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An Evaluation of In-Lake Enclosures for Increasing Short-Term Survival of Stocked Muskellunge

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Abstract

Low short-term survival (1-2 months) of stocked muskellunge (*Esox masquinongy*) is a major management problem. Poor survival has been attributed to various stressors and to predation following stocking. In this study, conducted in northwestern Wisconsin in 1988-90, we tested the hypothesis that short-term survival would be improved for muskellunge fingerlings held at low densities in predator-free in-lake enclosures prior to release. In 4 lakes stocked both by standard stocking procedures and by holding fingerling muskellunge 4 days in enclosures prior to release, no difference in short-term survival (42-71 days) was observed between the 2 groups. Enclosures may have been successful in protecting the fingerlings from certain predators; however, they may have made them more vulnerable to others. For example, river otters (*Lutra canadensis*) were observed inside one enclosure during the isolation period. Results of this study suggested no advantage in using this procedure for improving survival of stocked muskellunge.

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Introduction

Low short-term survival of stocked muskellunge (*Esox masquinongy*) has troubled fisheries managers for many years. Survival of various sizes of fingerlings during the first several months after stocking has averaged 39% and ranged from 0% to 96% (Hanson et al. 1986). If short-term survival of stocked muskellunge could be improved, recruitment into the fishery could be increased without additional production costs. Studies on stocking strategies have suggested that increased survival could be achieved by stocking larger muskellunge, but often even these fish suffer high mortalities shortly after stocking (Hanson et al. 1986, Serns and Andrews 1986, Margenau 1992).

Post-stocking losses of esocids have been attributed to a combination of stressors such as abrupt temperature changes, handling, and confinement during transport (Miles et al. 1974, Mather et al. 1986, Mather and Wahl 1989). Predators can also affect survival after stocking. Predation by largemouth bass (*Micropterus salmoides*) has been identified as a factor affecting short-term survival of hybrid muskellunge (*E. masquinongy* × *E. lucius*) (Stein et al. 1981, Carline et al. 1986, Wahl and Stein 1989).

The relationship between stocking stress and subsequent vulnerability of stocked muskellunge to predation is not well understood. Hanson and Margenau (1992), using radio telemetry, observed that stocked muskellunge were quiescent and lacked an escape response the first day after their release. Researchers could easily approach a muskellunge without any avoidance reaction from the fish. However, over the course of that study (34 days), these fish became highly elusive and difficult to approach (Hanson and Margenau 1992). Hence, sublethal stress may negatively affect muskellunge avoidance behavior prior to acclimation and thus indirectly affect short-term survival.

These results suggest that allowing stocked muskellunge a period of time to rest in a predator-free area until the initial stress from handling subsides may improve short-term survival. In an earlier study, Johnson (1982) conditioned stocked muskellunge in pens for 48 hours prior to release, but short-term survival was not improved. It is possible that muskellunge in Johnson's study were not held for a long enough period, or that fish were confined at densities that were too high. Belusz (1975, 1978) was successful in reducing short-term stocking mortality by using blocked isolation coves for 48 hours; however, no survival evaluations were made after that period.

A research study was conducted during 1988-90 to further explore factors affecting short-term survival of stocked muskellunge. Objectives of this study were to compare survival of muskellunge stocked and held at low densities in predator-free enclosures for periods longer than 48 hours with survival of muskellunge stocked using standard procedures. Survival of both groups was evaluated 42-71 days after stocking.

Methods

Study Lakes

Four northwestern Wisconsin lakes were selected: Twenty-Six Lake (Burnett County) and Leisure Lake (Washburn County) were used during fall 1989; Barber Lake (Sawyer County) and Big Moon Lake (Barron County) were used during fall 1990 (Fig. 1). Twenty-Six Lake is a 230-acre hard-water drainage lake with a maximum depth of 47 ft. Leisure Lake is a 75-acre soft-water seepage lake with a maximum depth of 26 ft. Barber Lake is a 238-acre hard-water drainage lake with a maximum depth of 21 ft. Big Moon Lake is a 191-acre hard-water drainage lake with a maximum depth of 47 ft.

