MICHIGAN DEPARTMENT OF NATURAL RESOURCES

FISHERIES DIVISION

Fisheries Research Report No. 1795

June 14, 1973

DENSITY DEPENDENT GROWTH AND MORTALITY OF YELLOW PERCH IN PONDS [1]

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ABSTRACT

Survival and growth of perch during their first 6 months of life were studied in relation to the density of older perch in replicated ponds at the Saline Fisheries Research Station from 1969 to 1972. Data on the growth and survival of older perch, and on the effects of pond types, were obtained also. In the spring of the year, the ponds were stocked with fertilized perch eggs and either no, low, or high numbers of fingerling (mostly yearling) perch. Stocking rates were selected so as to simulate densities, and produce growth rates, found in natural populations. In the fall of the year, the ponds were drained and the fish counted.

I found that the number of young perch which survived was higher in the ponds rich in plankton than in the ponds with extensive stands of cattails, at all levels of fingerling density. In the cattail ponds, survival of young was reduced only at high fingerling densities, whereas in the plankton-rich ponds, even low numbers of fingerlings appeared to reduce survival of young. Growth of young compensated for abundance of young, with the result that cattail ponds produced 84 pounds of young per acre and the plankton ponds produced 108 pounds per acre, regardless of fingerling abundance. Growth of young was linearly related on a log-log scale to their own density. Competition with fingerlings did not affect growth of young until they reached a length of about 4.4 inches--a size not usually attained in natural populations in one year.

Between 10.9 and 52.9% of the planted fingerlings died of natural causes during each experiment. Survival was not related to density or pond type. Growth of individual fingerlings was inversely related to density; however, the ponds stocked at the highest rates produced the largest total standing crops.

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[1] Supported by Dingell-Johnson Project F-29-R-7, Michigan.

Introduction

Both the yellow perch (Perca flavescens) and its near relative, the European perch (Perca fluviatilis), undergo extreme fluctuations in abundance due to uneven recruitment. Reasons for these large variations in year class strength are poorly understood.

El-Zarka (1959) was unable to correlate the year class strength of yellow perch in Saginaw Bay, Lake Huron, with the number of adult perch or with temperature, precipitation, water level, or turbidity of the water. Similarly, LeCren (1955) reported that fluctuations in recruitment of the European perch were not correlated with the number of spawners; however, he observed that strong year classes often occurred in different lakes during the same years. This and other data led him to suggest that survival of perch during their first year of life is influenced by weather.

The most likely mechanism by which weather could affect the survival of perch is by influencing the food supply of newly hatched fry. Smyly (1952) has shown that perch fry select zooplankters on the basis of size, and that the onset of feeding is a very critical phase of life. Weather conditions favorable to the development of blooms of zooplankters of the proper size would theoretically favor survival of fry.

Survival of young perch and the formation of year class strength are dependent also upon the density of older perch. Earlier studies (Schneider, 1972) at experimental lakes containing only yellow perch indicated that a very strong year class was produced when the abundance of fingerling and adult perch was low. Succeeding year classes were very weak until the density of the strong brood was reduced--about 3 or 4 years. Similar observations were made by Buck and Thoits (1970) in ponds containing only yellow perch and by Alm (1952) in lakes and ponds containing only European perch. These authors suggest that cannibalism by the older perch is responsible for year class failure, but direct evidence is lacking.

From 1969 to 1972, I conducted a series of replicated pond experiments to measure more precisely the relationship between the survival of perch during their first 6 months of life and the abundance of older perch. I also obtained data on the relationship between abundance and growth of young, and the abundance and growth of older perch.

Methods

Experiments were conducted in ponds at the Saline Fisheries Research Station of the Michigan Department of Natural Resources. The ponds are from 0.51 to 0.71 acre in size and about 6 feet deep at the outlet. Ponds 7, 8, 9, 10, and 13 were usually turbid due to frequent plankton blooms. Ponds 14, 15, and 16 were usually clear and had extensive stands of cattails (Typha latifolia). Also, the ponds with cattails often contained large numbers of bullfrog tadpoles (Rana catesbeiana). Differences between the two types of ponds were taken into account in the design of the experiment by selecting a replicate from each type.

