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FACTORS AFFECTING SHORT-TERM SURVIVAL OF STOCKED MUSKELLUNGE FINGERLINGS IN WISCONSIN

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ABSTRACT

Factors potentially influencing the short-term survival of stocked muskellunge fingerlings were assessed in a series of releases in 20 Wisconsin waters. Date of stocking, water temperature at time of stocking, and presence of predators appear to be major factors affecting survival. Survival was greater when fish were released late in the season in waters 60-65 F or cooler. Better survival was achieved in 4 waters with no predators than in 16 lakes with predators.

Seven- to 9-inch fish survived about 87% as well as 9- to 12-inch fish, indicating that hatchery efforts could be reduced by not rearing fingerlings over 9 inches. However, very small fingerlings (2.3-inch average) suffered almost complete mortality after stocking.

Survival of muskellunge fingerlings was not affected by finclipping, sedation, numbers stocked, or in-lake conditioning before release. There was no significant relationship between survival and the biomass of forage fish or between survival and a number of physical-chemical factors.

Recommendations for management include: (1) discontinue stocking muskellunge in the 2- to 3-inch size range, (2) concentrate on rearing 7- to 9-inch fish, (3) begin stocking in late August when temperatures are no warmer than 60-65 F, and (4) make any efforts possible to reduce stress from handling and transport of fingerlings.

CONTENTS

INTRODUCTION

Evaluation of Wisconsin's fingerling muskellunge (Esox masquinongy Mitchill) stocking program during 1955-69 disclosed that average mortalities of 50-65% -- and as high as 96% -- occurred within 1-4 weeks after release (Johnson 1972). Despite these high losses, stocked fish comprised a high proportion of the numbers of muskellunge in the populations studied. That maintenance of muskellunge population levels was strongly dependent upon stocking was evident; it was also apparent that due to the high initial mortalities of stocked fingerlings, the potential effectiveness of the stocking program was not being achieved.

The objectives of this study were to determine factors which cause early mortality of stocked fingerlings and to develop stocking methods for increasing initial survival during the 1st 5 weeks after release. Attainment of the 2nd objective would be the equivalent of increased hatchery production at no extra cost.

During 1971-79, a series of 40 experimental muskellunge fingerling releases was made in 20 waters in 7 northwestern Wisconsin counties. Releases were made to evaluate the comparative survival of: (1) fin-clipped and unmarked fish, (2) small and large fish within the size range normally stocked, (3) conditioned fish (confined to in-lake holding pens before release) and fish stocked in the routine manner, (4) sedated and normal fish and, (5) fish stocked at weedy and weed-free locations. In addition, trials were run to determine survival of small (2.3-inch) fingerlings, and to determine the influence of stocked fingerlings on predator movements and satiation of predators on survival.

STUDY LAKES

Eighteen small lakes and 2 rearing ponds located within and outside of the original muskellunge range were utilized in this study (Fig. 1). They ranged from 9 to 263 acres and all but 5 were less than 100 acres in size (Appendix Table 1).

1. Little Sand Lake
2. Lund Lake
3. Perch Lake
4. Des Moines Lake
5. Twenty-Six Lake
6. Boot Lake
7. Clear Lake
8. Island Lake
9. Little Sand Lake
10. Lower Holly Lake
11. Sand Lake Rearing Pond
12. Derosier Lake
13. Harmon Lake
14. Leisure Lake
15. Mathews Lake
16. Pear Lake
17. Spooner Hatchery Pond No. 12
18. Pulaski Lake
19. Crane-Chase Lake
20. Bass Lake

FIGURE 1. Historic range of muskellunge in Wisconsin (shaded area) and the location of the lakes included in this study.

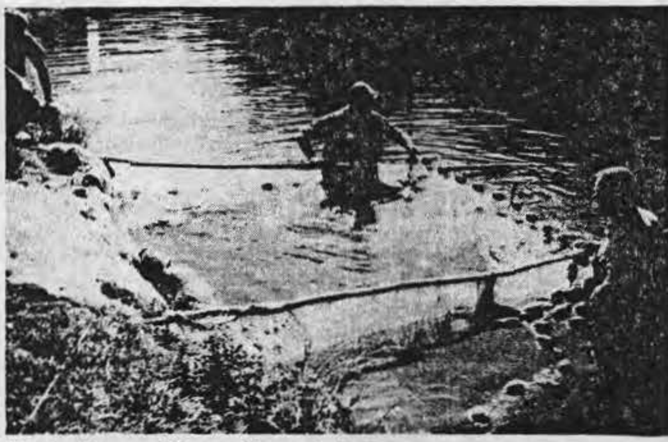
METHODS

PRESTOCKING SURVEYS

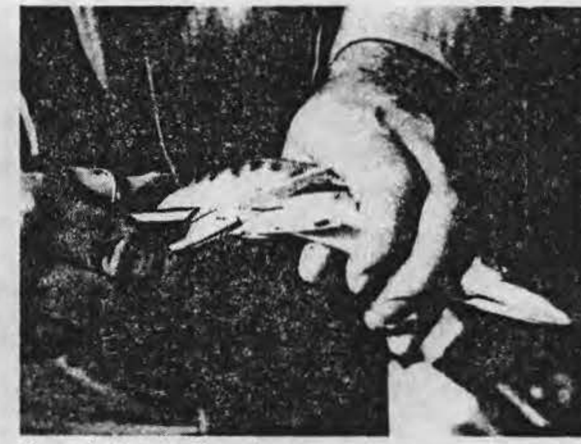
Prestocking surveys of lakes to be stocked in the fall were made each year during June through August. Survey results were used to establish indexes to abundance of predaceous fish species, large and small forage fish species, and aquatic vegetation. Total alkalinity determinations were also made at that time.

Predators and large forage fishes were captured with 8 fyke nets. All fish caught were placed on a measuring board covered with a matt acetate sheet. The fish were pushed snugly to the head stop and the acetate was punctured at the tip of the tail to record the total length to the nearest 0.1 inch. The frequency distribution resulting from a count of puncture marks was to be used for Petersen population estimates by size classes of the predator and forage fish populations present prior to stocking. For this purpose, fish caught during the 1-week marking period were given a temporary top tail clip. A bottom tail clip was given during the recapture period in the 2nd week. As the study developed, it was apparent that it would not be possible to make population estimates because of insufficient recaptures. Therefore, a predator fish index and a forage fish index were devised.

The predator fish index included all fish 15 inches and larger deemed to be capable of eating the stocked muskellunge fingerlings. The size was based mainly on studies of what can be eaten by northern pike (Johnson 1969). Muskellunge, northern pike, walleye, and largemouth bass were included in this classification. (Later, I found a 12-inch bullhead that had eaten a 9-inch muskellunge and would have qualified as a predator.) All predator fish captured during netting with 8 fyke nets over 8- to 24-hour periods plus those captured during post-stocking lake shocker surveys (procedures are described under Posttreatment Analyses) were added together to give a total number of predator fish/equal unit of effort. This total number was divided by the lake acreage to give relative numbers of predators/acre.



Muskellunge fingerlings being harvested from hatchery rearing ponds intended for stocking into study lakes.



One of the 4 fins (here a right pectoral) was clipped from muskellunge fingerlings to designate an experimental treatment.

Forage fishes which I considered to be of a size that could be eaten by the predator fishes were also considered as a unit. For example, all panfish, minnows, perch, etc., were considered to be edible size forage, based on data from Johnson (1969). The total number of potential prey fish, based on equal fyke netting effort, was used to obtain relative numbers of forage fish/acre.

A measure of small forage fishes in the study lakes was obtained just prior to muskellunge fingerling stocking with a 4- by 50-ft, 3/16-inch woven mesh seine, pulled parallel to the shoreline from a depth of approximately 4 ft and then beached on the shore. Fifteen to 20 seine hauls were made per lake in areas that were seinable, each haul covering an area of approximately 2,500 ft^2. All fish considered as edible size for muskellunge fingerlings (Johnson 1969) were weighed as a unit and converted to pounds of forage/acre seined.

During the aquatic vegetation surveys, location and approximate size of weed beds which extended from the bottom to the surface were noted on field lake maps. Actual measurements of the areas were made from aerial photographs, but no species identifications were made. Potamogeton sp., Myriophyllum sp., Ceratophyllum sp., and Scirpus sp. were the usual types of vegetation recorded; however, pond lilies, Nuphar sp. and Nymphaea sp., were not included because their stems are too far apart to provide dense escape cover for muskellunge fingerlings.

STOCKING TRIALS

The primary method of study consisted of stocking 2 groups of differentially fin-clipped fingerlings and then comparing the number of each group recovered by the electroshocker within 14-39 days after release. When no significant differences in recovery were found between the 2 experimental groups, recapture data for both were combined to make a Petersen-type estimate of the surviving fingerlings. Survival figures were correlated with various environmental parameters measured during the course of this study or already available.

Except those pertaining to predator movement and to survival of 2.3-inch fingerlings, each stocking trial involved the release of 2 groups (approximately equal numbers) of muskellunge fingerlings at the same time in the same water, thus permitting the use of 2 by 2 Chi-square evaluation. Each group was differentially fin-clipped for subsequent recognition and, except where size difference was the factor being evaluated, each was of the same length range.

Finclipping

Fin-clipped muskellunge were stocked in all lakes and ponds and unmarked muskellunge were stocked only in lakes where it had been demonstrated by my netting surveys that there was no natural muskellunge reproduction (6 waters, 8 trials). Six- to 12-inch fingerlings were marked by finclipping. Either a single pelvic or pectoral fin was clipped and all lots were held overnight to eliminate immediate handling mortality as a factor. Marked and unmarked fish were stocked in the same lake at the same time as were paired lots of differentially clipped fish. The fish were stocked in lakes containing predators and in ponds containing no predators.

Fingerling Size

Small Fingerlings. Seven lakes (7 trials) were selected for a short-term survival study of 2.3-inch unmarked muskellunge. These lakes ranged in size from 45 to 263 acres and had no natural muskellunge reproduction. A grand total of 26,183 hand-counted 2.3-inch fingerlings were stocked during the 2nd week of June during the 2 study years (1976-77). In these same lakes fin-clipped fingerlings averaging 9.5 inches in length (total of 2,850) were released approximately 2.5 months later (mid-August). The stocking rates varied, with 8-31/acre for 2.3-inch fingerlings and 2-3/acre for the 9.5-inch fingerlings. Fish recaptures were made during September and October when each group was near the same size and equally vulnerable to the collecting gear.

Large Fingerlings. Individual lots of large fingerlings were divided at the approximate mid-point into 2 size ranges and differentially fin-clipped. The lengths of the 2 size groups varied within the 20 trials in 13 waters, dependent upon the total size range of fingerlings available at the time. The upper limit of the lower size range was as large as 11.0 inches and the lower limit of the upper range was as small as 8.5 inches within the extreme limits of 5.9 and 13.0 inches. The average sizes of the smaller and larger groups were 7.5-9.5 and 9.7-11.7 inches, respectively.

All fingerlings were measured to the nearest 0.1 inch total length before stocking. Both small and large sizes were stocked on the same day, usually within 1 hour of each other. Stocking rates were 2-3 fingerlings/acre. The fish were not marked in 3 of the trials where the absence of natural reproduction had been clearly established.

Conditioning

Nylon netting holding pens were employed in 10 lakes (15 trials) to confine 6- to 12-inch fingerlings prior to release to determine if stress due to harvest from the rearing pond, finclipping, and hauling was a factor in survival. The size of the pen was 5 by 9 by 4 ft deep, except that for 2 years in 1 lake, a larger pen 12 by 38 by 4 ft deep was used. After 48 hours, with 100% survival, these fish were released by dropping the side of the pen; at the same time, a comparable lot of differentially fin-clipped fingerlings in the same size range was released in the usual manner directly into the lake from a fish distribution tank.

