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SOME OBSERVATIONS OF FOOD SELECTIVITY BY NORTHERN PIKE AND BOWFINS IN AQUARIA[1]

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Abstract

Northern pike and bowfins confined in tanks and aquaria were presented various species and sizes of food items. Although the tests were designed to determine food preference, differential accessibility of the prey apparently in most instances resulted in measures of selectivity only. Bowfins selected organisms (crayfish and chubsuckers) which tended to remain on or near the bottom. Centrarchids, which stayed near the sides and top of the tanks, were eaten less frequently. Golden shiners swam continuously at mid-depth and were captured least frequently by the bowfins. Northern pike selected minnows and chubsuckers over centrarchids and yellow perch. They showed no choice between centrarchids and yellow perch, but selected centrarchids over bullheads.

These results increase doubt as to the effectiveness of pike and bowfins for controlling pan fish populations in lakes, and suggest that large populations of soft-rayed food fishes favor good growth of pike.

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Introduction

In this study we wanted to determine (1) the extent to which northern pike (Esox lucius) and bowfins (Amia calva) are selective in feeding upon some common fishes and (2) if the selectivity resulted from innate preference rather than environmental factors such as differential abundance and accessibility of the prey.

In natural environments, adult northern pike feed mostly on fishes, but will also eat frogs, crayfish, ducklings, and various other organisms (Frost, 1954; Allen, 1939; Lux and Smith, 1960; Lagler, 1956; et al.). Most authors have concluded that pike are not particularly selective in their feeding habits; they eat whatever is available.

Pike have been used in attempts to control populations of stunted bluegills(Lepomis macrochirus) in lakes of southern Michigan. It was hoped that large pike as well as larger bluegills would result from these experiments. Generally speaking, these results have not been achieved. Growth of pike in such lakes has not been outstanding, and the bluegills have continued to be excessive in numbers and slow in growth. Other data indicate that the fastest growth of pike in Michigan waters occurs where either cyprinids, salmonids, or yellow perch (Perca flavescens) are abundant.

This failure stresses the need to investigate more closely the feeding behavior of pike and other predatory fishes, especially under controlled conditions. Ivlev (1961) studied the food habits of pike and

other fishes by many refined experiments in tanks and aquaria. He concluded that the intensity of feeding by a predatory fish depends on the amount of food available and the patchiness of its distribution. Food scattered evenly over the feeding area was not consumed as intensively as the same amount concentrated in patches or aggregations. Ivlev also determined that predators feed selectively. This selectivity is influenced by a number of interacting factors, including the accessibility, abundance, and size of food items, as well as inherent food preference and the degree of satiation of the predator. Ivlev has defined preference as "a capacity inherent in the feeding animal and determined by its physiological properties," and accessibility as "a property appertaining basically to the food material and depending on the constitutional defense of the given item as well as on its degree of concealment." In this paper all references to preference and accessibility are based on these definitions.

Methods

Experiments with bowfins and with pike longer than 12 inches were carried out in 500-gallon fiberglass or concrete tanks. Metal-reinforced glass aquaria of 27- or 48-gallon capacity were used for pike smaller than 12 inches.

The prey species included bluegills, pumpkinseeds (Lepomis gibbosus), green sunfish (L. cyanellus), yellow perch, golden shiners (Notemigonus crysoleucas), fathead minnows (Pimephales promelas),

lake chubsuckers (Erimyzon sucetta), and bullheads (Ictalurus spp.). We used crayfish (Orconectes immunis) in one experiment with bowfins because of the importance of this crustacean in the natural diet of bowfins (Lagler and Hubbs, 1940; Lagler and Applegate, 1942).

With few exceptions, equal numbers (usually five or less) of food fish of two or more species or size categories were introduced simultaneously into a tank or aquarium that contained one or more predators. No cover was provided for either predator or prey. The length of each predator and the number and lengths of food fish were recorded. An experiment was concluded when all food fish of any particular species or size category had been eaten. The remaining fish of other categories were then noted and removed from the aquarium.