The basic design of the experiments was as follows. In early spring the ponds were drained and refilled with water. In April the ponds (usually six) were stocked with enough fertilized perch eggs to assure that the ponds would be "saturated" with young. Before hatching took place, two ponds were also stocked with low numbers of 2- to 6-inch fingerling perch (mostly yearlings) and two other ponds were planted with high numbers. Two other ponds served as controls. Only male, immature or spent fingerlings were planted to circumvent natural spawning.

During the first half of October the ponds were drained and their fish, crayfish, and tadpoles were sorted and weighed. Many crayfish remained in the pond mud and were not estimated. Therefore the figures given in this report are only indices of crayfish abundance. Young-of-the-year perch could usually be distinguished from older perch on the basis of size; however, scale samples were used when necessary. An estimate of the number of young perch present was prorated from counts and weights of samples. All older perch were both counted and weighed.

In 1969, stocking rates were 34,700 eggs per pond, and 0, 333 or 1000 fingerlings per pond. Few young perch were found when the ponds were drained, suggesting the viability of the eggs had been low.

Consequently, only the portions of the 1969 data concerning growth of young and fingerlings and survival of fingerlings were useful.

The experimental procedures were modified in 1970. Instead of artificially fertilized eggs, the ponds were stocked with naturally fertilized eggs which had been collected from nearby lakes. Also, instead of simply releasing the eggs on the bottom of the pond, they were held in floating boxes, covered with screen. Hatching success could then be evaluated, subjectively, before the fry were released into the ponds. Large numbers of young perch were found when the boxes were checked after hatching and when the ponds were drained indicating that the modified procedure had been successful. Stocking rates were 52,000 eggs per pond and 0, 333 or 1000 fingerlings per pond. Some fish escaped from pond 9 during the drainage operation and that pond had to be repeated in 1972.

Two additional modifications were made in the experiment for 1971. First, the number of eggs planted was increased to assure that the ponds would be saturated with young perch, and second, stocking rates were computed on a per-acre basis to make adjustment for small differences in the size of the ponds. Stocking rates in 1971 were 100,000 eggs per acre plus 0, 784 or 1900 fingerlings per acre. An additional 5,000 eggs were added to pond 14 because hatching success had been poor there. On a per-pond basis, these fingerling stocking rates were similar to those used previously. Data from all years will be presented on a per-acre basis.

During 1969 and 1970, the stomach contents of 213 young-of-the-year and 248 fingerling perch were examined. The young perch ranged from 0.3 to 7.4 inches long; the fingerling perch were from 3.0 to 10.0 inches long. Estimates of fingerling survival rates were adjusted to take these removals into account.

Results

Summaries of stocking rates and number and pounds of perch and other organisms recovered in the fall may be found in Tables 1-3. The experiment at pond 9 in 1972 has been included in Tables 2 and 4 as a replacement for data missing in 1970; however, it is not very comparable because it was performed in a different year and because the fingerlings planted were smaller.

Survival of young-of-the-year perch was extremely low in 1969. Only 4 to 2,220 per acre were recovered in the fall. In 1970, from 4,602 to 13,746 young per acre survived when modified stocking procedures were used. In 1971, about 25% more eggs were planted. This appeared to increase the survival of young in the plankton-rich ponds which had no fingerlings or low numbers of fingerlings from 10,000-14,000 to 19,000-32,000 per acre but had no effect on the number of young surviving in the cattail ponds. Thus it appears that a stocking rate of 73,500 eggs per acre is adequate to saturate the cattail ponds with young perch but stocking rates of 100,000 (or more) are necessary to saturate the plankton-rich ponds with young.

Data from the cattail ponds in 1970 and 1971 were pooled for a regression of the number of young perch surviving to fall on the number of fingerling perch stocked in the spring (Fig. 1). Only the 1971 data from the plankton ponds were used for a similar regression. The lines were fitted by eye to the data from the cattail ponds and by least squares regression to the data from the plankton ponds. The equation for the line fit to the plankton pond data is:

$$\log_{10} \text{number of young} = 4.3882 - 0.000136 \text{ (number of fingerlings)}$$

Its slope is significant at the 92% confidence level.

It is evident from Figure 1 that survival of young perch was higher in the plankton ponds than in the cattail ponds at all levels of fingerling density. At no and low fingerling densities the difference was about two-fold; at high fingerling densities, the difference was about three-fold.