Sedation

Salt. Muskellunge fingerlings were held in a 0.3% salt solution (NaCl), 1 group for 24 hours and another group for 36 hours from the time of harvest from rearing ponds, including the hauling time to release in Boot Lake. An additional lot exposed for 2 hours in a 0.6% solution of salt was also released in Little Sand Lake, Barron Co. Equal numbers of differentially marked nontreated muskellunge fingerlings in the same size range were stocked in the lakes at the same time.

Anesthesia. Quinaldine sulfate, provided for experimental use by the National Fishery Research Laboratory, La Crosse, was used to slow the usual rapid muskellunge fingerling dispersal that occurs immediately after stocking. Fingerlings were submersed for 1.5 hours in water containing either 10 mg/l or 15 mg/l quinaldine sulfate. All survived through transport and release into the lakes. One half of each stocking quota, in the same size range and differentially marked, was stocked without anesthesia at the same time. Two trials were made at each concentration. Observations on behavior of the fingerlings upon recovery from the anesthesia and dispersal from the shoreline waters were made with binoculars from a distance of 75-100 ft, so as not to disturb the fish.

Satiation of Predators

Under the premise that hungry predators were a cause of high early mortality of stocked muskellunge fingerlings, a single trial of a release of 200 9- to 10-inch fingerlings was made 24 hours after a similar release in the expectation that the 1st release would satiate the predators. No prestudies were made to determine how many predators were present.

Stocking Location

Releases of differentially marked 6- to 12-inch fingerlings were made at aquatic vegetation-free public landings and in dense vegetation areas in 2 lakes (2 trials). Quotas for each location were stocked within an hour.

Date and Temperature at Stocking

The date of each stocking was recorded and the water temperature at the stocking site was measured with a mercury thermometer accurate to within 1/2 F.

Predator and Panfish Movement

The procedure consisted of fyke netting in 7 lakes (11 trials) for 2 days before stocking muskellunge fingerlings, and finclipping and counting all fish caught at each of 8 net sites distributed equidistant around the lake. After this initial netting period, fin-clipped muskellunge fingerlings were stocked in a nylon holding net located near 1 of the fyke nets, and held for a period of 2 days. After the stocking, the fish catch at the perimeter of the lake was recorded for an additional 2 days. Chi-square and Fisher's Exact Probability Test were used to determine if there were significant differences between fish distributions near the holding net vs. away from it, before and after the stocking.

POSTTREATMENT ANALYSES

Recapture of the stocked 6- to 12-inch fish was made within 14-39 days after release by use of a boat-mounted electroshocker powered by a 3 phase, 230 volt A.C. generator. Voltage and amperage was adjusted with a power transformer for best efficiency, or set in relation to the resistivity of the water. Electrofishing was conducted at night with the aid of above-water floodlights. In those trials where 2.3-inch fingerlings had been stocked 2.5 months previously, recapture was made at the same time as that of the larger fingerlings.

Captured fingerlings were measured from puncture marks made on a matt acetate sheet and the top of tail was clipped for the mark period and bottom of tail for the recapture period. Fingerlings were quickly measured, marked, and released along the shoreline close to the location where they were found.

Six to 8 shoreline circuits around the perimeter of each lake were made over a 3- to 5-night marking period. The 1st run was recorded separately in every case. Recaptures were made over a like period. Capture success often declined with successive circuits of the lake and this necessitated the skipping of 1 or more nights of electrofishing to allow for return of the fingerlings to the shoreline.

As stated before, approximately equal numbers of differentially marked muskellunge fingerlings were stocked in the same lake at the same time. Chi-square was used as the test to determine if recoveries in a lake (based on direct collections only, not population estimates) indicated a statistical difference in the comparative recoveries/nonrecoveries between groups. Chi-square values over 3.84 indicated a significant difference at $P < 0.05$ in these 2 by 2 tests. Often an overall test was made using the summed trials. When such a test is inconclusive, some of the individual stocking trial tests should be viewed very cautiously. Where differences occur, these individual trials may truly reflect significant survival differences, but it is possible the result may also reflect varying efficiency of the recovery process. This would be particularly true of those tests involving different groups of fish that cannot be closely matched as for size groups (where behavior and gear selectivity may be factors) or for association with vegetation. Allusion to this problem is made in the Discussion section when appropriate.

If no significant differences in recoveries were found, the data for each paired release were combined to make a Petersen-type (Bailey's modification) population estimate (Ricker 1975). Ninety-five percent confidence limits were read from Clopper and Pearson tables.

These population estimates of muskellunge fingerlings in each lake were used to derive survival data for correlation with various parameters of the lakes, measured during both the pre- and post-stocking studies. Least squares calculations of r were used to evaluate significance or nonsignificance of these survival data. Scatter plots were prepared for these relationships whether of acceptable statistical significance level or not, in order to assist in visualizing dispersion of values. Comparisons found to be statistically significant are illustrated in text figures (Figs. 2-6); comparisons made but found to be nonsignificant are shown in figures in the Appendix (Appendix Figs. 1-11).

Correlation coefficients were calculated for log-transformed values for percent survival and are stated on those plots illustrating statistically significant differences. Fitted lines, drawn from untransformed values, are only included when r had a value of 0.49 or higher. In all cases r calculated by both methods fell in the same significance range and these P values are given for Figs. 2-6.

RESULTS

CONTROLLABLE FACTORS

Finclipping

The comparative survival of fin-clipped and unmarked 6- to 12-inch muskellunge fingerlings was determined from 8 trials in 6 waters -- 4 lakes and 2 rearing ponds. Recapture by electrofishing in the lakes and by drainage of the rearing ponds indicated no significant difference in the short-term survival of the paired lots; fin-clipped fingerlings survived as well as unmarked fingerlings over periods of 14-39 days (Table 1).

Survival rates were calculated for paired lots in the rearing pond trials where drainage of the ponds permitted high recovery of survivors. Although the ponds contained no predator fish species capable of eating the muskellunge fingerlings, mortalities

TABLE 1. Comparative survival of stocked 6- to 12-inch fin-clipped and unmarked muskellunge fingerlings over periods of 14-39 days after release in the fall, 1974-75.

Lake and Year Stocked	No. Days At Large	No. Stocked: Fin-clipped	No. Stocked: Unmarked	No. Recaptured: Fin-clipped	No. Recaptured: Unmarked	Chi-square
Leisure						
1974	14	143	147	48	56	0.46
1975	34	150	150	47	38	1.05
Little Sand (Barron Co.)						
1975	24	200	200	81	75	0.26
Lower Holly						
1975	33	100	100	30	35	0.36
Pear						
1974	14	112	114	50	48	0.06
1975	27	102	100	39	39	0.00
Sand Lake Rearing Pond						
1974	21	48	49	33	28	0.95
Spooner Hatchery Pond No. 12						
1975	39	53	50	42	46	2.42
All	14-39	908	910	370	365	0.08

TABLE 2. Comparative survival of 6- to 12-inch differentially fin-clipped muskellunge fingerlings over periods of 19-34 days after release in the fall, 1971-74.

Lake	No. Days At Large	No. Stocked* RP	LP	RV	LV	No. Recaptured RP	LP	RV	LV	Chi-square
Bass										
1973	28	127	115			25	32			1.79
"	"			70	102			15	23	0.00
"	"		115		102		32		23	0.48
"	"	127			102	25			23	0.13
"	"		115	70			32	15		0.63
"	"	127		70		25		15		0.01
Boot										
1971	21	202	194			76	85			1.33
1972	29	163	196			53	59			0.14
"	"			92	59			24	14	0.02
"	"		196	92			59	24		0.32
"	"	163			59	53			14	1.20
"	"		196		59		59		14	0.62
"	"	163		92		53		24		0.87
Clear										
1972	26	143	147			56	52			0.30
"	"			72	76			26	25	0.06
"	"		147	72			52	26		0.00
"	"	143			76	56			25	0.59
"	"		147		76		52		25	0.05
"	"	143		72		56		26		0.08
1973	19	155	178			48	77			4.83
"	"		178	38			77	9		4.22
"	"	155		38		48		9		0.47
"	"	155			13	48			6	0.67
"	"		178		13		77		6	0.01
"	"			38	13			9	6	1.40
1974	"	170	164			74	57			2.34
"	"		164		31		57		11	0.02
"	"	170		25		74		8		0.76
"	"			25	31			8	11	0.00
"	"	170			31	74			11	0.40
"	"		164	25			57	8		0.00
Crane-Chase										
1971	34	245	245			103	91			1.03
1972	33	155	188			29	34			0.00
"	"	155		69		29		13		0.03
"	"		188		72		34		10	0.39
"	"	155			72	29			10	0.50
"	"		188	69			34	13		0.00
"	"			69	72			13	10	0.32
1973	26	109	188			31	58			0.09
"	"	109		91		31		27		0.00
"	"		188		29		58		8	0.02
"	"	109			29	31			8	0.02
"	"			91	29			27	8	0.00
"	"		188	91			58	27		0.00
Island										
1972	28		165		40		74		16	0.14
"	"			44	40			14	16	0.31
"	"		165	44			74	14		1.91
"	"	158			40	56			16	0.12
"	"	158	165			56	74			2.59
"	"	158		44		56		14		0.07

*Fin clip designations: RP = right pectoral, LP = left pectoral, RV = right ventral (pelvic), and LV = left ventral (pelvic).

TABLE 2. Continued.

Lake	No. Days At Large	No. Stocked* RP	LP	RV	LV	No. Recaptured RP	LP	RV	LV	Chi-square
Little Sand (Barron Co.)										
1973	33	99	199			28	51			0.12
"	"	99		100		28		20		1.44
"	"	99			23	28			6	0.00
"	"		199	100			51	20		0.87
"	"		199		23		51		6	0.04
"	"			100	23			20	6	0.13
1974	19	163	168			73	88			1.62
"	"		168		28		88		18	0.93
"	"	163		37		73		15		0.08
"	"		168	37			88	15		1.26
"	"	163			28	73			18	2.90
"	"			37	28			15	18	2.71
Little Sand (Sawyer Co.)										
1973	26		173		21		58		1	6.03
"	"	76			21	21			1	3.69
"	"			107	21			29	1	3.72
"	"	76	173			21	58			0.60
"	"		173	107			58	29		0.99
"	"	76		107		21		29		0.01
Lund										
1971	23	80	80			30	40			2.06
Perch										
1972	33	136	145			52	47			0.80
"	"		145		57		47		16	0.19
"	"	136			57	52			16	1.40
"	"		145	62			47	18		0.10
"	"	136		62		52		18		1.20
"	"			62	57			18	16	0.01
Pulaski										
1971	27	348	335			114	129			2.22

*Fin clip designations: RP = right pectoral, LP = left pectoral, RV = right ventral (pelvic), and LV = left ventral (pelvic).

occurred within both fin-clipped and unmarked lots. In Sand Lake Rearing Pond, 69% of the fin-clipped fish survived compared to 57% of those unmarked, over a period of 21 days. After 39 days, the survival figures were reversed and higher in Spooner Hatchery Pond No. 12; 79% of the fin-clipped fish survived compared to 92% of those unmarked.

The comparative survival of differentially fin-clipped 6- to 12-inch muskellunge fingerlings was determined from 76 comparisons in 10 lakes. The trials involved separate comparisons of 6 combinations of fin clips. There were 2 significant differences between 3 of the comparisons of single lots of pelvic or pectoral fin-clipped fingerlings with another fin-clipped group but these differences could be expected by chance in this many comparisons (Table 2).