Enclosure Design and Stocking Procedures

Two sites were selected on each study lake. Sites were chosen for adequate aquatic macrophytes or other submersed hiding cover and depths of at least 4-5 ft. One enclosure was placed at each site. Each enclosure consisted of a 6-ft deep 225-ft length of 0.25-inch commercial grade nylon seine. Each seine was staked from shore in a fashion such that 2 sides ran perpendicular to shore, one side ran parallel to shore, with the shoreline as the fourth side of the enclosure. When completely set up, the enclosures covered approximately 100-150 ft of shoreline, ran 40-60 ft offshore, and enclosed areas of 0.1-0.2 acre (Fig. 2). Maximum depth on most enclosures was 4-4.5 ft. Installation and removal of enclosures took about 7 hours/enclosure.

Precautions were taken to avoid entrapment of potential aquatic predators while installing enclosures. The seine was placed along the shoreline and workers slowly pulled the float line into position, allowing the lead line to drag bottom as much as possible. Visual inspections of enclosures were subsequently made from a boat and by a scuba diver before muskellunge were released.

In preliminary trials in 1988, 3-4 Bird Scare X balloons[1] were deployed within the bounds of each enclosure to deter predation from great blue herons (*Ardea herodias*). However, herons paid little attention to the balloons, and within 3 days herons were observed inside enclosures. As an alternative, the area extending 15-20 ft from shore in each trial enclosure was covered with 5-inch stretch bar gill net suspended approximately 1 ft above the water. This procedure was successful in keeping herons out of trial enclosures and was used on all enclosures in all 4 study lakes during 1989 and 1990.

All muskellunge were reared to approximately 4 months of age at the Spooner Fish Hatchery on a minnow diet. Upon their removal by seine from rearing ponds, muskellunge fingerlings were counted, and a sample (N = 100) were individually measured to the nearest 0.1 inch and weighed to the nearest 0.1 oz. (Mean length and weight of muskellunge stocked in 1989 to Twenty-Six Lake and Leisure Lake were 10.0 inches and 3 oz. Mean length and weight of muskellunge stocked

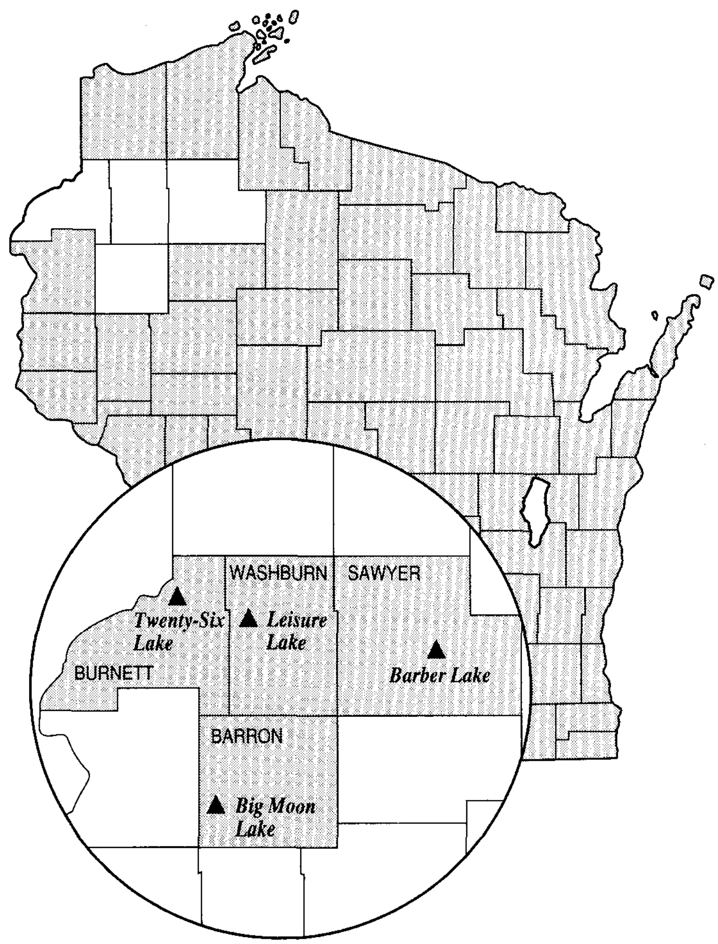

Figure 1. *Location of study lakes.*

[1]Reference to trade names does not imply government endorsement of commercial products.