It is also evident that fingerlings had some impact on the number of young which survived. In the cattail ponds, this effect was apparent only at high fingerling densities. In the plankton ponds, even low numbers of fingerlings appeared to reduce survival; however, the effect in these ponds becomes negligible also if the high point (32,000) on the graph was to be excluded.

These observations were confirmed by a two-way analysis of variance using all the data from 1970, 1971, and 1972 (Table 4). There were significant differences (95% confidence level) in number of young surviving to fall between cattail and plankton ponds. Among the plankton ponds, there were significant differences between the ponds with fingerlings and those without fingerlings but not between the two levels of fingerlings. Among the cattail ponds, there were significant differences between ponds with no fingerlings and high numbers of fingerlings, and also between ponds with low and high densities of fingerlings; however, survival of young in cattail ponds without fingerlings did not differ from that in cattail ponds with low numbers of fingerlings. Exclusion of 1972 data (pond 9) from the ANOVA did not alter these results.

Whereas fingerling perch had an effect on the survival of young, they had no effect on the pounds of young produced (Table 4). Thus growth of young was compensatory. In the plankton-rich ponds, about 108 pounds per acre were produced regardless of the number of fingerlings present. In the cattail ponds, production averaged less, 84 pounds per acre (significant at the 90% confidence level).

The relationship between growth of young and their abundance in the fall was linear on a log-log scale over most of the densities studied (Fig. 2). However as density declined to about 2,000 young per acre, growth of young leveled off when fingerlings were present, apparently due to competition for food. At that time the young weighed about 15 g each (4.4 inches long). When fingerlings were not present, growth of young continued in linear fashion until their abundance fell to about 500 per acre. At densities less than 500 per acre, growth leveled off at a mean weight of about 57 g (6-8 inches long) due to intra-age group competition for food or, what is more likely, due to a physiological limitation on growth.

Analysis of the stomach contents of perch showed that zooplankton was the only food of small young-of-the-year fish. At a length of about 2.0-2.6 inches the diet was supplemented by larval chironomids. At a slightly larger size other insects, crayfish, and green sunfish (in ponds where they were common) entered the diet. The planted fingerling perch ate the same types of food organisms as the larger young. Cannibalism was not observed; however, little sampling was done early in the season when the young were still small and most vulnerable to cannibalism.

Between 10.9 and 52.9% of the fingerlings planted in the spring died from natural causes prior to fall. At low stocking densities natural mortality averaged 35.1% in the plankton-rich ponds and 18.3% in the cattail ponds. At high densities natural mortality of planted fingerlings averaged 17.5% and 25.2%, respectively. A two-way ANOVA indicated that there were no significant differences in mortality rate between the two densities nor between the two types of ponds. No year-to-year differences in mortality were evident. The high average of 35.1% for the low density plankton ponds was due mainly to a single high value from pond 10 in 1970. Possibly these fish were in poor condition when planted.

Planted fingerlings grew faster in the low density ponds than in the high density ponds (Tables 1-3), but the high density ponds produced larger standing crops (Table 5). Thus, growth of fingerlings only partially compensated for their density. The difference in number of fall fingerlings was 1367:456 = 3.0, whereas the difference in biomass of fall fingerlings was 100.2:61.5 = 1.6. There were slightly higher standing crops of fingerlings in the cattail ponds (65 pounds per acre at low density, 103 at high density) than in the plankton-rich ponds (58 pounds per acre at low density, 98 at high density) but the difference was not statistically significant.

The abundance of crayfish and tadpoles had no obvious effect on the survival or growth of perch in these ponds. The standing crop of crayfish ranged from 12 to 200 pounds per acre (minimal estimates) and the biomass of tadpoles varied from 0 in the plankton-rich ponds to as much as 427 pounds per acre in the cattail ponds. Conversely, the abundance of perch had no effect on the biomass of crayfish or tadpoles present in the fall. These findings contrast with those of Buck and Thoits (1971) who noted an inverse relationship between the biomass of perch and the biomass of crayfish. I observed that small crayfish were numerous in ponds containing only small perch and sparse in ponds containing fingerling perch large enough to prey on young crayfish.

