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Comparative Survival of Pellet-Reared Muskellunge Stocked As Fingerlings In Bluegill Ponds With and Without Largemouth Bass

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Fisheries Research Report No. 1920

April 23, 1984

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

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COMPARATIVE SURVIVAL OF PELLET-REARED TIGER MUSKELLUNGE STOCKED AS FINGERLINGS IN BLUEGILL PONDS WITH AND WITHOUT LARGEMOUTH BASS[1]

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[1]Contribution from Dingell-Johnson Project F-35-R, Michigan

Abstract

For three consecutive years, 5.7- to 6.5-inch tiger muskellunge fingerlings were stocked at the rate of 10 per acre in four 3.0- to 4.0-acre ponds. The ponds contained either forage fish only (mainly bluegills) or forage fish and adult largemouth bass (9.0 inches and larger).

Survival of the muskellunge was inversely correlated to the density of largemouth bass 12.0 inches and larger in length. The effects of predator density on survival dominated and masked the effects of forage density. Survival of fingerling muskellunge stocked in lakes with known densities of 12.0-inch and larger largemouth bass is predicted.

Introduction

Since 1976, all tiger muskellunge (hybrids between northern pike, Esox lucius and muskellunge, Esox masquinongy) produced by Michigan hatcheries have been reared to fingerling size on pelleted food. Survival of these pellet-reared fingerlings after stocking in some Michigan lakes has been lower than for minnow-reared muskellunge stocked prior to 1976.

For minnow-reared tiger musky fingerlings stocked in Michigan in 1973-75, estimated statewide return to the angler was 25% in 1977 (Beyerle 1979). However, in two study lakes in southern Michigan survival of pellet-reared fingerlings stocked in more recent years averaged only 4.4% to fall of the first year, while minnow-reared fingerlings planted in the same lakes averaged 35.9% survival. The ratio of survival averaged 9.2 minnow-reared fingerlings for each pellet-reared fingerling (Beyerle 1982). Similar differences in survival between minnow- and pellet-reared fingerling tiger muskies have occurred in Wisconsin (Johnson 1978).

Initially, it was suspected that pellet-reared fingerlings might not readily adapt to a diet of young, spiny-rayed fishes. However, Beyerle (unpublished data) found that pellet-reared fingerlings immediately and successfully consumed spiny-rayed food fishes in hatchery troughs without physical damage to themselves.

More recently four inter-related factors have been identified that together probably are responsible for the difference in survival. Two factors related to the fingerlings are size at stocking and time of stocking. Examination of hatchery planting records has shown that, on the average, minnow-reared fingerlings were stocked on July 23, at a mean length of 7.7 inches, while pellet-reared fingerlings were stocked on August 22, at 6.6 inches mean

length. Thus the minnow-reared fingerlings were stocked 1 month earlier and averaged 1.1 inches larger when stocked.

Difference in size is especially important because for a week or more after planting, fingerlings often remain close to the surface in shallow water, exposed to predation. The difference in time of stocking is important because fingerlings stocked in July probably have access to more young forage fishes. By mid-August the age-0 forage fishes are fewer in numbers (because of predation) and more scattered. Some older forage fishes have grown too large to be utilized as food by the relatively small, pellet-reared fingerlings. Obviously these differences favor the survival of the minnow-reared tiger muskies.

Two other factors important to survival of fingerlings muskies are predator density and forage density. Pellet-reared fingerlings stocked at only 3.5 inches survived fairly well (36% to fall of age 0) in a lake with less than six predators (larger tiger muskies) per acre (Beyerle 1981). However, survival was extremely low for six groups of 3.5-inch pellet-reared fingerlings stocked in three typical southern Michigan lakes containing largemouth bass, Micropterus salmoides. Survival of production-size fingerlings (6.2-6.6 inches) was somewhat higher, but also relatively poor. Even minnow-reared fingerlings (7.8 inches) survived poorly in a lake with low forage density and high density of adult largemouth bass (Beyerle 1982).

It would be desirable to identify forage and predator parameters within which satisfactory survival of production-size musky fingerlings could be anticipated. The present study was designed to compare the survival of production-size fingerlings in ponds with and without the presence of significant numbers of adult largemouth bass.