in 1990 to Barber and Big Moon lakes were 11.5 inches and 4.4 oz.) After the sample was weighed and measured, all fingerlings were randomly separated into 2 equal groups (control and treatment) for stocking in each study lake. Control and treatment groups were distinguished by removal of one pelvic fin from each fish. Both groups were then transported from the hatchery to each study lake in separate compartments of aerated hatchery trucks, in water containing a 3% salt solution. The control group was stocked using standard procedures (i.e. direct release at public access sites), while the treatment group was divided for the 2 enclosures in that lake, transported in a large tank in a boat from the access site, and placed into the enclosures. Density of muskellunge fingerlings in enclosures ranged from 1 fish/50 ft^2 to 1 fish/165 ft^2. Enclosures were inspected by a scuba diver before and during the isolation period for damage and to ensure that the net lead line was secure to the lake bottom. Forage minnows were seined from each study lake and placed in the enclosures during the holding period.

The muskellunge fingerlings were confined to the enclosures for a period of 4 days. In earlier studies, monitoring of plasma glucose concentrations for esocid responses to stress suggested that 2 days was not a long enough recovery period (Miles et al. 1974), while after 4 days glucose levels returned to pretreatment levels (Mather et al. 1986). While plasma glucose concentrations were not strongly related to survival (Mather et al. 1986), they do indicate when stress has subsided. Thus a 4-day period may allow muskellunge to return to a "normal" physiological state in addition to allowing for detection of any mortality from stocking stress factors. During trials for this study in 1988, muskellunge held for 8 days developed abrasions on their snouts and fins. Hence, we chose a 4-day period to allow ample time for stocking stress to subside while also releasing muskellunge before they became vulnerable to abrasions that could hinder survival.

Following the 4-day confinement period, enclosures were carefully dismantled, allowing fingerlings to disperse. No efforts were made to quantify the number of muskellunge remaining in the enclosures upon release, as this procedure would induce stress.