Discussion

Density-dependent regulatory mechanisms are evident in several aspects of perch survival and growth. The pond studies at Saline and those reported by Buck and Thoits (1971) showed that growth of young perch was highly dependent on the size of the year class. These findings contrast with studies of perch in lakes which indicated that there was little correlation between abundance and growth of young (Schneider, 1971, 1972; Forney, 1971; Pycha and Smith, 1955; LeCren, 1958; Alm, 1946). Perhaps this difference is linked to the high fertility of the ponds which may favor higher survival during the early stages of life than is usual. The Saline ponds produced from 84 (cattail) to 108 (plankton-rich) pounds per acre of young. The ponds of Buck and Thoits also produced about 100 pounds per acre. By comparison, two experimental lakes containing only perch, produced about 30 pounds per acre each, and a lake with a mixed fish population, produced about 8 pounds per acre (Schneider, 1971, 1972). Survival from egg to October of the first year of life was as high as 32% in the Saline ponds; the highest survival reported from lakes was 12% (Schneider, 1972).

Both the pond and lake studies cited above indicated that growth of young perch is independent of the density of older perch unless young are growing unusually fast and, consequently, reach an unusually large size during the first summer. Typically, perch begin life as plankton feeders, then switch to benthic invertebrates and, eventually, to fish and crayfish (see reviews by Alm, 1946; LeCren, 1958; and Laarman and Schneider, 1972); although in some populations, plankton or benthos remains a principal food throughout life (McCormack, 1970; Laarman and Schneider, 1972). The sizes at which changes in diet often take place do not seem to be rigidly fixed and estimates of them have varied. In my earlier studies on lakes (Schneider, 1972), I estimated that the change from a diet of plankton to a diet of benthos occurred at about 3 inches. In the Saline ponds, there was no marked change in diet but the growth data suggested that competition between young and fingerling became noticeable when the young reached about 4.4 inches.

Growth of fingerling perch is density related also but not strongly so (Schneider, 1971, 1972). As a result, strong year classes of fingerlings developed larger standing crops of smaller sized fish, than weak broods. The fingerling stocking rates I used in the pond studies were higher than those found in typical lakes; however, because of the high fertility of the ponds, a typical range of fingerling growth was produced. Fingerlings in the low density ponds grew at rates exceeding the state-wide average compiled by Laarman (1963); fingerlings in the high density ponds grew at rates typical of "stunted" populations in lakes. Thus a wide range in survival of young perch was anticipated. Although survival of young was inversely related to the density of fingerlings, the relationship was not as strong as has been observed in other waters (Schneider, 1972; Alm, 1952; Eschmeyer, 1938). Again, this may be linked to the high fertility of the ponds. Perhaps if the fingerlings had been introduced into the ponds in the fall preceding the planting of the eggs, the fingerlings would have depleted their food supply during the winter and they would have been more predatory on young during the spring and summer. Nevertheless, in both lake and pond studies of populations in which perch are the only fish present, more young have survived than the environment can support in subsequent years at average (or satisfactory) growth rates. Extrinsic mechanisms, as predation or competition by other species of fish, apparently are necessary to stabilize perch populations at a level which will allow production of large sized perch.

Table 1.--Summary of the pond experiments in 1969

Pond No.	Perch planted: Eggs per acre	Perch planted: Fingerlings Number per acre	Perch planted: Fingerlings Length (inches)	Young recovered in fall: Mean length (inches)	Young recovered in fall: Number per acre	Young recovered in fall: Pounds per acre
8	56,000	0	...	6.4	520	73
15	49,000	0	...	6.4	162	23
Average	52,500	0	...	6.4	341	48
10	56,000	539	4.4	4.6	2,220	86
16	59,000	563	4.3	4.7	108	4
Average	57,500	551	4.4	4.6	1,164	45
9	53,000	1,520	4.4	5.2	33	2
14	66,000	1,901	4.4	5.0	4	<1
Average	59,500	1,711	4.4	5.1	18	1

Pond No.	Fingerlings recovered in fall: Mean length (inches)	Fingerlings recovered in fall: Number per acre	Fingerlings recovered in fall: Pounds per acre	Crayfish: Pounds per acre	Tadpoles: Pounds per acre*
8	...	...	...	183	2
15	...	...	...	62	30
Average	...	...	...	122	...
10	7.3	356[a]	70	56	0
16	7.3	328[b]	79	200	271
Average	7.3	342	74	128	...
9	6.4	1,189[c]	142	49	1
14	6.0	1,451[d]	136	87	427
Average	6.2	1,320	139	68	...

* A few green sunfish and other organisms are included in this category.

[a] 16 fingerlings (26 per acre) were removed during the summer.