Collectively, the data indicate that there were no differences detectable in the short-term survival of 6- to 12-inch unmarked or fin-clipped muskellunge fingerlings, regardless of which pectoral or pelvic fin was clipped.

Fingerling Size

Small Fingerlings. There was essentially no survival, over a period of 3-4 months, of stocked 2.3-inch fingerlings in any of the 7 lakes stocked. Only 5 of the 26,183 fish stocked were recaptured during sampling the following fall. In contrast, simultaneous recapture of the 9.5-inch fingerlings, which had been stocked in the same lakes 2.5 months later, ranged from 12 to 50% and averaged 28.7% (Table 3).

In a previous study, minimum long-term survival to legal size (equal to or greater than 30.0 inches) of 2.3-inch fingerlings in Lac Court Oreilles (5,000 acres) ranged from 0.10 to 1.90% and averaged 0.25% (Table 4) (Johnson, unpubl. data). The comparable survival of 9.5- to 10.0-inch fingerlings stocked the same years in Lac Court Oreilles ranged from 2.4 to 20.0% and averaged 7.0%. Recapture data in that study were obtained over a period of 5-17 years from fyke net collections, angler returns, and resort tabulations.

TABLE 3. Comparative survival of 2.3- and 9.5-inch muskellunge fingerlings stocked in 7 lakes, 1976-77.

Lake	Surface Acres	2.3-inch Fingerlings No. Stocked (fish/acre)	Percent* Recaptured	9.5-inch Fingerlings No. Stocked (fish/acre)	Percent Recaptured
Des Moines	229	31	0	3	42
Harmon	96	8	0	2	20
Leisure	75	20	0	2	46
Little Sand (Barron Co.)	101	8	0	2	50
Lower Holly	42	22	0	2	12
Mathews	263	30	0	3	15
Twenty Six	230	30	0	3	16
Mean			Trace		28.7

*Five 2.3-inch fingerlings were recaptured from 26,183 stocked.

TABLE 4. Recapture through 1976 of legal-sized muskellunge* stocked as 2.3-inch and 9.5- to 10.0-inch fingerlings in Lac Court Oreilles during 1955-57 and 1971 (Johnson, unpubl. data).

Year	2.3-inch Fingerlings No. Stocked	Recaptured No.	Recaptured Percent	9.5- to 10.0-inch Fingerlings No. Stocked	Recaptured No.	Recaptured Percent
1955	19,500	25	0.13	1,000	35	3.5
1956	2,350	45	1.90	1,000	200	20.0
1957	28,850	75	0.26	1,000	65	6.5
1971	10,000	10	0.10	2,000	48	2.4
Total	60,700	155	0.25	5,000	348	7.0

*Equal to or greater than 30 inches.

Large Fingerlings. In comparisons of fingerlings of an average size of 7.5-9.5 inches vs. 9.7-11.7 inches, there was no significant difference in survival between the 2 groups in 15 of 19 stocking trials (Table 5). There were significant differences in 4 trials, 3 where survival of large muskellunge fingerlings and 1 where survival of medium-sized fingerlings was better than could be expected on the basis of chance variation. Lakes where survival was significantly better for the larger fingerlings were Crane-Chase (1972), Little Sand (Barron Co.) in 1975, and Lower Holly (1975). Survival of medium-sized fingerlings was significantly better only in Little Sand (Sawyer Co.) in 1973. However, the summed trials gave a definite edge to the large fingerlings, significant at $P < 0.01$ with Chi-square = 18.84. If the numbers of fish recaptured (Table 5) are expanded to an estimate of the population, the overall estimated survival was 55.2% for the large fingerlings and 49.0% for the medium-sized fish, or an indicated advantage of 12.6%.

An overall effect of size of muskellunge fingerlings on survival is also apparent for 29 releases in which the average lengths ranged from 8.0 to 11.5 inches. The larger fingerlings exhibited a higher survival rate with $r = 0.53$ significant at $P < 0.01$ (Fig. 2). However, the considerable scatter of points on the plot suggests that this increased survival is not consistent and may be of minor consequence.

Both series of releases indicate a slightly higher survival of larger fingerlings but not of a magnitude where size differential can be considered to be a major factor in survival of stocked fingerlings.

Conditioning

There was no significant difference in

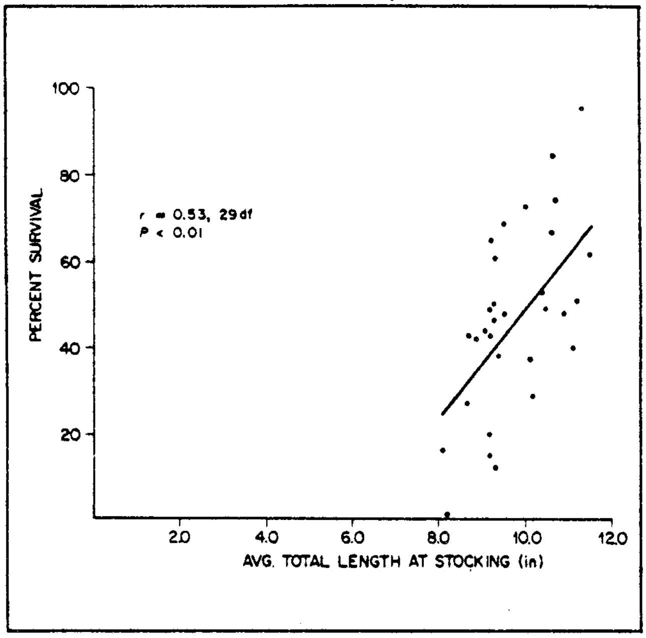


FIGURE 2. Relationship of stocked muskellunge fingerling survival to average length of stocked fish.

overall survival of the conditioned fish (35%) and of the direct lake release (34%). In 13 of the 15 trials there was no significant difference, but in the remaining 2 cases the conditioning gave a higher result in 1 and a lower result in the other at $\underline{P} < 0.05$ (Table 6). The latter was part of a 2-year test of a larger confinement pen (12 by 38 by 4 ft deep) carried out in Clear Lake in 1973 and 1974. The lower 1973 result contradicted the 1974 result in that survival of the 1974 confined group did not significantly differ from that of the 1974 direct lake release.

Again occasional "significant" differences can be expected from a probability standpoint, and other unevaluated circumstances may cause aberrations. No effect of pre-release conditioning appeared to be present in this series.

Sedation

Salt. There was no significant difference in survival, over a 28-day period, of treated fingerlings [0.3% salt (NaCl) for 24 hours] and those that were stocked directly into Boot Lake. A repeat of this experiment with an immersion time of 36 hours produced the same results. A 2-hour immersion in a 0.6% (NaCl) solution also did not improve survival, over a 28-day period, of fingerlings stocked in Little Sand Lake (Barron Co.).

Anesthesia. At 10 mg/l quinaldine sulfate, about half the fingerlings were sedated (immobilized but still upright) and half anesthetized (some floating upside down at the surface, but most lying upside down on the bottom of the transport tank). All fish exhibited excitability demonstrated by a start or flutter in response to any sudden movement by persons near the tank. The fingerlings were released from the beach and the truck was driven away before they recovered from the anesthesia to avoid alarming the fish. All fish recovered in a calm manner, and lingered in the area or swam slowly from shore within 10-15 minutes, as viewed from a vantage point 75-100 ft away. The calm movement of anesthetized fingerlings was in stark contrast to the fast arrowlike movements of the nonanesthetized fish as they left the stocking sites.

Muskellunge fingerlings immersed in 15 mg/l quinaldine sulfate for 1.5 hours were all upside down with 14% of the fish floating at the surface and the rest on the bottom. These fish were also excited by outside movements by persons, but all recovered in a calm fashion in the lake. A characteristic of this anesthesia seemed to be that anesthetized fingerlings (belly up) continued to respond to outside stimuli.

Quinaldine sulfate anesthetized fingerlings survived no better than the untreated fingerlings in each of the 4 waters studied than could be expected by chance (Table 7).

Satiation of Predators

Under the premise that predation is a cause of high initial mortality of stocked muskellunge fingerlings, 2 releases of 200 9- to 10-inch fish were made 24 hours apart in a single trial in Little Sand Lake (Barron Co.). If the predator fishes were truly satiated, the fingerlings from the 2nd stocking should have shown better survival than those from the 1st.

On the basis of actual electroshocker recoveries, 73 fingerlings from the 1st group and 68 from the 2nd were recaptured 35 days later. There was no significant difference in survival between the 2 groups.

On the basis of the subsequent Petersen population estimates, 74% of the initial stocking survived compared to 56% of the fingerlings that were stocked 24 hours later. This was a significant difference in favor of better survival of those fingerlings that were stocked as potential forage (Chi-square = 4.63, 1 df, $\underline{P} < 0.05$), in contrast with the direct collection result. In any case, the original premise was not substantiated in this trial.

Stocking Location

Vegetated vs. Open Water Areas. Survival of 6- to 12-inch muskellunge fingerlings stocked in dense aquatic vegetation was compared to that of finglerings stocked at weedfree boat landings in 2 lakes. No significant difference was found in the survival of 1 group over the other in Little Sand Lake (Barron Co.); however, in Harmon Lake, fingerlings stocked in open water survived better (Table 8). The area of aquatic vegetation was not significantly related to survival in all lakes studied (Appendix Fig. 1).

Spot vs. Scatter Planting. Comparative survival of fingerlings stocked at 1 shoreline location and those scattered individually along the shoreline from a boat was evaluated previously (Johnson, unpubl. data). In 8 trials in 6 lakes, no difference in survival could be determined between the 2 methods as confidence intervals of all tests

TABLE 5. Comparative survival of medium-sized (5.9-11.0 inches) and large (8.5-13.0 inches) muskellunge fingerlings stocked, 1972-75*.

Lake and Year Stocked	No. Days At Large	Medium-sized Fingerlings Range (inches)	Medium-sized Fingerlings No. Stocked	Medium-sized Fingerlings No. Recaptured	Large Fingerlings Range (inches)	Large Fingerlings No. Stocked	Large Fingerlings No. Recaptured	Chi-square
Bass								
1973	28	5.9-8.9	173	39	9.0-10.9	242	58	0.05
Boot								
1972	29	6.5-8.9	151	38	9.0-11.2	359	112	1.58
Clear								
1972	26	8.0-11.0	148	51	11.5-13.0	289	108	0.24
1973	19	8.0-9.9	51	15	10.0-12.5	333	125	0.93
1974	19	9.1-10.9	62	19	11.0-12.4	338	131	1.15
Crane-Chase								
1972	33	6.5-8.4	270	23	8.5-11.2	229	63	30.02
1973	26	6.5-8.4	120	35	8.5-11.2	297	89	0.00
Island								
1972	28	7.5-10.6	84	30	10.7-13.0	323	127	0.23
Leisure								
1974	14	8.4-9.9	24	5	10.0-11.9	266	99	1.91
1975	34	7.3-8.9	25	9	9.0-10.7	124	38	0.08
Little Sand (Barron Co.)								
1973	33	6.7-9.9	123	36	10.0-12.2	298	79	1.07
1974	19	8.3-9.7	65	33	9.8-11.4	331	161	0.03
1975	24	7.2-8.4	17	1	8.5-10.8	182	74	6.59
Little Sand (Sawyer Co.)								
1973	26	7.2-9.9	128	79	10.0-12.3	249	79	30.02
Lower Holly								
1975	33	8.2-9.4	36	5	9.5-10.9	64	25	5.81
Pear								
1974	14	8.4-9.9	26	8	10.0-11.5	200	90	1.36
1975	27	8.1-9.4	36	9	9.5-11.3	66	30	3.31
Perch								
1972	33	7.9-10.2	119	34	10.7-12.8	281	99	1.38
Sand Lake Rearing Pond								
1974	21	6.0-9.9	13	5	10.0-11.4	84	56	2.72
Spooner Hatchery Pond No. 12								
1975	39	7.4-8.3	3	0	8.6-10.4	47	42	No test
Total		5.9-11.0	1,674	474**	8.5-13.0	4,602	1,685**	18.84
Average		7.5-9.5			9.7-11.7			

*Both sizes of fingerlings were stocked on the same day in each lake or pond.
**Percent survival was 49.0% for medium-sized fingerlings and 55.2% for large fingerlings.