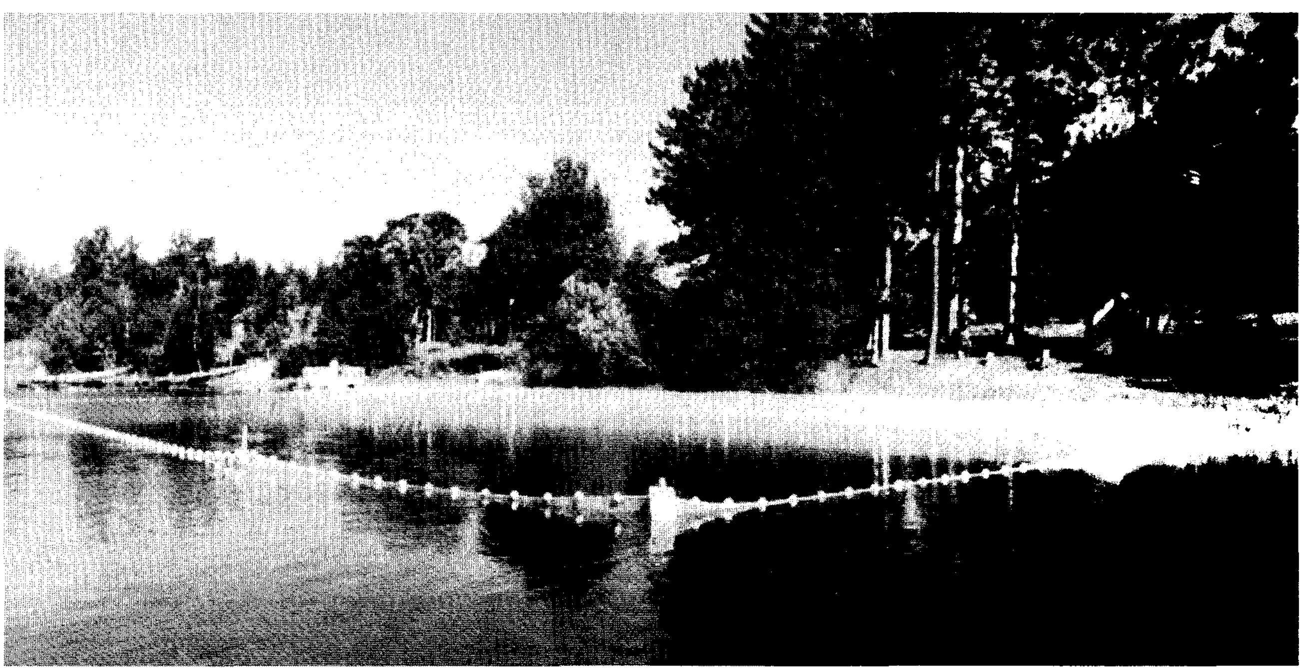

PHOTO: TERRY MARGENAU

Figure 2. *Holding enclosure for muskellunge fingerlings.*

Survival Evaluations

Survival of stocked muskellunge was evaluated beginning 30 days after their release from the enclosures. Using a boat-mounted A.C. boom-shocker, sampling consisted of shocking one entire circuit around each lake on each date. Sampling was conducted on 3-5 different dates on each study lake. Muskellunge sampled were inspected for a fin clip, measured to the nearest 0.1 inch, and immediately released near the shoreline close to the location where they were found. All captured fish were given a temporary mark by clipping the top portion of the caudal fin to facilitate identification during the recapture period. Days at large (42-71 days) were determined by the last sampling date on each lake.

Comparison of the 2 groups (direct-release and enclosure-held muskellunge) was made using chi-square analysis of the actual number of fish captured from each group and by population estimates. As approximately equal numbers of fingerlings from each group were released into each study lake, similar survival of the 2 groups would result in a 1:1 ratio during the recapture period. Population estimates were made from multiple samples and were based on the maximum-likelihood solution to the Schnabel model (Robson and Regier 1978).

Results

Initial mortality (within 48 hours) of muskellunge in enclosures as a result of stocking stressors (handling, fin-clipping, transport, and temperature change) was nil. In all 4 study lakes, only one muskellunge was found dead inside an enclosure. Hatchery water temperature at stocking on 29 August 1989 was 68 F compared with lake temperatures of 75 F (Twenty-Six Lake and Leisure Lake). Lake temperatures in Barber Lake and Big Moon Lake at stocking on 10 September 1990 were 73 F, compared with the hatchery temperature of 67 F.

Holding muskellunge in enclosures for 4 days did not improve short-term (42-71 days) survival. Results from both chi-square comparisons and population estimates suggested similar survival of muskellunge held in enclosures and released directly at the lake access site.

Actual numbers of muskellunge recaptured from the 2 groups (enclosure-held versus direct-release into the lake) were not significantly different (Table 1). Numbers of muskellunge recaptured from the standard stocking procedure group were greater than recaptures that had been isolated in enclosures in Twenty-Six Lake in 1989. Conversely, numbers of muskellunge recaptured during 1989 from Leisure Lake and during 1990 (Barber and Big Moon lakes) were greater for fish held in enclosures. None of these differences were significant for any of the study lakes.

Short-term survival (42-71 days) based on population estimates indicated similar survival between enclosure-held and direct-release muskellunge in all 4 study lakes (Table 2). The range in survival among groups in different lakes varied considerably (13.0% to 64.7%). Survival of muskellunge stocked during 1989 evaluations was considerably lower than survival of muskellunge stocked during 1990 for both treatment and control groups.

Results from the chi-square analysis were in agreement with population estimates. The greatest discrepancy in the 2 methods was seen in data from Big Moon Lake, for which population estimates were similar for the 2 groups, while more muskellunge from enclosures were recaptured (76 enclosure-held, 55 direct-release) (Tables 1, 2).

During the period that muskellunge were held in enclosures, there was no evidence that herons made any attempt to enter the enclosures. However, during a routine morning inspection of Twenty-Six Lake, 2 river otters (*Lutra canadensis*) were found inside one of the enclosures. The extent of their predation on muskellunge inside the enclosure was not determined, but 5 muskellunge heads were found near shore. Hence, predation by otters in at least one enclosure of Twenty-Six Lake may help explain the low observed survival. Exclusion of the Twenty-Six Lake data did not affect the general conclusion that the enclosures did not aid survival.

Casual observations of muskellunge both from a boat and by a scuba diver indicated that muskellunge typically remained in deeper portions of the enclosures during daylight, utilizing submersed vegetation, netting of the enclosure, and other available hiding cover. At night, fingerlings generally moved to shallow water with emersed vegetation, and they were also seen in deeper water (3-4 ft) just under the surface. No extensive behavioral observations were made due to risk of alarming or causing undue stress to enclosure-held fish.

