2004. Proceedings of the Indiana Academy of Science 113(2):109–114

CHANGES IN POPULATION STRUCTURE OF YELLOW PERCH FOLLOWING MANUAL REMOVAL

William F. Bauer[1], **Trent M. Sutton**[2], and **Roger W. Greil:** Aquatic Research Laboratory, Lake Superior State University, 650 W. Easterday, Sault Sainte Marie, Michigan 49783 USA

Kenneth G. Ostrand: Sam Parr Biological Station, Center for Aquatic Ecology, Illinois Natural History Survey, 6401 Meacham Road, Kinmundy, Illinois 62854 USA

ABSTRACT. In small inland lakes that support stunted yellow perch *Perca flavescens*, reduction of fish density by manual removal may be the only feasible approach to increase growth and alter population structure. We examined changes in the size distribution, condition, and stock density of yellow perch in Soldier Lake, Michigan between pre-manipulation (1997 and 1998) and post-manipulation years (1999 and 2000). Although mean total length of yellow perch decreased from 95.4 to 85.2 mm between pre- and post-manipulation years, there was a 12% increase in larger (> 150 mm) fish in the population following manual removal. The yellow perch population following manual removal was broader in total length and was positively kurtotic and skewed toward larger fish than in pre-manipulation years. The mean weight of yellow perch (9.6 g) prior to manual removal was significantly lower (13.8 g) than for fish collected during post-manipulation years. Mean relative weight (92 and 85, respectively) and proportional stock density (38 and 5, respectively) of yellow perch were higher in post-manipulation years than prior to the manual removal. Based on these study results, we recommend the use of manual removal to increase the growth and size structure of yellow perch in small inland lakes.

Keywords: Yellow perch, *Perca flavescens*, manual removal, growth, size structure

Many small lakes and impoundments in north temperate latitudes support abundant populations of yellow perch (*Perca flavescens*) that are too small to sustain a viable recreational fishery (Persson 1983; Sandheinrich & Hubert 1984; Jansen & MacKay 1991). Limited growth and subsequent stunting of overabundant yellow perch can occur from intra- or interspecific competition for limited trophic resources (Ridgway & Chapleau 1994). For example, Lott et al. (1996) found that the lack of an adequate prey base during their ontogenetic shifts in yellow perch food habits from zooplankton to aquatic insects was a major factor that contributed to the slow growth. This problem is often compounded because this species may reach reproductive maturity at small sizes and young ages (i.e., within the first year of life), which allows for rapid production of offspring that often cannot be harvested by sport fishes or anglers (Herman et al. 1959; Diana & Salz 1990; Roff 1992). As a result, yellow perch are unable to grow to lengths where they can consume piscine prey and reach harvestable sizes.

To alleviate stunting of fish populations in small lakes, a variety of management solutions have been proposed including the alteration of trophic resources and introducing or augmenting top predator populations (Noble 1980; Diana 1987). However, management solutions based solely on density-dependent mechanisms have been met with mixed success because predator stocking rates are either inadequate to control prey fishes or are too high and result in resource competition with other desirable sport fish populations (Diana 1987; Wydoski & Wiley 1999). In addition, maintaining an adequate and effective preda-

[1] *Current address:* Sam Parr Biological Station, Center for Aquatic Ecology, Illinois Natural History Survey, 6401 Meacham Road, Kinmundy, Illinois 62854 USA

[2] *Current address:* Department of Forestry and Natural Resources, Purdue University, 195 Marsteller Street, West Lafayette, Indiana 47907 USA

tor base is often difficult in many small lakes due to excessive recreational harvest. However, the use of entrapment gears to reduce densities of overabundant fishes has been shown to be effective for meeting management objectives. For example, the manual removal of black crappie (*Pomoxis nigromaculatus*) and black bullhead (*Ameiurus melas*) from a Wisconsin lake had a significant impact on population size structure of these fishes, increasing the density of black crappie longer than 200 mm in length by 430% and the number of black bullhead longer than 260 mm in length by 1100% (Hanson et al. 1983).

Soldier Lake, a small lake located in the Upper Peninsula of Michigan, supports a stunted yellow perch population. Because top piscivores in this system have been unable to effectively control the yellow perch population, we examined the effectiveness of using fyke nets to manually remove yellow perch. This study compared changes in the size distribution, condition, and population structure of yellow perch between pre-manipulation (1997 and 1998) and post-manipulation years (1999 and 2000).