TABLE 6. Comparative survival of 6- to 12-inch muskellunge fingerlings conditioned 48 hours in a 5 by 9 by 4 ft deep holding net compared to fingerlings stocked directly into the lake.

Lake and Year Stocked	Conditioned in Net		Released Directly in Lake		Chi-square
	No. Stocked	No. Recaptured*	No. Stocked	No. Recaptured*	
Bass					
1973	200	40 (20)	215	57 (27)	2.10
Boot					
1971	302	171 (57)	298	101 (34)	30.36
1972	257	77 (30)	253	73 (29)	0.30
Clear					
1972	215	88 (40)	222	71 (32)	3.40
1973**	186	55 (29)	198	85 (43)	6.82
1974**	202	82 (41)	198	68 (34)	1.41
Crane-Chase					
1971	245	103 (42)	245	91 (37)	1.03
1972	250	42 (17)	249	44 (18)	0.02
1973	209	58 (28)	208	66 (32)	0.61
Island					
1972	200	70 (35)	207	87 (42)	1.83
Little Sand (Barron Co.)					
1973	209	58 (28)	212	57 (27)	0.01
Little Sand (Sawyer Co.)					
1973	185	75 (40)	192	83 (43)	0.18
Lund					
1971	79	49 (62)	80	55 (69)	0.53
Perch					
1972	200	69 (35)	200	64 (32)	0.18
Pulaski					
1971	353	114 (32)	350	129 (37)	1.42
All	3,292	1,151 (35)	3,327	1,131 (34)	0.65

*Percent recaptured shown in parenthesis.
**Fingerlings were conditioned in a large holding net 12 by 38 by 4 ft.

TABLE 7. Survival of muskellunge fingerlings anesthetized in quinaldine sulfate for 1.5 hours before stocking in lakes, compared to the survival of nonanesthetized fingerlings stocked directly into lakes during the fall of 1975.

Lake	No. Days At Large	No. Stocked		No. Recaptured		Chi-square
		Anesthetized	Nonanesthetized	Anesthetized	Nonanesthetized	
Leisure*	34	150	150	47	38	1.05
Lower Holly*	33	100	100	30	35	0.36
Pear**	27	102	100	39	39	0.00
Spooner Hatchery Pond No. 12**	39	53	50	42	46	2.42
All		405	400	158	158	0.005

*Anesthesia applied at rate of 10 mg/l.
**Anesthesia applied at rate of 15 mg/l.

TABLE 8. Comparative survival of 6- to 12-inch muskellunge fingerlings stocked in dense vegetation and open water areas of 2 lakes.

Lake	No. Days At Large	No. Stocked Weedy Area	No. Stocked Open Water	No. Recovered Weedy Area	No. Recovered Open Water	Chi-square
Harmon 1976	28	100	100	9	21	4.75
Little Sand (Barron Co.) 1975	28	200	200	81	75	0.26
All	28	300	300	90	96	0.19

TABLE 9. Comparative survival* of spot-planted and scatter-planted muskellunge fingerlings in lakes (Johnson, unpubl. data).

Lake and County	No. Days At Large	No. Stocked	Estimated Survival No.	Estimated Survival %	Estimated Survival 95% Confidence Limits on %
Spot-planted					
Mason (Sawyer Co.)	25	1,075	242	23	15-60
McDonald (Sawyer Co.)	18	740	740	100	68-100
Partridge (Vilas Co.)	25	1,000	575	58	30-100
Mean				60	
Scatter-planted					
Big Gibson (Vilas Co.)	28	1,000	555	56	27-100
Evergreen (Sawyer Co.)	20	940	34	4	2-100
Twenty Six (Burnett Co.)	18	1,000	340	34	22-87
Mean				31	

*t-test of spot vs. scatter: $t = 1.08$, NS, 4 df, not paired.

overlapped (Table 9). A t-test yielded $t = 1.08$, 4 df, $P > 0.1$.

Date and Temperature at Stocking

The date of stocking was positively related to higher fingerling survival, significant at $r = 0.62$ ($P < 0.01$) (Fig. 3). The trend for higher survival with later stocking appeared to extend to the latest dates, well into September. The greater success may have been related to cooler water temperatures, which were as low as 60 F. This was significant with $r = -0.49$ ($P < 0.01$) (Fig. 4).

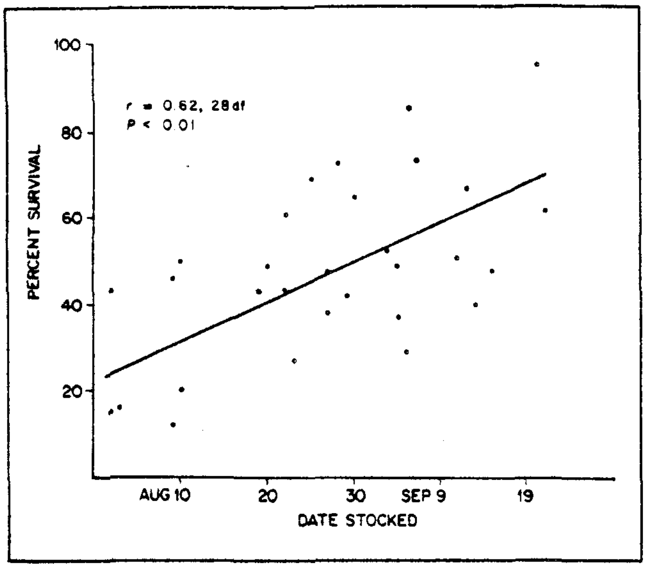


FIGURE 3. Relationship of stocked muskellunge fingerling survival to stocking date.

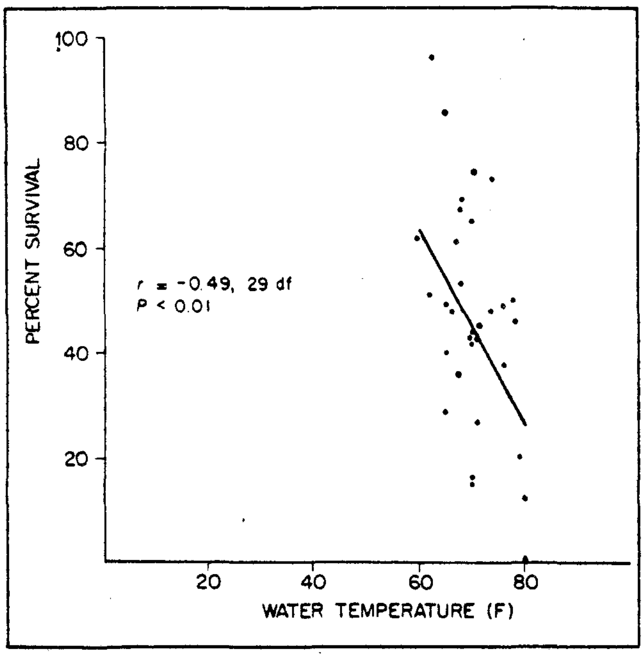


FIGURE 4. Relationship of stocked muskellunge fingerling survival to lake water temperature on date of release.

Number Stocked

No significant relationship was found between survival and the number of fingerlings stocked (Appendix Fig. 2).

NATURAL FACTORS

Biological Factors

Vegetation. As noted previously, release of muskellunge fingerlings in dense aquatic vegetation did not increase survival in 2 stocking trials. Data were examined to determine the relationship between survival and the extent of vegetated area in the lakes. For 27 releases in 15 lakes containing predaceous fish species, no relationship could be detected between survival and the log transformation extent of vegetated area ranging from 1 to 41% of the surface area. Moreover, survival varied from year to year within 7 of those lakes (Table 10) where the extent of vegetated area, within our ability to measure it, did not change.

Forage Species Present. No significant relationship was found between survival and pounds/acre of forage species present in all lakes, either for small (2- to 4-inch) or large (4- to 7-inch) forage fish (Appendix Figs. 3 and 4).

Predator Size and Abundance. No correlation of significance was found of average size of the fish predators in the lake with fingerling survival (Appendix Fig. 5). Nor were numbers of predators/acre significantly correlated with fingerling survival (Appendix Fig. 6). Despite lack of evidence of predator effect, the longer the fingerlings were in the lakes, the lower the survival, significant at $P < 0.01$ with $r = -0.49$ (Fig. 5). In 2 rearing ponds without predators in which fish were stocked after normal handling and transport, survival ranged from 63 to 85%. In 2 lakes known to be without predators (Lund and Perch), survival was 74-85% (Table 10). However, survival in Little Sand Lake (Sawyer Co.), originally thought to contain no predators large enough to consume the muskellunge fingerlings, was only 37%; largemouth bass were present but pre- and post-stocking surveys failed to detect the presence of large bass. It is possible that relation of predators to survival is clouded by imprecise estimation of predator stocks present.

Predator Movement. These trials, which were designed to detect predator movements in response to possible stress and injury of stocked muskellunge, suggested significant changes in predator distribution that could be attributed to the presence of the stocked muskellunge fingerlings. Predators appeared to actively seek out fish confined in holding pens (Table 11).

The individual lakes required evaluation by Fisher's Exact Probability Test and the values entered are the direct probability of the result being obtained by chance alone. Only Little Sand Lake (Barron Co.) had a low probability. The result from Little Sand may be an infrequent chance occurrence (since there are 11 trials which greatly raises the expectation that an anomaly may occur) or may possibly indicate that northern pike respond differently than other predators. Sample sizes are much to small to explore this.

Data were also collected to determine if other fish species, not normally considered predators, would be attracted to the stocking site.

These data (Tables 12 and 13) indicated that, for all lakes combined, there were no significant differences in the concentration of the various species of the nonpredators,

TABLE 10. Relationship of stocked muskellunge fingerling survival and growth to selected biological characteristics of lakes stocked, 1971-79.