The abundance of food was not kept constant; items that were eaten were not replaced because preliminary tests had shown that the fright reaction of a newly introduced organism increased its accessibility. This phenomenon was demonstrated previously by Lewis, et al. (1961) with largemouth bass (Micropterus salmoides). Also, if a particular food decreased in abundance but still was selected by the predator while other, more numerous forms were not, we assumed this choice indicated that the predator preferred the least abundant food.

In the tests on different food species, we tried to use fishes of similar length. Fishes of different shapes, e.g., golden shiners and pumpkinseeds, were matched by overall size or bulk. In every test all prey fish of any one category, e.g., pumpkinseeds, were approximately

the same length. Either two or three categories of food fishes were used in each test. We reasoned that tests with two categories would show simple preference, while tests of three categories would indicate what happens when a food complex is available, a situation more closely resembling that found in nature.

The experiments were divided into series based on the size of the predator, size of food fishes, and species of food fishes. Although some individual predators were used in more than one experimental series, the majority of series utilized predators not previously tested. The latter procedure was preferred to avoid conditioning of the predators to a particular food.

The results of the experiments were analyzed statistically by applying the test for independence in a fourfold contingency table (Snedecor, 1956). We arbitrarily established the presentation of 10 food fish of each category (or as close to 10 as possible) as a measure of significance for each series of tests. For the evaluation of experiments in which three food categories were involved, the two categories of less frequently selected items were combined and treated as a single category.

Results

Although we designed these experiments to determine food preference, the results may not truly reflect the actual preference of bowfins and pike. Closely related fishes, e. g., bluegills and pumpkinseeds, usually showed similar behavior patterns, while distantly related species

ordinarily behaved quite differently. These behavior differences resulted in differential accessibility, and influenced food selectivity. Therefore tests that involved food species not closely related were more nearly measures of selectivity than of preference.

In the discussion of results, we have combined bluegills, pumpkinseeds, and green sunfish into the category "centrarchids" because these species behaved similarly and were chosen in about equal proportions.

Food selectivity by bowfins

Table 1 shows that bowfins were selective in their feeding. The following order of selectivity is suggested: crayfish, chubsuckers, centrarchids, golden shiners. The bowfins selected prey (crayfish and chubsuckers) that was not highly active and which was inclined to remain on or near the bottom. Centrarchids, which generally remained "hidden" in the corners and near the surface, were captured less frequently. Golden shiners swam continuously at mid-depth, and although often chased by the relatively slow-moving bowfins, they were captured least frequently.

Food selectivity by northern pike

Northern pike also were rather selective (Table 1). Minnows and chubsuckers were chosen over centrarchids and yellow perch, and centrarchids were selected over bullheads. No selectivity appeared

between centrarchids and yellow perch. As in the bowfin experiments, the differential behavior patterns (accessibility) of the prey fishes seemed to affect the selection by pike. Golden shiners tended to school and swim nervously at mid-depth, while fathead minnows behaved similarly but usually stayed near the bottom of the aquarium. Chubsuckers were less active, but also were inclined to school on the bottom. Centrarchids, yellow perch, and bullheads usually dispersed to the corners of the aquarium, often near the top. Frequently they maintained a vertical position so as to crowd into the aquarium corners. They did not swim about unless disturbed, and when they swam their movements were slower and steadier than those of the minnows. Apparently the behavior of the soft-rayed fishes made them more susceptible to attack by the pike, which typically remained near the aquarium bottom and were stimulated to feed by ". . . an object within certain size limits and moving not too slowly" (Baerends, 1957). A pike often showed interest in a swimming bullhead but would not attack it. Only one bullhead was eaten by a pike, after the other available food had been consumed, and this pike died soon after a pectoral spine punctured its stomach.