Procedure

For many years the Department of Natural Resources hatchery section has raised various warm- and cool-water fishes in the five state-owned ponds at Almena, Van Buren County. The ponds are fed by water from springs in the pond bottoms and by a small stream that is tributary to the Paw Paw River. Stream flow through all the ponds is regulated at a control structure upstream from Pond 1.

The four ponds used in this study vary in surface area from 3.0 to 4.0 acres and in maximum depth (at the outlet box) from 9.5 to 13.4 feet. The ponds are relatively deep for their size and therefore relatively free of weed problems.

In 1979 the ponds were drained and kept dry over winter. In April 1980 the springs and water flows in each pond were treated with rotenone to eliminate unwanted fishes. The ponds were then filled and stocked with 150 bluegills (Lepomis macrochirus) per acre. I anticipated the adults (mean length 6.4 inches) would produce adequate numbers of young bluegills that could be utilized as forage by predator fishes. In addition, each pond was stocked with about 20 adult golden shiners, (Notemigonus crysoleucas) per acre to provide a secondary forage fish.

Largemouth bass from 9.5 to 14.4 inches (mean length 10.7 inches) were stocked in Ponds 3 and 4 at a rate of 21.8 per acre. No bass were stocked in Ponds 1 or 2. In August of three consecutive years (1980-82) pellet-reared (production) tiger musky fingerlings were stocked at the outlet box in each pond at a rate of 10 per acre. Mean lengths of the fingerlings were 6.5 inches in 1980, 6.3 inches in 1981, and 5.7 inches in 1982.

In summer of 1980 shoreline observations confirmed that all ponds contained age-0 bluegills and Ponds 3 and 4 contained age-0 largemouth bass. In April 1981 each pond was surveyed with a shocker boat to check survival of the

tiger muskies. Because of the scarcity of shallow water the survey was relatively ineffective. Only four tiger muskies were collected, one in Pond 1 and three in Pond 2. Unfortunately, eight yearling bass (7 to 8 inches) were found and removed from Pond 1. It was deduced that age-0 bass escaped from a private pond upstream and entered Pond 1 in 1980 when the ponds were filled.

In August 1981, 53 additional yearling bass (9 to 12 inches) were removed from Pond 1. The stomachs were examined from 22 bass captured in trap nets on August 25 because the second annual plant of tiger muskies had been made only 12 days previously. Six stomachs contained a total of five bluegills, three crayfish, and one tadpole. The remaining stomachs were empty. No evidence was found of predation on young tiger muskies. The trap nets in Pond 1 also took seven yearling tiger muskies, two of which died when they became gilled in one wing of a net. Consequently use of the nets was discontinued.

The study was completed in fall 1982, when each pond was drained; all fishes were collected, and survival, growth, and density were determined for each species.

Results

Predator effects

There was a strong negative correlation between survival of musky fingerlings and abundance of largemouth bass. Survival was considerably higher for all three plants of tiger muskies in control Pond 2 (34-94%) and the 1980 and 1981 plants in control Pond 1 (43-65%) than for the equivalent plants in experimental Ponds 3 and 4 (3-38%), which had been stocked with adult largemouth bass (Table 1). The relatively low survival of the 1982 plant in Pond 1 (10%) was associated with development of an unusually dense population of largemouth bass (Table 2).

Complicating the interpretation of the results was that fingerling survival also tended to decrease as the density

of older muskies progressively increased. Thus for each pond, survival was higher for the 1980 plant than for the 1982 plant (Table 1).

In order to determine if survival of musky fingerlings was more closely related to density of largemouth bass, density of large tiger muskies, or combined density of both predators, and if musky fingerling survival was related to predator size, I estimated the density and size frequency of musky and bass present each year in three steps. The first step was to separate the known densities of bass and muskies for 1980 and 1982 (Table 2) into densities by length groups; i.e., 9.0 inches and larger, 10.0 inches and larger, etc., through 16.0 inches and larger (Table 3). Second, using the empirical predator densities for 1980 and 1982, I estimated survival and mean length parameters for the predators in each pond as of late summer, 1981. Third, these parameters were used to calculate predator densities by length group for 1981 (Table 3).