Lake and Date Stocked	Size (Acres)	Percent of Area Vegetated	Forage Species (lb/acre)* Small	Forage Species (lb/acre)* Large	Predator Species No./acre	Predator Species Avg. Length (Inches)	Muskellunge Fingerlings No. Stocked	Muskellunge Fingerlings Percent Survival	Muskellunge Fingerlings No. Days at Large	Muskellunge Fingerlings Avg. Length When Stocked (Inches)	Muskellunge Fingerlings 30-day Growth (Inches)
Bass	84	22									
8-22-73			11.3	1.5	0.12	31.2	415	43	28	8.7	0.9
Boot	87	13									
9-21-71			7.4	4.2	0.28	27.2	600	62	21	11.5	0.3
8-30-72			22.7	7.0	0.45	26.0	510	65	29	9.2	0.5
Clear	77	11									
9-13-72			22.1	5.1	0.66	22.8	437	40	26	11.1	0.07
9-12-73			17.1	2.0	0.36	23.4	384	67	19	10.6	0.9
9-11-74			35.6	1.9	0.62	23.4	400	51	19	11.2	0.9
Crane-Chase	86	1									
8-25-71			26.9	7.9	0.12	32.9	490	69	34	9.5	1.1
8-23-72			18.3	3.3	0.20	30.7	499	27	33	8.7	1.0
8-29-73			31.9	2.6	0.47	23.9	417	42	26	8.9	2.1
Derosier	109	30									
8-9-76			10.8	4.5	0.41	23.5	50	0	38	8.3	-
Des Moines	229	6									
8-2-77			22.7	9.0	0.29	23.9	698	43	29	9.2	1.5
Harmon	96	20									
8-10-76			63.9	3.7	1.18	20.8	200	20	30	9.2	1.5
Island	68	38									
9-20-72			12.0	6.9	0.78	26.8	407	96	28	11.3	0.3
Leisure	75	17									
9-5-74			15.7	10.2	0.29	25.6	290	49	14	10.5	1.2
8-20-75			13.8	5.0	0.19	26.8	300	49	34	9.2	1.2
8-9-76			43.0	7.0	0.15	27.0	150	46	29	9.3	2.0
Little Sand (Barron Co.)	101	13									
9-5-73			24.7	13.2	0.53	22.4	421	29	33	10.2	0.6
8-28-74			26.9	22.9	0.82	21.0	396	73	19	10.0	0.9
8-20-75			19.8	15.9	0.45	22.7	400	44	24	9.1	0.9
8-10-76			21.9	22.2	0.62	21.8	200	50	29	9.3	1.2
8-22-79			**	**	**	**	397	61	28	9.3	0.9
Little Sand (Sawyer Co.)	78	10									
9-5-73			53.0	3.2	0.00	-	377	37	26	10.1	0.9
Lower Holly	42	7									
8-27-75			25.0	8.9	2.50	21.6	200	38	33	9.4	0.6
8-9-76			29.0	4.1	0.86	22.6	100	12	55	9.3	0.6
Lund	22	13									
9-8-71			0.03	2.0	0.00	-	159	74	23	10.7	0.7
Mathews	263	35									
8-2-77			6.5	1.9	0.79	22.8	798	15	27	9.2	1.2
Pear	49	41									
9-4-74			27.9	4.5	0.55	22.9	226	53	14	10.4	0.9
8-27-75			28.5	5.5	1.20	21.8	202	48	27	9.5	0.9
Perch	70	31									
9-6-72			2.5	2.7	0.00	-	400	85	33	10.6	0.4
Pulaski	126	7									
9-15-71			5.8	4.6	0.20	22.6	703	48	27	10.9	0.6
Twenty Six	230	12									
8-3-77			35.2	6.5	0.44	22.1	700	16	34	8.1	1.5

*Small = 2-4 inches in length; large = 4-7 inches in length.
**Data not collected.

TABLE II. Movement of predator fish in a series of lakes following the stocking of muskellunge fingerlings in a holding net.

Lake and Year Stocked	Predator Species**	Predator Fish Catch Before Stocking		Predator Fish Catch After Stocking		Direct Probability*
		Near Holding Net	Away From Holding Net	Near Holding Net	Away From Holding Net	
Bass						
1973	Muskellunge	0	0	0	0	1.00
Boot						
1971	Muskellunge	3	0	2	0	0.99
1972		1	0	2	1	0.75
Clear						
1972	Walleye &	2	2	8	3	0.33
1973	Muskellunge	4	2	3	0	0.42
Crane-Chase						
1971	Walleye &	0	2	3	1	0.20
1972	Muskellunge	0	5	1	1	0.29
1973		2	3	2	2	0.48
Island						
1972	Muskellunge	5	7	2	2	0.42
Little Sand (Barron Co.)						
1973	Northern Pike	1	6	3	0	0.03
Pulaski						
1971	Muskellunge & Northern Pike	1	4	0	0	0.99
All		19	31	26	10	0.01

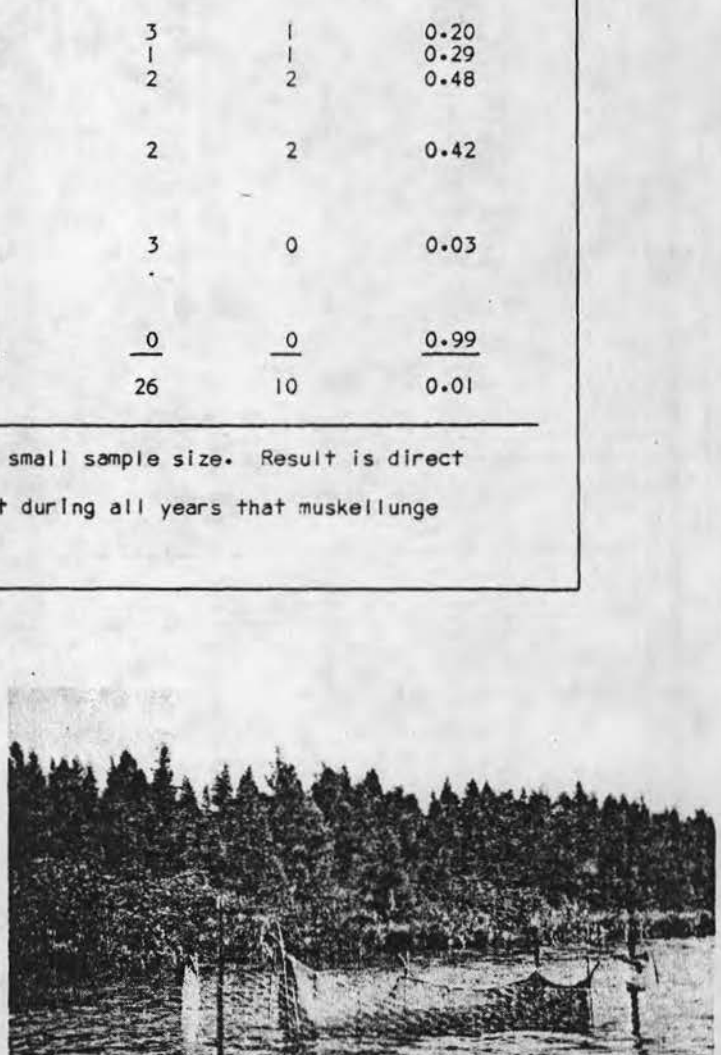
*Fisher's exact probability test used due to small sample size. Result is direct probability.
**Predators listed for any 1 lake were present during all years that muskellunge fingerlings were stocked.

before and after stocking. However, individual cases of fish movement occurred in both directions, but it is doubtful that it was related to the stocking of muskellunge. There was evidence in some cases of movements from side to side in the lakes regardless of holding nets. It appeared that fish traveled in groups instead of individual random movements thus producing erratic results. These data provide evidence that the native nonpredator fish ignored the muskellunge, or at least were not actively attracted to them.

Growth. No significant relationship was found between survival and the 30-day growth of the fingerlings after stocking (Appendix Fig. 7). However, the average growth in length over that period was positively related to the pounds/acre of 2- to 4-inch forage fish, with r significant at 0.54, $P <$ 0.01 (Fig. 6).

Physical-Chemical Factors

Alkalinity. Alkalinity, as a measure of water quality, might affect survival, since all stocked fingerlings were reared in the Spooner Hatchery with a total alkalinity of



A nylon holding pen was used in 2 different experiments: to condition fingerlings for 48 hours prior to release into the lakes, and to observe the effects of stocked muskellunge on the movements of predator fishes. (The wire mesh fencing protected the pen from muskrats.)

TABLE 12. Movement of bluegills in a series of lakes following the stocking of muskellunge fingerlings in a holding net.

Lake and Year Stocked	Bluegill Catch Before Stocking: Near Holding Net	Bluegill Catch Before Stocking: Away From Holding Net	Bluegill Catch After Stocking: Near Holding Net	Bluegill Catch After Stocking: Away From Holding Net
Bass				
1973	123	66	33	45
Boot				
1971	86	326	77	169
1972	92	143	34	87
Clear				
1972	59	49	38	23
1973	45	62	24	52
Crane-Chase				
1971	9	6	3	4
1972	3	3	1	3
1973		1		1
Island				
1972	81	114	117	109
Little Sand (Barron Co.)				
1973	337	138	311	467
Pulaski				
1971	352	286	332	65
All	1,187	1,195	970*	1,045*

*Chi-square for all lakes combined was 1.21.

TABLE 13. Movement of bluegills, crappies, rock bass, pumpkinseed, and yellow perch in a series of lakes following the stocking of muskellunge fingerlings in a holding net.

Lake and Year Stocked	Panfish Catch Before Stocking: Near Holding Net	Panfish Catch Before Stocking: Away From Holding Net	Panfish Catch After Stocking: Near Holding Net	Panfish Catch After Stocking: Away From Holding Net
Bass				
1973	125	71	34	47
Boot				
1971	201	546	144	288
1972	137	240	96	165
Clear				
1972	74	75	47	40
1973	94	169	62	134
Crane-Chase				
1971	394	198	180	61
1972	79	66	50	39
1973	37	36	11	23
Island				
1972	240	230	278	217
Little Sand (Barron Co.)				
1973	380	382	339	587
Pulaski				
1971	352	286	332	65
All	2,113	2,299	1,573*	1,666*

*Chi-square for all lakes combined was 0.31.

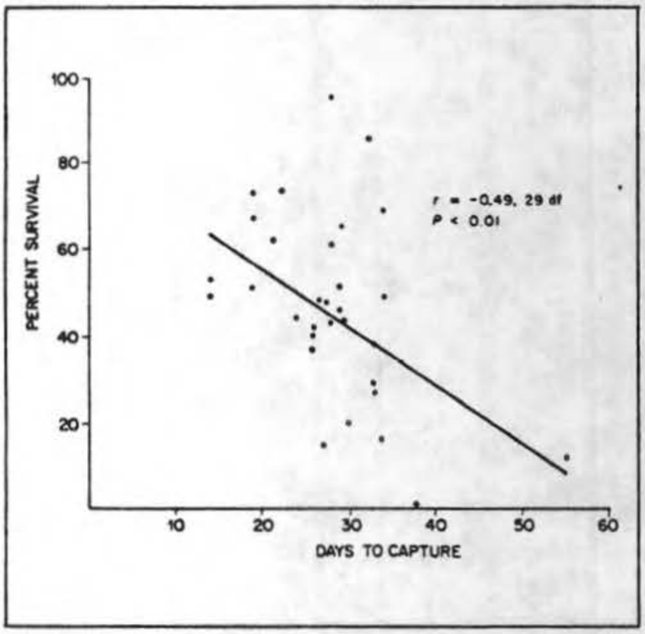


FIGURE 5. Relationship of stocked muskellunge fingerling survival to number of days in the lake after stocking.

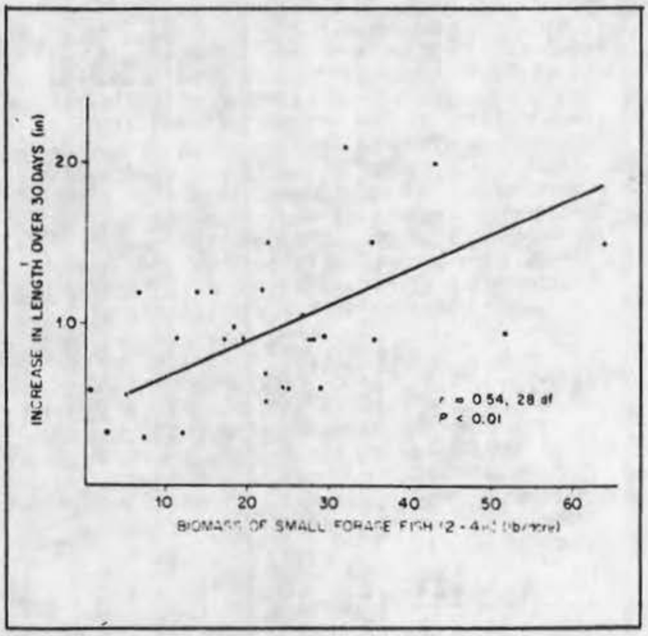


FIGURE 6. Relationship of stocked muskellunge fingerling growth during the 30-day period following stocking to biomass of small forage fish present.