We also investigated the selectivity by young pike (7 to 12 inches) for various sized centrarchids. Pumpkinseeds (1.4 to 3.3 inches) were divided into four groups by length. Equal numbers of pumpkinseeds of each length-group were used in all tests, and in each test the length between successive groups differed by 0.5 inch. Table 2 shows the results of 14 tests that involved a total of 50 pumpkinseeds of each

length-group. Contrary to the theory (Ivlev, ibid.) that predatory fishes usually consume the largest of the available items, the pike in these experiments consistently ate the smallest pumpkinseeds. Perhaps our offering included pumpkinseeds that exceeded the optimum size for these pike, which conceivably could explain the difference in results. Only one of the 50 pumpkinseeds in the largest length-group (2.9 to 3.3 inches) was eaten. On several occasions a pike was observed to catch one of the larger pumpkinseeds, try to swallow it, and eventually release it. Thus the optimum size of pumpkinseeds for 7- to 12-inch pike was about 1.5 inches and the maximum about 3 inches.

In the tests on selectivity of larger pike (13 to 23 inches) for different sizes of centrarchids (pumpkinseeds and green sunfish), greater numbers of small centrarchids were presented to simulate natural situations more closely. These pike also were inclined to eat the smaller fish. Apparently 2.5-inch centrarchids were close to the optimum size for these pike, and 4.5-inch specimens were near the maximum size.

The tests in which only centrarchids were used as food items provided the most valid measures of preference because in these situations size of the prey was virtually the only factor that determined choice, and therefore differential accessibility was reduced to a minimum.

Effects of conditioning

Even though we tried to minimize conditioning of predators to a particular food, it was thought that some tests should be made on

conditioning. Three pike were fed only fathead minnows for 69 days while three other pike were fed only green sunfish and pumpkinseeds for this length of time. Two pike of each group were then tested for conditioning. The remaining two were continued on the respective diets for 232 additional days, and then were subjected to a similar test. In each test, five minnows and five centrarchids were introduced into an aquarium with one pike (Table 3). Comparison of the results with those of the various minnow-centrarchid tests shown in Table 1 indicates that the conditioning had no discernible effect on selectivity. The only pike to consume more centrarchids than minnows had been on a minnow diet for nearly 10 months. Such behavior may represent an example of reverse conditioning, but we assume it was atypical as none of the other pike reacted similarly.

Discussion

The outcome of these experiments emphasizes the difficulty of evaluating the factors that influence predatory fishes to eat certain amounts, kinds, and sizes of prey. Although we attempted to determine food preference, the effect of another factor, differential accessibility, probably made many of the results measures of food selectivity only. Nevertheless, the empirical data allow some predictions on predator-prey relations in natural environments.

If bowfins were used to control pan fish in lakes that also contained substantial populations of bottom-dwelling organisms such as suckers, crayfish, tadpoles, and large insects, these organisms probably would

buffer predation on pan fish so extensively that no benefit would be gained. Conversely, in waters where bottom-dwelling organisms are scarce, an abundant population of bowfins might control pan fish effectively.

Although pike in natural situations feed on almost any available fish, the pike in these experiments selected soft-rayed species over those with spiny rays. This result leads to the supposition that in a natural mixed population an abundance of soft-rayed fishes not only acts as a buffer between pike and pan fish, but perhaps also enhances the feeding intensity of pike, and therefore also their growth. If this reasoning is valid, then a lake containing only soft-rayed species and pike will tend to produce fast-growing pike, and a lake that contains mainly spiny-rayed fishes and pike will produce slow-growing pike that will not control excessive abundance of pan fish.

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INSTITUTE FOR FISHERIES RESEARCH

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Table 1.--Feeding selectivity by bowfins and northern pike when offered various food items. P = probability that food item A was eaten in greater numbers than item(s) B by chance.