Table 1. *Number of muskellunge recaptured from the 2 treatment groups (direct-release and enclosure-held) and chi-square significance.**

Lake	Year	Group	No. Muskellunge Recaptured	χ^2
Twenty-Six	1989	Direct-release	37	
		Enclosure-held	29	1.0 n.s.**
Leisure	1989	Direct-release	10	
		Enclosure-held	13	0.4 n.s.
Barber	1990	Direct-release	80	
		Enclosure-held	83	0.1 n.s.
Big Moon	1990	Direct-release	55	
		Enclosure-held	76	3.4 n.s.

* H_0: Equal returns from each group. Degrees of freedom = 1.
** n.s. = not significant at $P < .05$.

Table 2. *Survival, based on population estimates, of direct-release and enclosure-held muskellunge stocked in study lakes.*

Lake	Year	Group	Initial No. Muskellunge Stocked	Days at Large	Population Estimate	95% C.I.	Observed Survival (%)
Twenty-Six	1989	Direct-release	230	56	45	36-53	19.6
		Enclosure-held	230	56	32	27-36	13.9
Leisure	1989	Direct-release	100	71	13	7-18	13.0
		Enclosure-held	100	71	22	3-37	22.0
Barber	1990	Direct-release	237	42	140	100-180	59.1
		Enclosure-held	238	42	147	104-191	61.2
Big Moon	1990	Direct-release	190	49	123	70-177	64.7
		Enclosure-held	191	49	121	92-150	63.4

Discussion and Implications for Management

Results from this study showed no improvement in short-term survival from holding muskellunge in enclosures for 4 days prior to their release. Survival rates between groups (enclosure-held and direct-release) were similar in all 4 study lakes. Enclosures did appear to isolate muskellunge successfully from aquatic predators such as northern pike (*Esox lucius*); however, no quantitative sampling was done to confirm if predators were present or could enter the enclosures, or if muskellunge could escape from the enclosures. The enclosure design was successful in keeping great blue herons away from muskellunge; however, the extent to which muskellunge were vulnerable to other predators was not known. Observations of otters inside one enclosure suggest that while enclosures protected muskellunge from certain predators, they may also have made them more vulnerable to others.

It is possible that survival may have been improved by modifying the time of confinement and the density of fingerlings inside enclosures. However, results from our trials (holding muskellunge for 8 days) and physiological studies conducted by Miles et al. (1974), Mather et al. (1986), and Mather and Wahl (1989) suggest that a confinement time of 4 days should have been adequate without being excessive. Density of muskellunge within enclosures during this study (1 fish/50-165 ft^2) was considerably less than the mean density of 1 fish/0.5 ft^2 tested by Johnson (1982). In addition, enclosures used in this study offered a diversity of habitat types and greater depths.

Another consideration is that the muskellunge in this study (having never been exposed to predators in hatchery ponds) were still naive to predators upon release from enclosures. Conditioning muskellunge to predators prior to stocking is a justifiable and testable hypothesis which warrants consideration in future research of fingerling muskellunge survival. Experiments with coho salmon (*Oncorhynchus kisutch*) have indicated that juvenile salmon conditioned to predators showed considerably higher survival rates than naive salmon (Olla and Davis 1989).

The lower survival of stocked muskellunge in 1989 compared with 1990 may be partially explained by length at stocking (1989 mean = 10.0 inches; 1990 mean = 11.5 inches) and/or the greater number of days at large for muskellunge in 1989. However, this study was not designed to consider factors affecting mortality between lakes, but rather to compare mortality of the 2 treatment groups within each lake.

This study did not attempt to explore underlying reasons for why muskellunge do or do not survive the first several months after stocking. Instead, the experimental design was intended to test whether this specific enclosure and holding procedure held promise for improving muskellunge survival. To be a useful tool for management, use of enclosures such as those evaluated in this study would have to result in improved short-term survival of muskellunge; this could result in more cost-effective management by increasing recruitment of stocked muskellunge into the fishery. Survival increases resulting from the use of enclosures need to be significant enough to offset the additional costs (in labor and equipment) of operating holding enclosures in a lake. This was not the case with the 4 lakes in this study.

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