The most logical statistical analyses of the data in Table 3 were regressions of percent survival of musky fingerlings against the logarithms of predator densities. Predator densities were transformed by $\log_{10}(x + 1)$ because the effect of varying predator density on mortality of musky fingerlings should be negatively proportional rather than additive. This transformation also produced the best linear fits to the data. The resulting correlation coefficients for largemouth bass only (Table 4) indicated that a statistically significant (0.01 level) relation existed between bass density and musky fingerling survival for all bass sizes from 9.0 inches and larger through 15.0 inches and larger. However, the best correlation ($r = 0.83$) was with the 12.0 inches and larger bass (Fig. 1). These results suggest that the 9.0-inch through 11.9-inch bass were less inclined to feed on musky fingerlings than were the 12.0-inch and larger bass.

Stein et al. (1981) found that largemouth bass from 300-449 mm (11.8 to 17.7 inches) fed on 175-mm (6.9-inch) tiger musky fingerlings at levels exceeding those which would be expected if all size classes fed randomly on the fingerlings. Bass from 9.8 to 11.7 inches fed randomly on the fingerlings while bass from 8.0 to 9.8 inches did not show much tendency to consume muskies.

For tiger muskies only, correlation coefficients are given only for length groups 14.0 inches and larger through 16.0 inches and larger (Table 4). In 1980 no large tiger muskies were present in any pond and in 1981 and 1982 no pond contained any tiger muskies less than 14.0 inches long at the time of the fingerling plants. There were no statistically significant correlations between the density of 14.0-inch and larger through 16.0-inch and larger tiger muskies and the survival of fingerling muskies.

In Pond 2 in 1981 and 1982, density of 12.0-inch and larger largemouth bass was low but density of 16.0-inch and larger muskellunge was relatively high. In both cases survival of fingerling tiger muskellunge was moderately high (34.3 and 45.7%, respectively). Conversely, when the relative densities of the predators were reversed, as in Pond 4 in 1981 and 1982, survival of fingerling tiger muskellunge was much lower (13.3 and 6.7%, respectively). It will be shown later that in both ponds and in both years the relative abundance of forage was similar (1981) or adequate (1982). These observations confirm the correlation results that 12.0-inch and larger largemouth bass were much more efficient than 16.0-inch and larger tiger muskellunge in preying on fingerling tiger muskellunge.

Esocids are stimulated to attack prey that move at relatively fast speeds. Slow-moving prey elicits fewer attacks (Beyerle 1968). Bass tend to be more aggressive feeders than esocids. The typical post-planting behavior pattern of the fingerling muskies (very slow movement and

close to the surface in shallow water) may make them more susceptible to attack by bass than by larger muskies.

For "bass and muskies combined", correlation coefficients are given for predator length groups 14.0 inches and larger through 16.0 inches and larger only (Table 4). The only significant correlation ($r = 0.68$) was for 14.0-inch and larger predators but this was less significant than the correlation ($r = 0.78$) for 14.0-inch and larger bass only.

In summary, a strong correlation was found between survival of tiger muskellunge fingerlings and density of largemouth bass 12 inches and larger in length. The survival-density regression (Fig. 1) was used to predict survival for fingerling muskies stocked in lakes with known densities of 12-inch and larger largemouth bass (Table 5).

Forage effects

The vital statistics of the bluegills and golden shiners collected from the Almena Ponds in fall 1982 are summarized in Table 6. Additional forage fishes collected from Pond 1 included adult yellow perch, Perca flavescens (three fish per acre), age-0 yellow perch (257 fish per acre), bullheads, Ictalurus sp. (37 fish per acre, weighing 18 pounds per acre), and mudminnows, Umbra limi (10 pounds per acre).

A statistical analysis, comparing survival of fingerling tiger muskies with abundance of forage, was not feasible because of the lack of quantitative data on forage abundance in the summers of 1980 and 1981. However, the following observations from the 1982 data suggest that forage was of minor importance.

In 1982 in Pond 2, as discussed previously, survival of age-0 tiger muskies was only moderately high (45.7%) with a very small largemouth bass population, an abundance of age-0 bluegills, and a small population of golden shiners. In this case, a relatively dense population of larger tiger

muskies probably preyed to some extent on the fingerlings. In Pond 3, a scarcity of both age-0 bluegills and golden shiners and a moderately high population of largemouth bass was coincident with very low survival of fingerling muskies (2.5%).

In Pond 4 survival of fingerling tiger muskies was also low (6.7%) despite an abundance of age-0 bluegills. Apparently the moderately dense population of largemouth bass was more important than the bluegills in determining survival of age-0 tiger muskies. In Pond 1 a slightly higher survival of fingerlings (10.0%) was associated with only a trace of age-0 bluegills and a density of bass six times greater than in Pond 4. Perhaps the combination of golden shiners, mudminnows, and age-0 yellow perch in Pond 1 was an important food source for the surviving tiger muskies and also functioned as a mild buffer between the fingerling muskies and the large population of bass.