TABLE 14. Relationship of stocked muskellunge fingerling survival to physical-chemical characteristics of lakes stocked, 1971-79.

Lake and Date Stocked	Lake Characteristics: Size (acres)	Miles of Shoreline	Total Alk. (ppm)	Water Temperature (F)	Mean Depth (ft)	Total Dissolved Solids (TDS)	Morphoedaphic Index (TDS/ Mean Depth)	Muskellunge Fingerlings: No. Stocked	Percent Survival	No. Days At Large
Bass	84	1.6			16	34	2.2			
8-22-73			9	71				415	43	28
Boot	87	2.1			17	40	2.4			
9-21-71			14	60				600	62	21
8-30-72			14	70				510	65	29
Clear	77	2.2			14	56	4.0			
9-13-72			27	65				437	40	26
9-12-73			27	68				384	67	19
9-11-74			27	62				400	51	19
Crane-Chase	86	1.5			13	72	5.4			
8-25-71			41	68				490	69	34
8-23-72			41	71				499	27	33
8-29-73			38	70				417	42	26
Derosier	109	2.3			6	33	5.3			
8-9-76			8	80				50	0	38
Des Moines	229	3.2			23	76	3.3			
8-2-77			44	70				698	43	29
Harmon	96	3.8			9	38	4.4			
8-10-76			12	79				200	20	30
Island	68	1.5			12	90	7.3			
9-20-72			56	62				407	96	28
Leisure	75	1.7			12	57	4.6			
9-5-74			28	65				290	49	14
8-20-75			28	76				300	49	34
8-9-76			28	78				150	46	29
Little Sand (Barron Co.)	101	2.1			13	38	2.9			
9-5-73			12	65				421	29	33
8-28-74			9	74				396	73	19
8-20-75			9	72				400	44	24
8-10-76			-	78				200	50	29
8-22-79			9	67				397	61	28
Little Sand (Sawyer Co.)	78	-			-	-	-			
9-5-73			17	66				377	37	26
Lower Holly	42	-			-	-	-			
8-27-75			31	76				200	38	33
8-9-76			31	80				100	12	55
Lund	22	-			-	-	-			
9-8-71			6	71				159	74	23
Mathews	263	2.6			12	77	6.5			
8-2-77			45	70				798	15	27
Pear	49	1.4			17	72	4.3			
9-4-74			41	68				226	53	14
8-27-75			41	74				202	48	27
Perch	70	-			-	-	-			
9-6-72			8	66				400	85	33
Pulaski	126	2.5			17	43	2.6			
9-15-71			16	66				703	48	27
Twenty Six	230	3.8			20	84	4.3			
8-3-77			51	70				700	16	34

80 ppm and stocked in lakes with alkalinity values that ranged from 8 to 56 ppm (Table 14). However, no relationship was found between survival and alkalinity (Appendix Fig. 8).

Water Temperature. Better survival was clearly associated ($r = -0.49$) with stocking at cooler water temperatures, best toward 60 F (significant at $P < 0.01$) (Fig. 4, Table 14).

Lake Size and Shoreline Length. No significant relationship was found between fingerling survival and either the shoreline length (Appendix Fig. 9) or the area of the lakes.

Mean Depth. There was no significant relationship between survival and lake mean depth (Appendix Fig. 10).

Morphoedaphic Index. No significant relationship was found between survival and the morphoedaphic index (total dissolved solids/mean depth) (Appendix Fig. 11).

DISCUSSION

Many factors influence survival of stocked muskellunge fingerlings. Within the limitations of this study, some of those factors, both controllable (by management) and uncontrollable (natural) were virtually eliminated as major causative elements of significant mortality. Others were implicated to varying degrees, but it is important to point out that there is a larger problem of interaction and/or combination of factors that operate to influence survival. Three factors appear to be the most important: (1) date of stocking, (2) water temperature at stocking, and (3) presence of predators. A 4th factor -- stress from handling in the rearing pond-seining-transport operation -- was implicated in a companion study.

In my study, it is important to note that finclipping had little effect on the well being of the fish because differential marking of the fingerlings was a necessary technique for this study. There was no significant difference in the survival of fin-clipped and unmarked fingerlings; nor between fingerlings marked with different pectoral or pelvic clips. Studies of other species have also shown that amputation of one of the paired ventral fins had negligible effect on survival (Shetter 1951, 1952; Churchill 1963; Brynildson and Brynildson 1967; Coble 1967).

Miles et al. (1974) measured physiological responses of muskellunge fingerlings in some of the trials reported here to the stress of harvest by seining, finclipping, salt treatment, transportation by truck, and to holding in the lake for 48 hours before release. Blood and liver samples taken from specimens after each of those stages showed increases in plasma chloride and liver glycogen concentrations. Some of the physiological symptoms of stress were alleviated by holding the fingerlings in 0.3% salt (NaCl). Finclipping and transport by truck had little effect in causing stress in comparison to that due to the initial pond seining. Conditioning in pens in the lake for 48 hours did not appreciably reduce the stress symptoms.

It seemed logical that temporary confinement in holding pens before actual release would allow the stocked muskellunge to overcome the stress of harvest and handling. However, survival did not improve and there was no significant difference in survival between those fingerlings conditioned in the pens for 48 hours compared to those stocked directly in the lake. Nevertheless, since the stress symptoms were not reduced within 48 hours, these results do not eliminate stress as a factor influencing survival. The pens, however, allowed me to observe that immediate mortality i.e., within 48 hours and before actual release in the lake, was nil. Belusz (1978) reported a 45% mortality of stocked muskellunge fingerlings within 24 hours while confined in an isolated cove; this figure rose only slightly to 51% after 72 hours. A previous study involving the isolation cove technique had demonstrated a survival after 53 hours in confinement of virtually 100% (Belusz 1975).

Two nighttime releases in isolated coves indicated survival of 100% after 56 hours; however, these findings are masked by the inclusion of 2 other variables, transport in salt and furacin (concentrations not indicated) (Belusz 1978). In my study, holding of fingerlings in a 0.3% salt (NaCl) solution appeared to calm them; however, there was no significant difference in survival of those and untreated fingerlings.

Predation was implicated as a major cause of muskellunge fingerling mortality through examination of 3 data sets. Length of time in the lake negatively influenced survival; stocking appeared to attract predators; and survival was highest in the absence of predators.

Survival was highest in 2 rearing ponds (restocked with fish that had been subjected to the normal seining, handling, and transport procedures) and in 2 lakes containing no predaceous fish species, ranging from 63 to 85%. In a previous study, Johnson (unpubl. data) reported survival in 6 rearing pond trials, in which the fingerlings were also subjected to normal handling procedures, of 92-100%. However, the importance of that finding, in relation to predation, is masked by the fact that the water temperature was 46 F.

In the present study, the size of predators did not significantly affect fingerling survival, but I was surprised to find in Little Sand Lake (Barron Co.), a 12-inch yellow bullhead with a 9-inch newly stocked muskellunge fingerling protruding from its mouth. The estimated 1,100-1,200 bullheads between 8.0 and 12.5 inches in that lake could have been a substantial factor, together with the northern pike and large muskellunge present, in reducing the number of stocked fingerlings.

Confinement of fingerlings in holding pens, referred to above, permitted us to assess the influence of stocking on predator and nonpredator movement. There were differences in the concentration of the various predator species near the holding pens before and after stocking, but none for the nonpredator species.

Whatever the degree to which predator fishes seek out the stocked fingerlings, it is likely that fingerlings further increase their vulnerability to predation by rapid dispersion from the stocking sites. Previous shocker surveys have shown phenomenal distances traveled by newly stocked fingerlings; for example, 10 miles traveled in Lac Court Oreilles within 7 days and 1/2 mile along the lake shore in 30 minutes in other lakes (Johnson, unpubl. data).

Two approaches to delaying that dispersion of fingerlings from the stocking site were evaluated. Anesthetized fingerlings dispersed much more slowly from the stocking site than did nonanesthetized fish. Fingerlings were also stocked in aquatic vegetation sufficiently dense to provide a physical impediment to penetration by large predators, but the fingerlings did not remain there for any extended period. Neither procedure increased fingerling survival.

Previous research (Johnson, unpubl. data) had indicated that survival of small fingerlings approximating 2.3 inches in average length was virtually nil; that finding was reaffirmed in this study. Those early results led to emphasizing production of larger fingerlings which did in fact survive much better, but still, in total, not very well. Propagation of 6- to 13-inch fingerlings prompted the question whether larger fish within that size range survive better than those in the lower end of the range.

An indicated advantage of 12.6% was obtained from combined data for the larger size catagory (averaging 9.7-11.7 inches in total length). For the comparative groups of medium-sized (averaging 7.5-9.5 inches in total length) and large fingerlings stocked in the same waters at the same time, significant differences were demonstrated in only 4 of 19 trials. Of those 4 releases, 1 was in a lake with no predators, hence the higher survival there could not be related to a predator-prey relationship. Despite the overall slight advantage of the larger fish, it is apparent that in practice, inconsistent results can be expected. The better survival of larger fingerlings may be of small advantage when costs are considered. In most cases, growth of medium-sized fingerlings (7.5-9.5 inches) after stocking approximated that expected for fingerlings in rearing ponds, but without the cost of providing forage.

The factor most clearly related to increased survival was the date of stocking. Fingerlings stocked in lakes toward the end of August and into September generally survived better than fish stocked earlier. The cooler waters accompanying the later stocking undoubtedly influenced the higher survival. That conclusion is reinforced by Johnson's (unpublished) data on high survival of fingerlings restocked in rearing ponds at a water temperature of 46 F. Fish culturists have long known of better survival of harvested fingerlings within the hatchery system when cooler water temperatures prevailed (Johnson 1958). Cooler temperatures, near 60 F, were found to be better for survival after stocking in lakes as well.

SUMMARY

(1) During 1971-79, a series of 40 muskellunge fingerling releases was made in 20 northwestern Wisconsin waters lying both within and outside of the historic range of the muskellunge. The primary method of study consisted of stocking 2 groups of fingerlings, each treated by a different method, and then comparing the numbers recovered by electrofishing within 39 days after release. Survival figures were correlated with various parameters measured.

(2) Previous assessments of the muskellunge stocking program in Wisconsin have been made essentially on a trial and error basis. In this study, attention was directed at both the quality of the hatchery product and the physical-chemical and biological conditions prevailing in the receiving waters to which the stocked fingerlings must adjust. As in many other pioneering ventures, the objectives of this study were not fully met. Nevertheless, some factors have been essentially eliminated as major causative elements of early fingerling mortality and the scope for further needed research in this area has been narrowed. The collective findings do suggest some modifications in the muskellunge rearing and stocking program.

(3) No differences were found in survival of fin-clipped and unmarked 6- to 12-inch fingerlings nor in survival of differentially fin-clipped fish.

(4) Survival of small (2- to 3-inch) fingerlings was virtually nil.

(5) Within the size range normally stocked (6- to 12-inch), survival of larger fingerlings was slightly better than that of the smaller fish.

(6) Conditioning in holding pens in the lakes for 48 hours prior to actual release did not increase survival.

(7) Treatments with salt (NaCl) and quinaldine sulfate failed to increase survival.

(8) Survival was not increased either by stocking in dense vegetation or by scatter-planting; nor was survival related to extent of vegetated areas of the lakes.