METHODS

Study area.—Soldier Lake (Chippewa County, Michigan) is a shallow (mean depth = 4.4 m) lake with a surface area of 7.6 ha (Fig. 1). Although the pH of the lake is moderately acidic (range 4.5–6.9), dissolved-oxygen levels are sufficient to support aquatic life (range 7.4–10.8 mg/L). The lake supports sparse emergent and submergent aquatic macrophytes around its perimeter, and the bottom substrate is comprised of a thick layer of detritus. A small recreational fishery for yellow perch and largemouth bass (*Micropterus salmoides*) exists. The latter species was stocked at low levels as fingerlings in 1996 and 1997 by the Michigan Department of Natural Resources. The only other fish species present in the lake is the brown bullhead (*Ameiurus nebulosus*) which occurs at a relatively low density. The invertebrate community is dominated by odonates, but also includes trichopterans, ephemeropterans, coleopterans, dipterans, hemipterans, and gastropods.

Data collection.—Yellow perch were collected from Soldier Lake using four fyke nets from 1997 through 2000. Pre-manipulation (i.e., prior to manual removal) years were

Figure 1.—Map of the Upper Peninsula of Michigan showing the location (●) of Soldier Lake in Chippewa County.

1997 and 1998, while post-manipulation (i.e., following manual removal) years included data collected in 1999 and 2000. Two of the fyke nets had a 2.0 m × 1.2 m mouth and were covered by 1.3 cm stretch mesh, while the other two fyke nets had a 1.0 m × 0.7 m mouth and were covered by 0.6 cm stretch mesh. Fyke nets were set overnight at four fixed stations once each month during April and October 1997, 1998, and 1999 and once each month from May through September 2000.

In 1997, 1998, Fall 1999, and 2000, yellow perch were measured for total length (TL) to the nearest 1 mm, weighed to the nearest 0.01 g, and released alive at the location of capture. In April 1999, fish were measured and weighed as previously described and permanently removed from Soldier Lake (approximately 8116 fish weighing a total of 642 kg). Condition of yellow perch was calculated using relative weight (W_r), described as:

$$W_r = (W/W_s) \times 100$$

where W was the measured wet weight of each individual fish and W_s was the length-specific standard weight for yellow perch derived from the standard-weight equation $\log_{10}(W_s) = -5.386 + 3.23 \times \log_{10}TL - 5.386$ (Wege & Anderson 1978; Willis et al. 1991; Anderson & Neumann 1996). Proportional stock-density (PSD) was calculated using length-category values developed by Gabelhouse (1984), where the minimum total length for each category was as follows: stock (130 mm) and quality (200 mm). Relative stock density indices were not calculated because of the low numbers of yellow perch collected that were greater than quality length (i.e., the minimum length for yellow perch [200 mm] that anglers like to catch; Gabelhouse 1984).

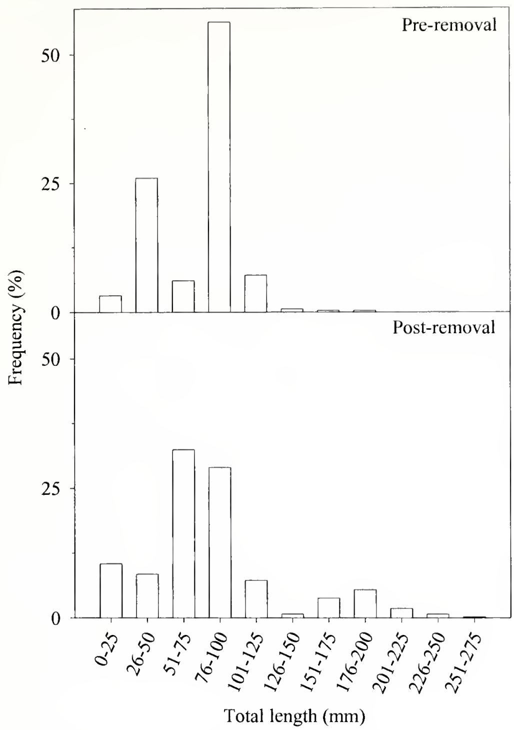

Figure 2.—Length-frequency distributions of yellow perch in Soldier Lake, Michigan, during pre-manual removal (1997 and 1998) and post-manual removal (1999 and 2000) years. Fish were grouped into 25 mm total length intervals.