Although density of forage fishes must be important to survival of tiger musky fingerlings, in this study the effects of predator density dominated and masked the effects of forage density.

Management Implications

The results of this study strongly suggest that other factors being equal, survival of production-size fingerling tiger muskellunge is inversely proportional to the density of largemouth bass 12.0 inches and larger. From the relationships presented, the fisheries manager can predict survival of planted tiger musky fingerlings at any given density of bass (Table 5).

Acknowledgements

R. E. Fitch, R. N. Cobb, and D. L. Waite were instrumental in preparing the ponds for the study, collecting and stocking fish, maintaining water flows, and draining the ponds and processing fish. J. R. Ryckman, R. N. Lockwood, and J. C. Schneider provided the statistical analysis. J. C. Schneider and W. C. Latta critically reviewed the manuscript.

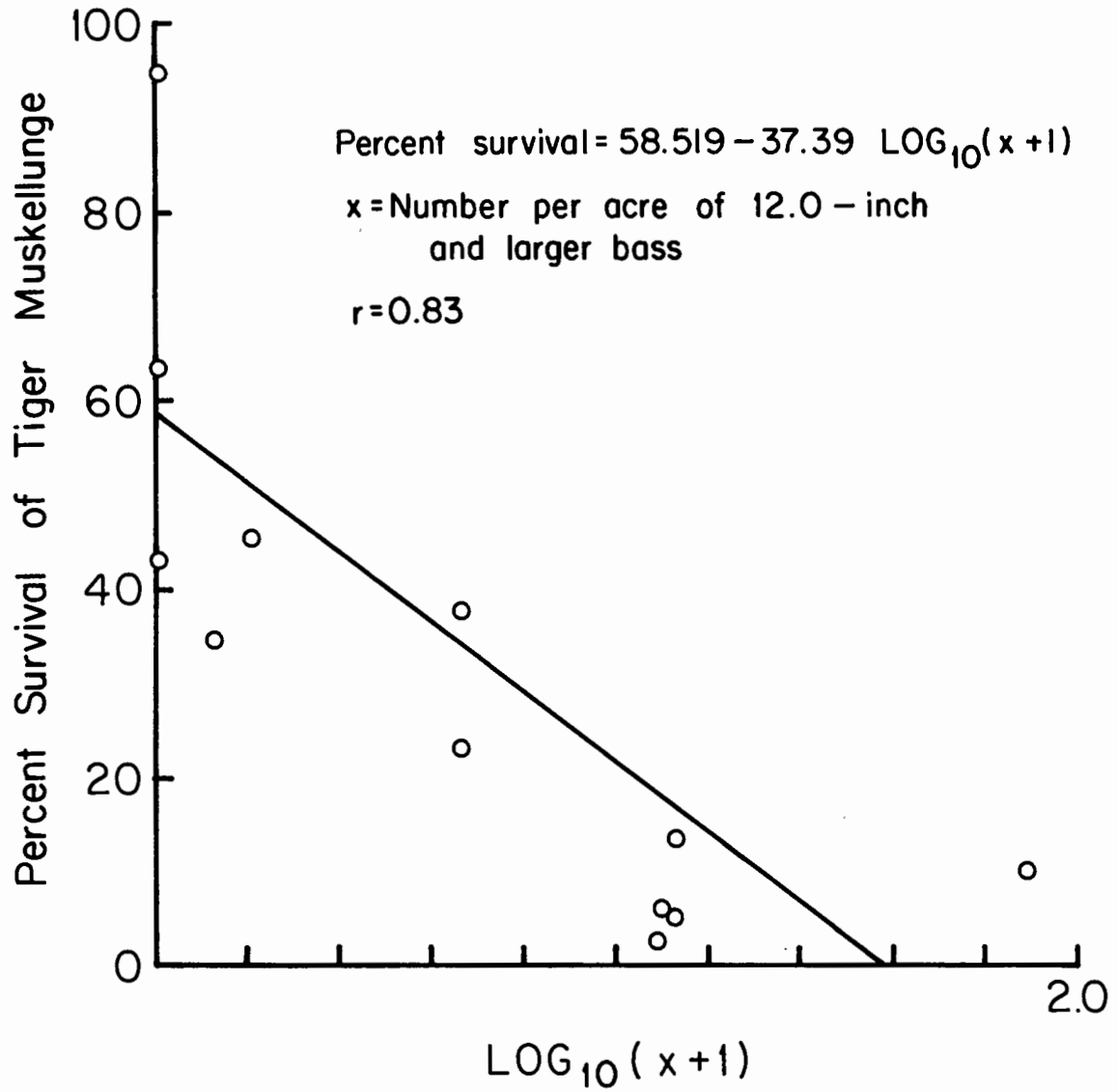

Figure 1.--Relationship between survival of tiger muskellunge fingerlings and number per acre of largemouth bass 12.0-inches and larger.

Table 1. Survival and growth to fall 1982 of three annual plants of tiger muskellunge stocked at a density of 10 fish per acre in four Almena Ponds.

Year class	Total stocked	Survival			Growth		
		Number				Weight (pound)	
		Total	Per acre	Percent	Length (inches)	Total	Per acre
Pond 1, 3.0 acres							
1980	30	19[a]	6.3	63.3	24.3	48.8	16.3
1981	30	13	4.3	43.3	19.8	22.2	7.4
