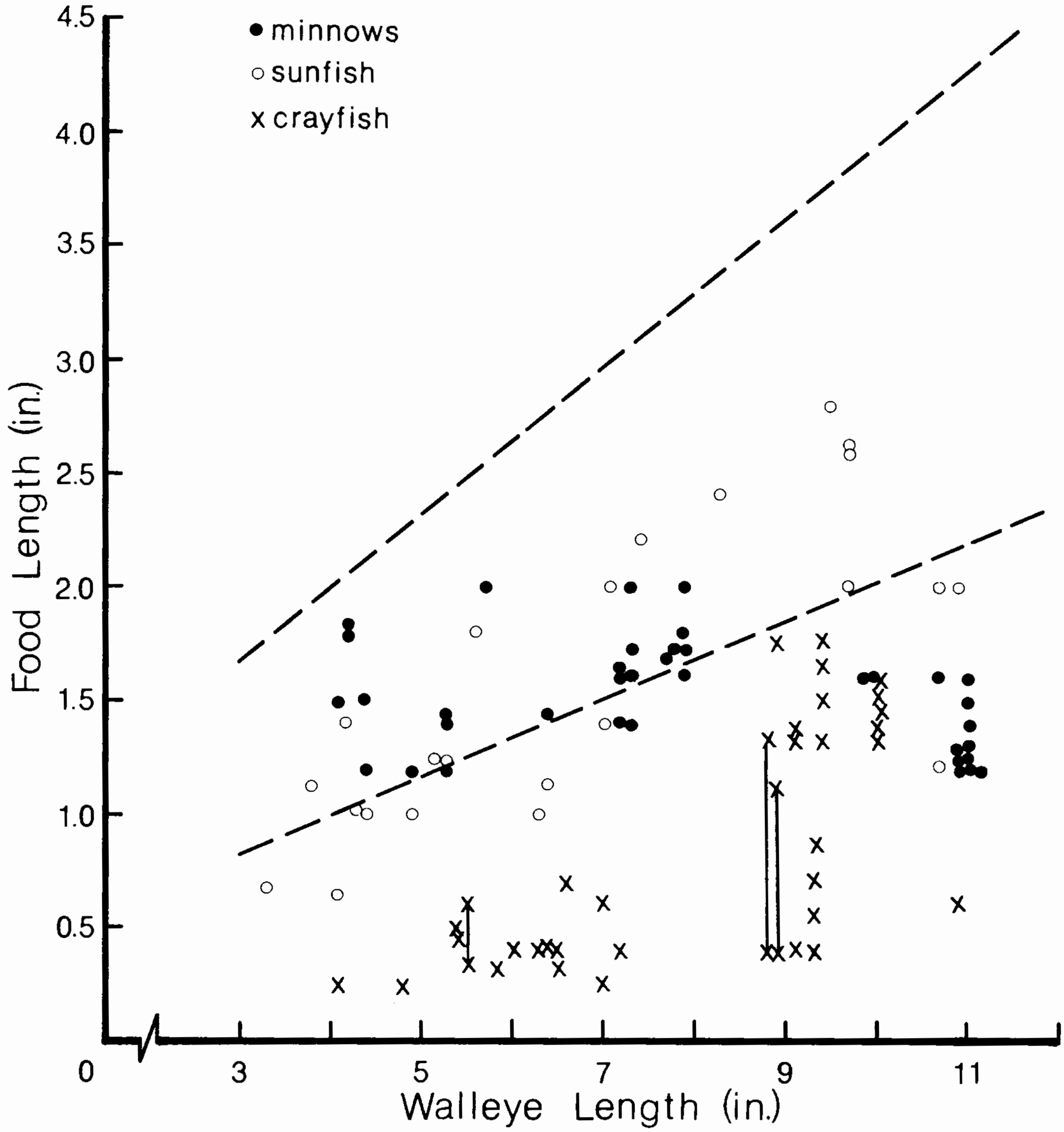

Figure 4.--Length of minnows, sunfish, and crayfish eaten by walleyes 3 to 11 inches long. The slanted dashed lines mark the preferred size range according to Figure 1 of Parsons (1971), and the vertical solid lines denote the range in size of many crayfish eaten by individual walleyes.

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