[b] 32 fingerlings (54 per acre) were removed during the summer.

[c] 32 fingerlings (49 per acre) were removed during the summer.

[d] 22 fingerlings (42 per acre) were removed during the summer.

Table 2.--Summary of the pond experiments in 1970

Pond No.	Perch planted: Eggs per acre	Perch planted: Fingerlings Number per acre	Perch planted: Fingerlings Length (inches)	Young recovered in fall: Mean length (inches)	Young recovered in fall: Number per acre	Young recovered in fall: Pounds per acre
8	84,000	0	...	2.7	13,746	90
15	73,500	0	...	3.0	10,890	110
Average	78,750	0	...	...	12,318	100
10	84,000	538	3-6	3.2	10,485	123
16	88,000	562	3-6	2.8	10,204	85
Average	86,000	550	3-6	...	10,344	104
9[a]	79,000	1,520	3.9	2.9	13,340	126
14	99,000	1,901	3-6	4.1	4,608	98
Average	89,000	1,710	3-6	...	8,974	112

Pond No.	Fingerlings recovered in fall: Mean length (inches)	Fingerlings recovered in fall: Number per acre	Fingerlings recovered in fall: Pounds per acre	Crayfish: Pounds per acre	Tadpoles*: Pounds per acre
8	...	...	...	39	0
15	...	...	...	56	139
Average	...	...	...	47	...
10	7.4	254	47	56	3
16	6.7	502	57	36	387[b]
Average	7.0	378	52	46	...
9[a]	5.3	1,346	73	135	0
14	5.9	1,295[c]	112	12	39
Average	5.6	1,320	92	73	...

* A few green sunfish and other organisms are included also.

[a] This pond experiment was done in 1972.

[b] This includes 10 pounds per acre of green sunfish, the highest amount found in any pond.

[c] 12 fingerlings (23 per acre) were removed during the summer.

Table 3.--Summary of the pond experiments in 1971

Pond No.	Perch planted: Eggs per acre	Perch planted: Fingerlings Number per acre	Perch planted: Fingerlings Length (inches)	Young recovered in fall: Mean length (inches)	Young recovered in fall: Number per acre	Young recovered in fall: Pounds per acre
10	100,000	0	...	2.6	20,189	122
7	100,000	0	...	2.3	32,402	126
13	100,000	0	...	2.3	22,561	85
16	100,000	0	...	2.5	7,595	48
Average	100,000	0	...	2.4	20,687	95
8	100,000	793	3.0	2.5	18,729	92
15	100,000	774	3.0	2.9	10,438	88
Average	100,000	784	3.0	2.7	14,583	90
9	100,000	1,900	3.0	2.8	13,574	95
14	105,000*	1,900	3.0	3.7	4,308	77
Average	102,500	1,900	3.0	3.2	8,941	86

Pond No.	Fingerlings recovered in fall: Mean length (inches)	Fingerlings recovered in fall: Number per acre	Fingerlings recovered in fall: Pounds per acre	Crayfish: Pounds per acre	Tadpoles**: Pounds per acre
10	...	...	...	53	0
7	...	...	...	111	2
13	...	...	...	74	0
16	...	...	...	55	286
Average	...	...	...	73	...
8	6.3	611	60	35	1
15	6.2	682	58	99	362
Average	6.2	647	59	67	...
9	5.2	1,468	78	78	2
14	4.9	1,454	60	41	451
Average	5.0	1,461	69	60	...

* Five thousand eggs were added to the original group as an adjustment for egg mortality.

** A few green sunfish and other organisms are included in this category.

Table 4.--Number and pounds, per acre, of young-of-the-year perch recovered in October 1970-1971

Pond type	Year	Fingerling density		
		Zero	Low	High
Number of young				
Plankton	1970	13,746	10,485	13,340*
	1971	20,189	18,729	13,574
		32,402	...	...
		22,561	...	...
Average		22,224	14,607	13,457
Cattail	1970	10,890	10,204	4,608
	1971	7,595	10,438	4,308
Average		9,242	10,321	4,458
Pounds of young				
Plankton	1970	90	123	126*
	1971	122	92	95
		126	...	...
		85	...	...
Average		106	108	110
Cattail	1970	110	85	98
	1971	48	88	77
Average		79	86	88

* Data from pond 9, 1972.