1982	30	3	1.0	10.0	10.0	0.5	0.2
Total		35	11.6	36.6	---	71.5	23.9
Pond 2, 3.5 acres							
1980	35	33	9.4	94.3	21.4	53.3	15.2
1981	35	12	3.4	34.3	18.2	11.2	3.2
1982	35	16	4.6	45.7	10.6	4.0	1.1
Total		61	17.4	58.3	---	68.5	19.5
Pond 3, 4.0 acres							
1980	40	15	3.8	37.5	21.8	27.1	6.8
1981	40	2	0.5	5.0	17.6	2.0	0.5
1982	40	1	0.2	2.5	9.2	0.1	0.0
Total		18	4.5	15.0	---	29.2	7.3
Pond 4, 3.0 acres							
1980	30	7	2.3	23.3	22.1	12.9	4.3
1981	30	4	1.3	13.3	16.3	2.9	1.0
1982	30	2	0.7	6.7	9.0	0.2	0.1
Total		13	4.3	14.3	---	16.0	5.4

[a] Includes two fish that were killed in a trap net in 1981.

Table 2. Number of largemouth bass per acre in Almena Ponds at the beginning (1980) and end (1982) of the experiment. No bass were present in Ponds 1 and 2 in the beginning.

Length group (inches)	Pond 1	Pond 2	Pond 3		Pond 4	
	End	End	Begin	End	Begin	End
2.0-3.9	1,967	20.2	0.0	0.0	0.0	24.0
4.0-5.9	0.0	0.0	0.0	10.9	0.0	35.3
6.0-7.9	0.0	1.2	0.0	102.4	0.0	43.7
8.0-8.9	0.0	0.0	0.0	30.6	0.0	8.5
9.0-9.9	2.0	0.0	6.5	32.1	6.5	12.7
10.0-10.9	2.2	0.0	7.6	8.3	7.6	4.7
11.0-11.9	1.1	0.0	4.0	3.3	4.0	0.7
12.0-12.9	13.3	0.3	1.8	0.2	1.8	0.0
13.0-13.9	45.5	0.0	1.5	0.5	1.5	0.3
14.0-14.9	15.5	0.0	0.4	5.1	0.4	6.4
15.0-15.9	2.2	0.3	0.0	4.0	0.0	2.7
16.0-16.9	0.0	0.0	0.0	1.3	0.0	2.0

Table 3. Percent survival of planted fingerling tiger muskellunge compared with density (number per acre) of selected size groups (lengths in inches) of predators (line 1, largemouth bass only; line 2, tiger muskellunge only; line 3, bass and muskellunge combined).