Predator		Food item				
Length in inches	Number	Species	Mean length in inches	Total number offered	Total number eaten	P[1]
		Bowfins				
18.9-21.2	5	Crayfish, A	1.7	44	44	<0.001
		Bluegill and Pumpkinseed, B	2.0	15	4	
18.9-21.2	5	Pumpkinseed, A	1.9	10	10	<0.005
		Golden shiner, B	3.4	10	3	
15.2	1	Green sunfish, A	2.3	11	11	<0.010
		Golden shiner, B	3.1	11	6	
18.9-21.2	5	Chubsucker, A	5.8	10	10	<0.005
		Green sunfish, B	3.8	10	4	
		Green sunfish, B	5.2	10	3	
		Northern pike				
11.2	2	Fathead minnow, A	3.3	10	10	<0.001
		Pumpkinseed, B	2.7	10	0	
11.2	2	Fathead minnow, A	3.3	10	10	<0.001
		Green sunfish, B	2.3	10	1	

[1] When two B items are given, P is the probability of A being eaten in greater numbers than the two combined B items.

Table 1.--continued

Predator		Food item				
Length in inches	Number	Species	Mean length in inches	Total number offered	Total number eaten	P[1]
		Northern pike (continued)				
8.5-9.3	3	Chubsucker, A	2.9	10	10	<0.001
		Green sunfish, B	2.2	10	1	
12.0-14.5	4	Green sunfish, A	2.1	12	9	N.S.
		Yellow perch, B	3.8	12	9	
11.5	1	Green sunfish, A	2.1	10	10	<0.001
		Bullhead, B	2.2	10	0	
14.3	1	Fathead minnow, A	3.4	10	10	<0.001
		Pumpkinseed, B	2.7	10	1	
		Green sunfish, B	2.6	10	0	
25.3-27.9	2	Fathead minnow, A	3.4	10	10	<0.001
		Pumpkinseed, B	2.8	10	3	
		Green sunfish, B	2.8	10	1	
6.2-7.9	6	Golden shiner, A	2.6	10	10	<0.005
		Bluegill, B	1.8	10	5	
		Yellow perch, B	2.2	10	2	
9.5-9.7	3	Chubsucker, A	2.7	12	12	<0.005
		Yellow perch, B	2.7	12	6	
		Pumpkinseed, B	2.2	12	4	
17.7-19.9	6	Chubsucker, A	4.0	10	9	<0.010
		Yellow perch, B	5.2	10	7	
		Pumpkinseed, B	3.6	10	1	

Table 1.--concluded

Predator		Food item				
Length in inches	Number	Species	Mean length in inches	Total number offered	Total number eaten	R[1]
		Northern pike (concluded)				
7.4-9.7	6	Chubsucker, A	3.3	12	9	N.S.[2]
		Pumpkinseed, B	1.8	12	9	
		Green sunfish, B	2.6	12	5	
19.4-19.8	3	Green sunfish, A	3.8	10	8	N.S.[3]
		Yellow perch, B	4.5	10	3	
		Pumpkinseed, B	3.9	10	2	

[2]Also not significant if pumpkinseeds are compared with chubsuckers and green sunfish.

[3]Also not significant if yellow perch are compared with green sunfish and pumpkinseeds.

Table 2. --Selectivity by northern pike for centrarchids of various sizes

Length of pike, in inches	Food items			
	Species	Mean length (inches)	Number offered	Number eaten
7-12	Pumpkinseeds	1.6	50	49
	Pumpkinseeds	2.1	50	33
	Pumpkinseeds	2.6	50	18
	Pumpkinseeds	3.1	50	1
13-23	Centrarchids[1]	2.5	50	50
	Centrarchids	3.5	40	27
	Centrarchids	4.5	30	5
	Centrarchids	5.5	20	0

[1] Pumpkinseeds and green sunfish.

Table 3.--Results of conditioning six 12- to 14-inch pike to particular food items. P = probability that the observed ratio resulted from chance

Conditioned to	Conditioning period (days)	Conditioning test		P
		Minnows eaten	Centrarchids eaten	
Minnows	69	5	0	<0.001
Minnows	69	5	0	<0.001
Centrarchids	69	5	1	<0.010
Centrarchids	69	5	1	<0.010
Minnows	301	4	5	N.S.
Centrarchids	301	5	0	<0.001