Table 5.--Number and pounds, per acre, of fingerling perch recovered in October 1969-1971

Pond type	Year	Fingerling density Low	High
Number of fingerlings			
Plankton	1969	356	1,189
	1970	254	1,346*
	1971	611	1,468
Average		407	1,334
Cattail	1969	328	1,451
	1970	502	1,295
	1971	682	1,454
Average		504	1,400
Pounds of fingerlings			
Plankton	1969	70	142
	1970	47	73*
	1971	58	78
Average		58	98
Cattail	1969	79	136
	1970	57	112
	1971	60	60
Average		65	103

*Experiment was done in 1972.

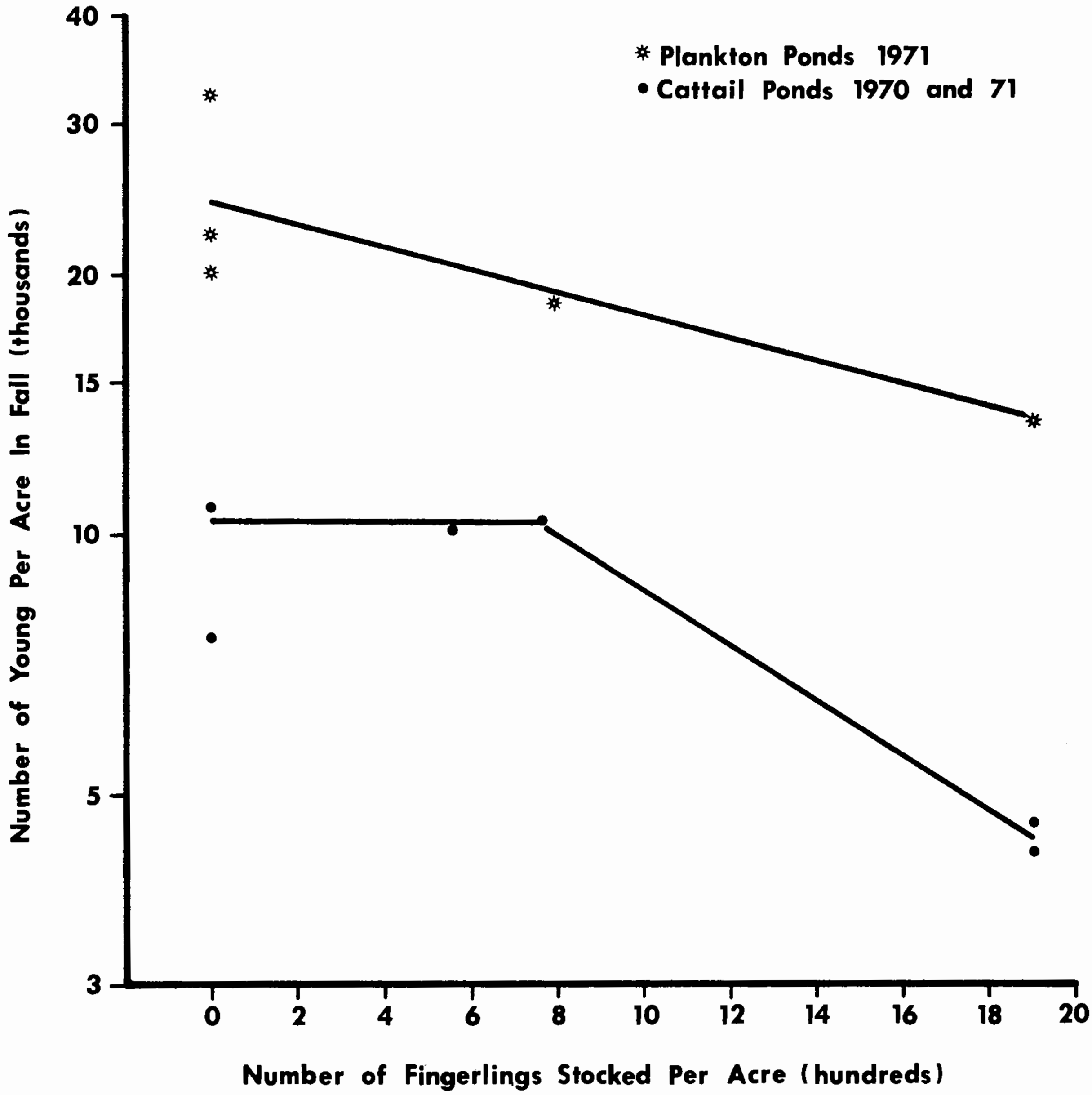

Figure 1.--Survival of young-of-the-year perch in relation to the abundance of fingerling perch stocked in the Saline Ponds.