(9) Higher survival was achieved by late season stocking at cooler water temperatures.

(10) Survival was not related to the number of fingerlings stocked.

(11) Biomass of forage species present, either small (2- to 4-inch) or large (4- to 7-inch), was not related to survival.

(12) Growth of fingerlings in the lakes was directly related to the pounds/acre of small forage species present.

(13) The number of predaceous fish/acre could not be shown to negatively influence survival; however, the longer the fingerlings were in the lake and presumably exposed to predation, the lower was the survival. Highest survival was attained in 2 lakes and 2 rearing ponds containing no predators.

(14) Predaceous fish appeared to be attracted to fingerlings confined in holding pens.

(15) Survival was not related to alkalinity, lake size, shoreline length, mean depth, or the morphoedaphic index.

MANAGEMENT AND RESEARCH IMPLICATIONS

Results of this study suggest consideration of the following modifications in the muskellunge rearing, stocking, and research programs.

(1) Discontinue stocking small (2- to 3-inch) muskellunge fingerlings -- they did not survive in this study. The take of muskellunge spawn should be continued as usual because calamities may occur that will require egg or fry transfers between hatcheries, or replacement within the same hatchery. Since the small fingerlings will not be needed, the rearing pond stocking rate should be reduced. Within recent years, Spooner rearing ponds have received 25,000-50,000 fry/acre. Such rates could conceivably be cut to 10,000/acre, or even less. Fewer stocked fry will mean greater quantities of zooplankton for the starting fry and better survival and growth as well. Any surplus fry should be discarded or stocked en masse at a nearby muskellunge lake.

(2) Should a need still remain to crop the 2- to 3-inch muskellunge fingerlings from ponds, they should be stocked in large 3,000- to 5,000-acre lakes. Prior data for 5,000-acre Lac Court Oreilles indicated at least some survival for fingerlings of this size, compared to virtually zero for that in small lakes.

(3) Concentrate on rearing 7- to 9-inch muskellunge fingerlings. They survive about 87% as well as the larger 9- to 12-inch fingerlings when stocked in lakes. Rearing smaller fingerlings will be less costly because of the smaller forage supply required. Transportation costs will also be less for the smaller fish.

(4) Stock muskellunge fingerlings during periods of cooler water temperatures, preferably in the 60-65 F range. This generally means stocking during the last weeks in August and into September. However, the problems of rearing smaller fingerlings over a longer growing season will still have to be resolved.

(5) Every effort should be made to reduce the handling of muskellunge fingerlings between the harvest and the stocking in lakes. Physiological stress due to harvest has been documented (Miles et al. 1974). During my study, I was unable to assess the survival of unstressed fingerlings and fingerlings harvested by conventional methods. But reduced handling may be I key to increased survival.

(6) The recreational and cost benefits of an increase in survival of stocked muskellunge dictate that research on this issue be continued, on both the hatchery and stocking aspects. Candidate areas of further research, both new and supplemental to those involved in this study, include: (1) developing a cultural regime to carry smaller fingerlings longer for late-season harvest and stocking in cooler waters; (2) refining the relationship of fingerling size to survival through close sorting of lots prior to release; (3) confining fingerlings longer in holding pens or isolated areas prior to actual release; (4) testing of night stocking, alone and in combination with confinement; (5) radio tracking of fingerlings to more precisely determine movements, habitat selectivity, and possibly fate as prey; (6) using genetically different strains as brood stock and subsequently evaluating fingerling survival; and (7) evaluating higher fingerling stocking rates.

APPENDIX

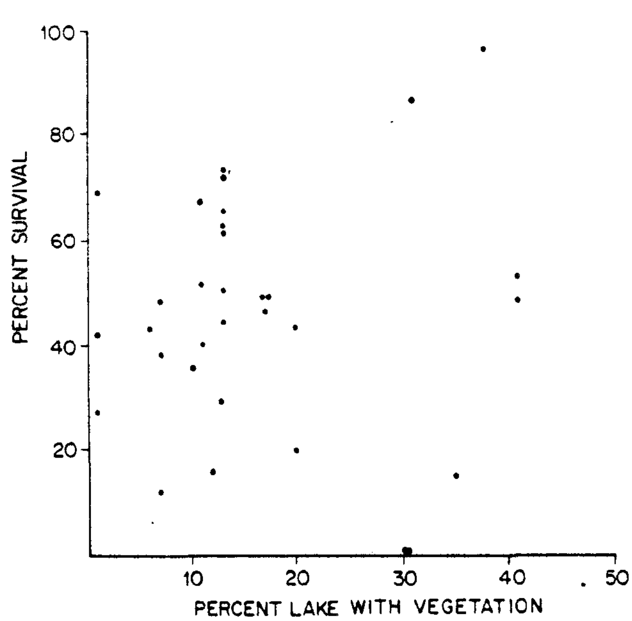
APPENDIX TABLE 1. Selected characteristics of study lakes.

County and Lake	Area (acres)	Max. Depth (ft)	Lake Type*	Secchi Disk(ft)	Alkalinity (ppm)	Other Fish Species Present **
Barron County						
Little Sand	101	41	S			NP,LMB,BG,BC,YB
Bayfield County						
Lund	22	36	S	10	6	LMB,BG
Perch	22	12	S	2	3	LMB,W
Burnett County						
Des Moines	229	37	S	18	44	NP,LMB,W,BG,BC,YP,YB,WS
Twenty Six	230	47	D	10	51	NP,LMB,BG,BC,YP,RB,PS,YB,BS

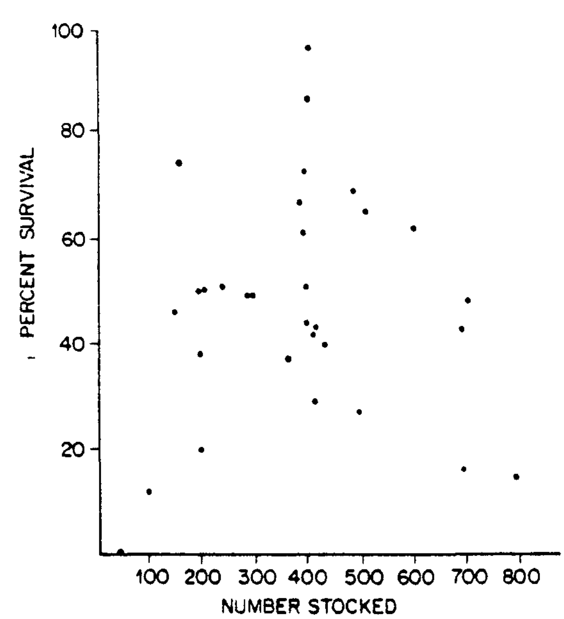
APPENDIX TABLE I. Continued.

County and Lake	Area (acres)	Max. Depth (ft)	Lake Type*	Secchi Disk(ft)	Alkalinity (ppm)	Other Fish Species Present **
Price County						
Bass	84	46			9	
Crane-Chase	86	22			41	
Rusk County						
Boot	87	44	S	14	14	LMB,YP,BG
Pulaski	126	40			16	
Sawyer County						
Clear	74	32	S	18	27	LMB,W,P
Island	67	31	D	7	56	LMB,W,YP,BG,BC,PS,GS,B
Little Sand	78	16	S		17	LMB,P
Lower Holly	42	10	S		31	LMB,P
Sand Lake Rearing Pond	9	9	D		34	M
Washburn County						
Derosier	109	11	D	8	8	NP,LMB,BG,BC
Harmon	96	33	S	15	12	NP,LMB,BG,SMB
Leisure	75	26	S	7	28	NP,LMB,BG,PS,RB,WS,B
Mathews	263	26	S	13	45	LMB,W,BG,YP,WS
Pear	49	32	S	12	41	NP,LMB,W,BG,BC,RB,PS,SMB,B,WS,R,CS
Spooner Hatchery Pond No. 12	13	6	D		78	M

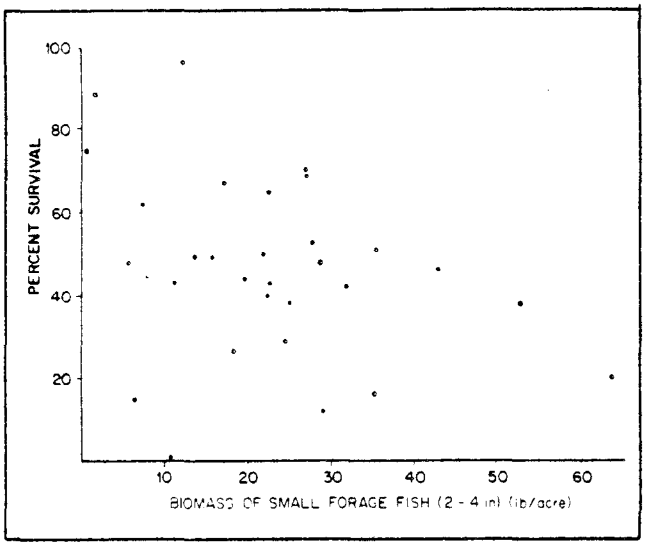
*S = seepage, D = drainage.
**NP = northern pike, LMB = largemouth bass, W = walleye, SMB = smallmouth bass, BG = bluegill, BC = black crappie, YP = yellow perch, RB = rock bass, YB = yellow bullhead, WS = white sucker, PS = pumpkinseed, GS = green sunfish, BS = brook silverside, P = panfish, B = bullheads, M = minnows, R = redhorse, and CS = common shiner.



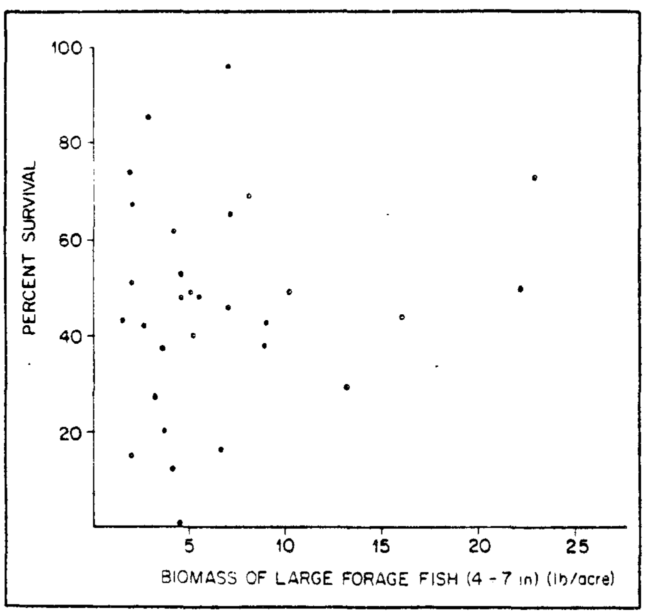
APPENDIX FIGURE 1. Plot of stocked muskellunge fingerling survival on extent of lake area vegetated. (No statistically significant relationship was found.)



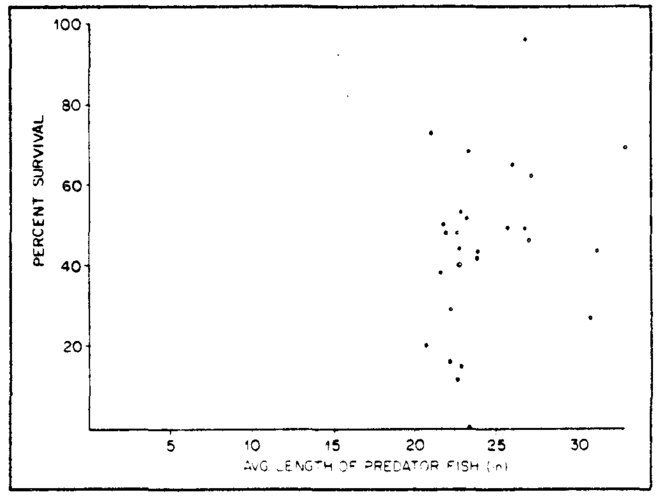
APPENDIX FIGURE 2. Plot of stocked muskellunge fingerling survival on number stocked. (No statistically significant relationship was found.)