Pond and year	Percent survival of tiger muskies	Predator density by size group							
		≥9.0	≥10.0	≥11.0	≥12.0	≥13.0	≥14.0	≥15.0	≥16.0
Pond 1									
1980	63.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	43.3	97.9	93.5	57.9	0.0	0.0	0.0	0.0	0.0
		6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
		104.3	99.9	64.3	6.4	6.4	6.4	6.4	6.4
1982	10.0	82.0	80.0	77.7	76.6	63.3	17.8	2.2	0.0
		10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1
		92.1	90.1	87.8	86.7	73.4	27.9	12.3	10.1
Pond 2									
1980	94.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	34.3	0.6	0.6	0.3	0.3	0.3	0.0	0.0	0.0
		9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
		10.2	10.2	9.9	9.9	9.9	9.6	9.6	9.6
1982	45.7	0.6	0.6	0.6	0.6	0.3	0.3	0.3	0.0
		12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9
		13.5	13.5	13.5	13.5	13.2	13.2	13.2	12.9
Pond 3									
1980	37.5	21.8	15.3	7.7	3.6	1.8	0.4	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		21.8	15.3	7.7	3.6	1.8	0.4	0.0	0.0
1981	5.0	16.5	16.5	16.5	12.3	6.3	2.8	1.4	0.8
		3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
		20.3	20.3	20.3	16.1	10.1	6.6	5.2	4.6
1982	2.5	54.8	22.7	14.4	11.1	10.9	10.4	5.3	1.3
		4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
		59.1	27.0	18.7	15.4	15.2	14.7	9.6	5.6
Pond 4									
1980	23.3	21.8	15.3	7.7	3.6	1.8	0.4	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		21.8	15.3	7.7	3.6	1.8	0.4	0.0	0.0
1981	13.3	16.5	16.5	16.5	12.4	6.3	2.8	1.4	0.8
		2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
		18.8	18.8	18.8	14.7	8.6	5.1	3.7	3.1
1982	6.7	29.6	16.9	12.1	11.5	11.5	11.1	4.7	2.0
		3.7	3.7	3.7	3.7	3.7	3.7	3.4	3.4
		33.3	20.6	15.8	15.2	15.2	14.8	8.1	5.4

Table 4. Correlation coefficients between percent survival of fingerling tiger muskellunge and density of predators of various sizes. Predator densities were transformed to $\log_{10}(x + 1)$.

Predator length group (inches)	Largemouth bass only	Tiger muskellunge only	Bass and muskellunge only
$\geq$ 9.0	-0.74**	---	---
$\geq$10.0	-0.72**	---	---
$\geq$11.0	-0.72**	---	---
$\geq$12.0	-0.83**	---	---
$\geq$13.0	-0.81**	---	---
$\geq$14.0	-0.78**	-0.48	-0.68*
$\geq$15.0	-0.75**	-0.49	-0.57
$\geq$16.0	-0.65*	-0.49	-0.52

* Significant at 0.05 level.

**Significant at 0.01 level.

Table 5. Predicted mean survival to fall of age-0 tiger muskellunge stocked as 6.0- to 7.0-inch fingerlings in lakes with known densities of largemouth bass 12.0 inches and larger in length.

Density of largemouth bass (fish per acre)	Predicted mean survival of fingerling tiger muskellunge (percent)
0	>50
2	40-50
4	35-40
6	30-35
8	25-30
10	20-25
12	15-20
>12	>15

Table 6. Number and weight of bluegills and golden shiners collected from the Almena Ponds in fall 1982.

Species	Length group (inches)	Mean length	Number		Weight (pounds)	
			Total	Per acre	Total	Per acre
Pond 1						
Bluegill	<2.0	---	trace	trace	trace	trace
	2.0-6.0	~3.0	68,707	22,902	881.6	293.9
	>6.0	~8.0	239	80	82.8	27.6
Golden shiner	2.0-6.0	---	1,927	642	82.6	27.5
Pond 2						
Bluegill	<2.5	1.7	191,690	54,769	466.4	133.3
	2.5-6.0	4.0	4,426	1,265	156.6	44.7
	>6.0	---	380	109	143.8	41.1
Golden shiner	5.0-6.0	---	730	209	31.2	8.9
Pond 3						
Bluegill	<3.0	---	~200	~50	trace	trace
	3.0-5.0	---	22,063	5,516	756.0	189.0
	>5.0	~6.5	2,053	513	378.8	94.7
Golden shiner	---	---	trace	trace	trace	trace
Pond 4						
Bluegill	<2.0	~1.1	33,792	11,264	32.4	10.8
	2.0-5.0	3.8	2,832	944	83.3	27.8
	>5.0	---	487	162	138.6	46.2
Golden shiner	---	---	0.0	0.0	0.0	0.0

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Report approved by W. C. Latta

Typed by G. M. Zurek