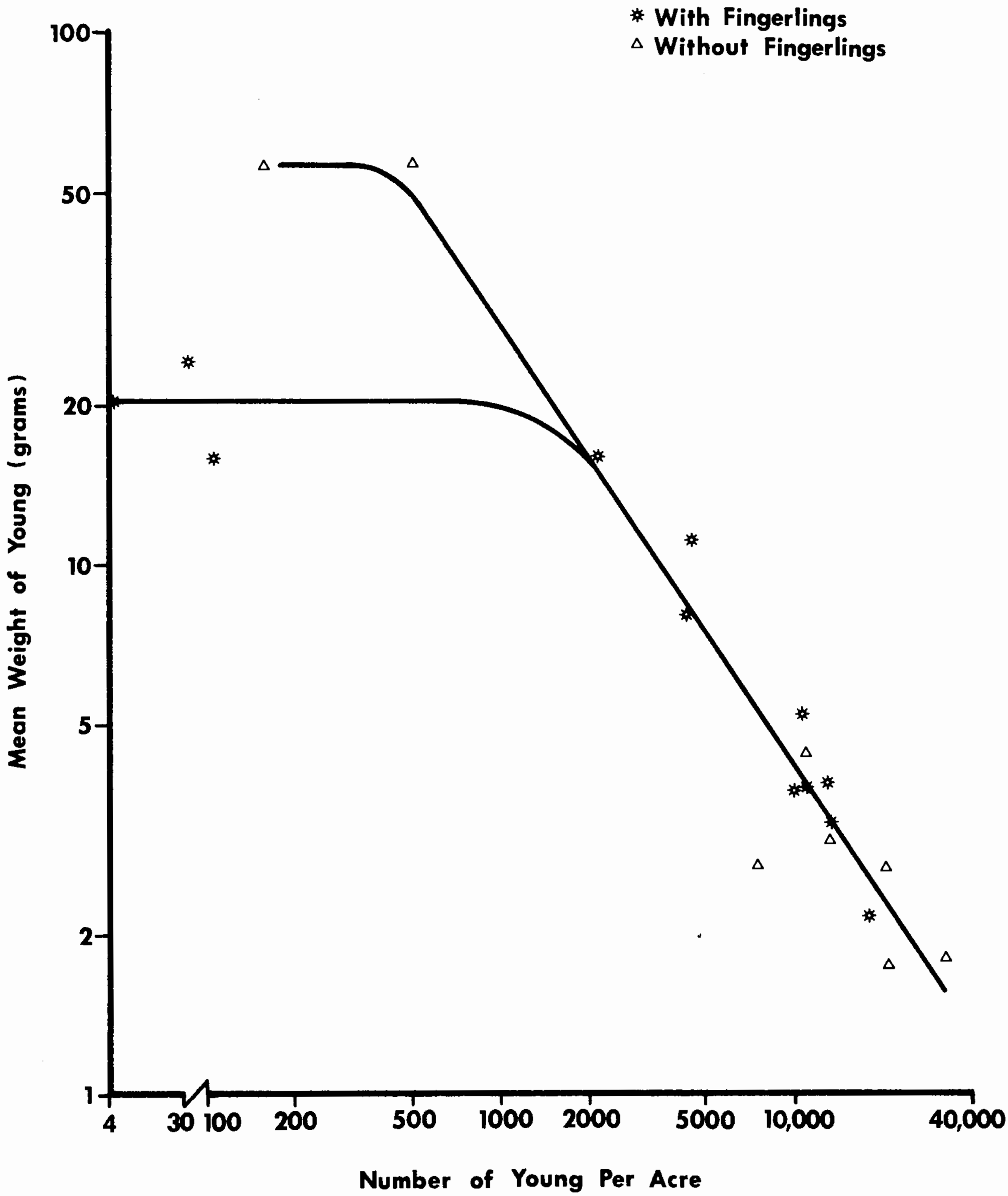

Figure 2. --The relationship between growth of young-of-the-year (mean weight in fall) and abundance of young in fall.

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Report approved by G. P. Cooper

Typed by M. S. McClure