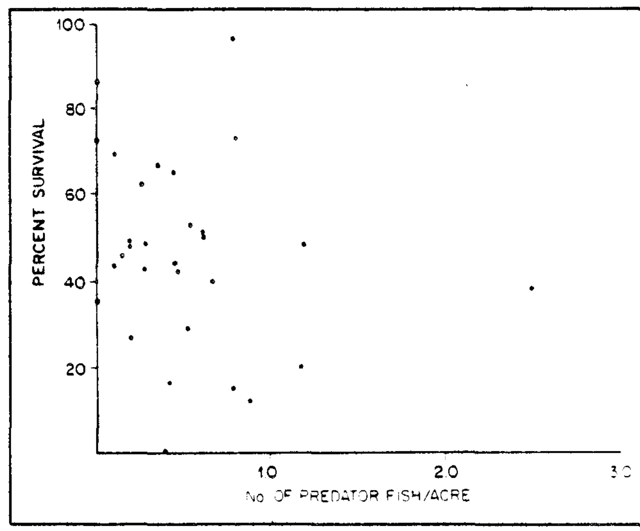
APPENDIX FIGURE 3. Plot of stocked muskellunge fingerling survival on biomass of small forage fish present. (No statistically significant relationship was found.)



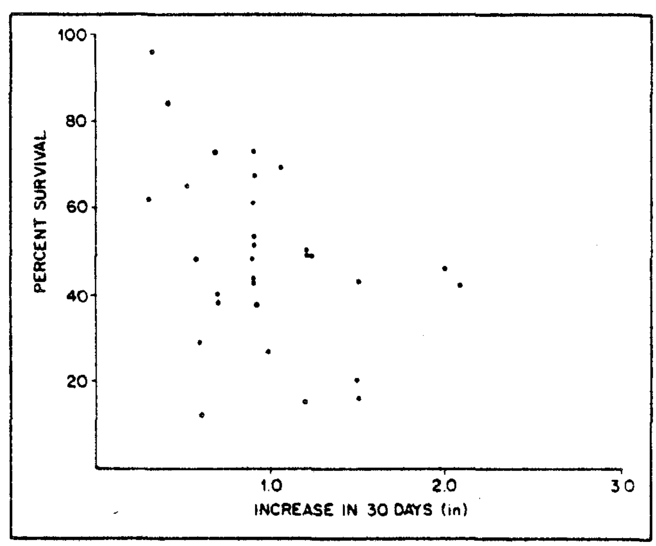
APPENDIX FIGURE 4. Plot of stocked muskellunge fingerling survival on biomass of large forage fish present. (No statistically significant relationship was found.)



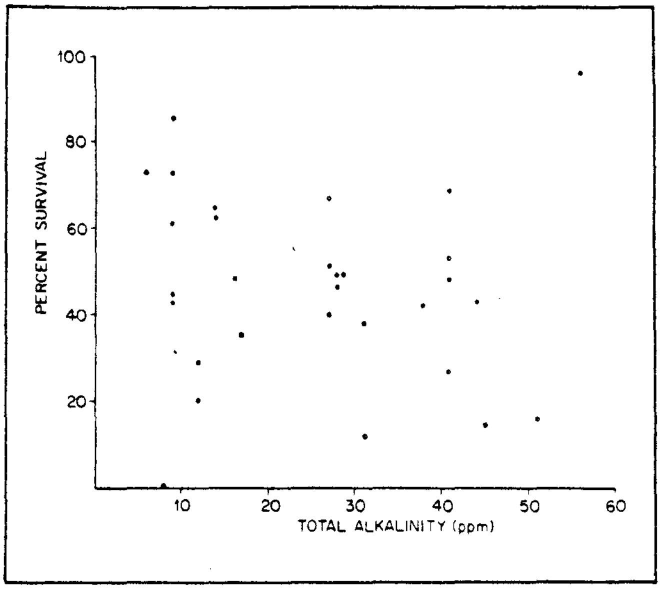
APPENDIX FIGURE 5. Plot of stocked muskellunge fingerling survival on size of predator fish present. (No statistically significant relationship was found.)



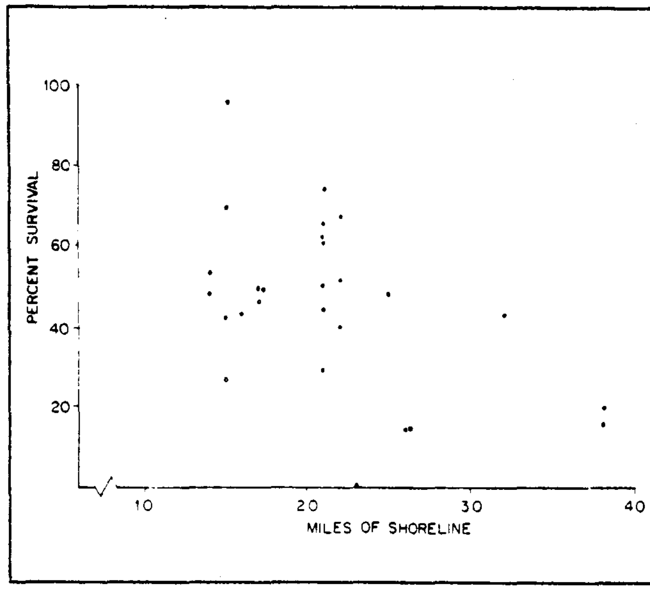
APPENDIX FIGURE 6. Plot of stocked muskellunge fingerling survival on the number of predator fish present. (No statistically significant relationship was found.)



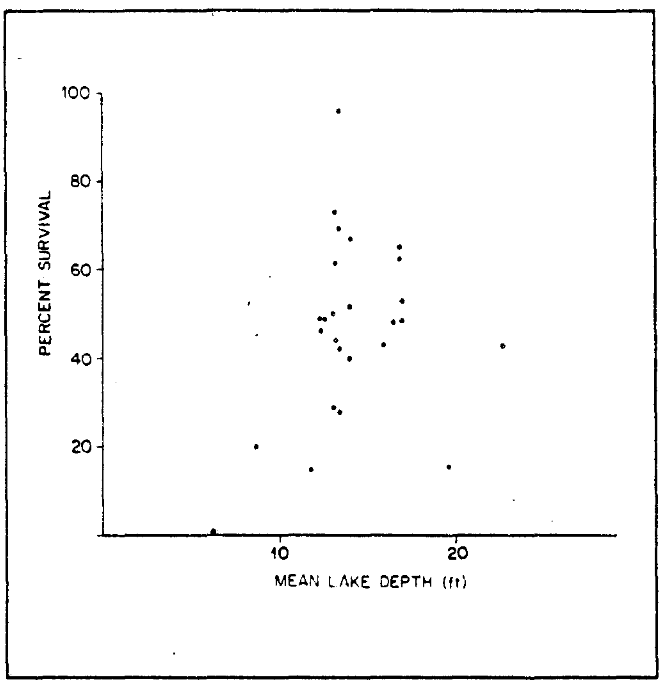
APPENDIX FIGURE 7. Plot of stocked muskellunge fingerling survival on growth during the 30-day period following stocking. (No statistically significant relationship was found.)



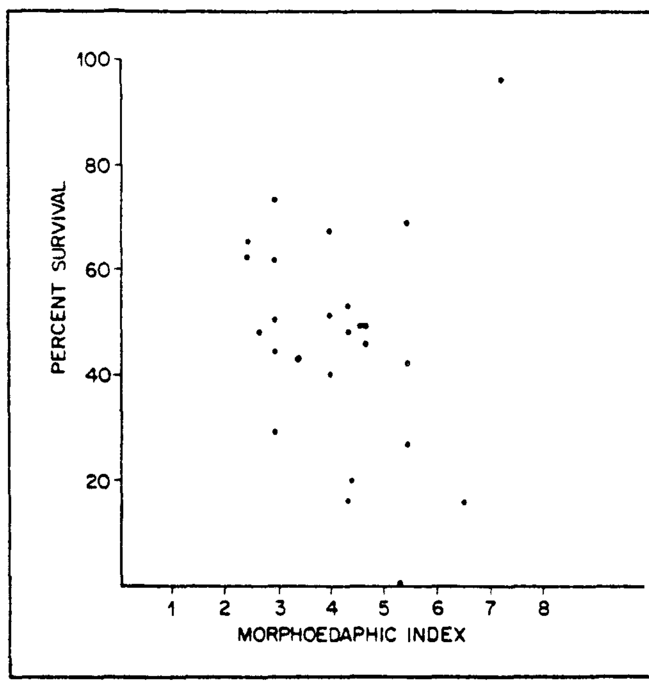
APPENDIX FIGURE 8. Plot of stocked muskellunge fingerling survival on alkalinity of lakes. (No statistically significant relationship was found.)



APPENDIX FIGURE 9. Plot of stocked muskellunge fingerling survival on shoreline length of lakes. (No statistically significant relationship was found.)



APPENDIX FIGURE 10. Plot of stocked muskellunge fingerling survival on mean depth of lakes. (No statistically significant relationship was found.)



APPENDIX FIGURE 11.. Plot of stocked muskellunge fingerling survival on morphoedaphic index of lakes. (No statistically significant relationship was found.)

LITERATURE CITED

Belusz, L. C.
1975. The use of isolation coves in assessing muskellunge stocking mortality. Proc. Am. Conf. Southeast. Assoc. Game and Fish Comm. 29:251-53.

1978. An evaluation of the muskellunge fishery of Lake Pomme de Terre and efforts to improve stocking success. pp. 292-97 in R. L. Kendall, ed. Selected cool water fishes of North America. Am. Fish. Soc. Spec. Publ. No. 11. 437 pp.

Brynildson, O. M. and C. L. Brynildson
1967. The effect of pectoral and ventral fin removal on survival and growth of wild brown trout in a Wisconsin stream. Trans. Am. Fish. Soc. 96:353-55.

Churchill, W. S.
1963. The effect of fin removal on survival, growth and vulnerability to capture of stocked walleye fingerling. Trans. Am. Fish. Soc. 92:292-300.

Coble, D. W.
1967. Effects of fin clipping on mortality and growth of yellow perch with a review of similar investigations. J. Wildl. Manage. 31:173-80.

Johnson, L. D.
1958. Pond culture of muskellunge in Wisconsin. Wis. Dep. Nat. Resour. Tech. Bull. No. 17. 53 pp.

1969. Food of angler-caught northern pike in Murphy Flowage. Wis. Dep. Nat. Resour. Tech. Bull. No. 42. 25 pp.

1972. Musky survival. Wis. Conserv. Bull. 37:3(8-9).

Miles, H. M., S. M. Loehner, D. T. Michaud, S. L. Salivar
1974. Physiological responses of hatchery reared muskellunge (Esox masquinongy) to handling. Trans. Am. Fish. Soc. 103(2):336-42.

Ricker, W. E.
1975. Computation and interpretation of biological statistics of fish populations. J. Fish. Res. Board Can. Bull. No. 191. 382 pp.

Shetter, D. S.
1951. The effect of fin removal on fingerling lake trout (Salvelinus namaycush). Trans. Am. Fish. Soc. 80:260-77.

1952. The mortality and growth of marked and unmarked lake trout fingerlings in the presence of predators. Trans. Am. Fish. Soc. 81:17-34.

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