Yellow perch captured in fyke nets during 2000 (n = 401) received a partial dorsal fin clip prior to release back into the lake for a mark-and-recapture population estimate using the Chapman's modification of the Schnabel estimator (Schnabel 1938; Chapman 1951). For the population abundance estimate, we determined a 95% confidence interval using a Poisson distribution (Ricker 1975). Biomass of yellow perch (kg/ha) was estimated to compare Soldier Lake to other inland lakes by multiplying the overall mean weight by the estimated population abundance and dividing it by the total surface area of the lake.

Data analyses.—For all statistical analyses, pre-manipulation (i.e., 1997 and 1998) and post-manipulation (1999 and 2000) year data were pooled to incorporate annual variability and increase sample sizes and statistical power. Total length, wet weight, and relative weight of yellow perch were compared between pre- and post-manipulation years using student's t-tests that were Bonferroni corrected to control experiment-wise error (Zar 1999). In addition, qualitative comparisons of proportional stock density index values for yellow perch were also made between pre- and post-manipulation years. Estimates of kurtosis and skewness were used to further describe changes in length-frequency distributions between pre- and post-manipulation years, and a Kolmogorov-Smirnov test was used to test the significance of the skewness estimates (Zar 1999). All data analyses were conducted using the SAS statistical analysis program (SAS Institute 1990) at an α = 0.05 level of confidence.

RESULTS

Prior to the manual removal, small (< 150 mm TL) yellow perch were abundant in Soldier Lake, comprising 99% of the population (Fig. 2). Within one year following the manual removal, the mean total length was significantly lower, decreasing by 10 mm. However, the number of yellow perch greater than 150 mm TL increased by 12% (Fig. 2). Following the manual removal, the length-frequency distribution was more broadly distributed, positively kurtotic, and skewed toward larger size classes than in pre-manipulation years (Table 1).

The mean weight of yellow perch was significantly greater following the manual removal (13.8 g; range 0.6–166.0 g) than during pre-manipulation years (mean = 9.6 g; range 1.0–88.0 g; Table 1). Following the manual removal, Soldier Lake contained approximately 79,000 yellow perch (95% confidence interval; 30,905–152,052 fish), with an estimated biomass of 124 kg/ha (95% confidence interval; 52.5–258.5 kg/ha). Relative weight and proportional stock density index values of yellow perch were greater in post-removal years (92 and 38, respectively) than for pre-manipulation years (85 and 5, respectively; Table 1).

DISCUSSION

Our results suggest that the manual removal of yellow perch from Soldier Lake was effective in altering the size structure and condition while also improving the quality of the recreational fishery. One year following the manual removal, the population structure of yellow perch had shifted to larger (> 150 mm)

Table 1.—Comparison of mean (ranges in parentheses) total length (mm), wet weight (g), relative weight, proportional stock density (PSD), skewness, and kurtosis of yellow perch collected from Soldier Lake, Michigan, before (1997 and 1998) and after (1999 and 2000) conducting a manual removal in spring 1999. Contrast denotes t and D statistic, respectively.

Response variable	Pre-manipulation	Post-manipulation	Contrast	P-value
Total length (mm)	95 (25–240)	85 (41–252)	5.5	<0.01
Wet weight (g)	9.6 (1.0–88.0)	13.8 (0.6–166.0)	5.2	<0.01
Relative weight	85 (37–361)	92 (41–132)	−2.8	<0.01
Proportional stock density	5	38	—	—
Kurtosis	−0.12	2.26	—	—
Skewness	−0.08	1.71	0.45	<0.01

fish with a greater relative weight. Post-manipulation biomass of yellow perch in Soldier Lake (124 kg/ha) was substantially greater than average biomass estimates reported in small lakes in Wisconsin (56 kg/ha), Michigan (32 kg/ha), and Minnesota (21 kg/ha; Herman et al. 1959). A significant change in stock structure also occurred after the manipulation, with proportional stock density index estimates increasing more than seven-fold in post-removal years. According to Anderson & Weithman (1978), a balanced yellow perch population has a proportional stock density that ranges between 30 and 60. A post-manipulation proportional stock density of 38 suggests the population may be developing into a more balanced state. Our results also suggest that this shift in population structure and increase in relative weight may be the result of lower intraspecific competition for food resources. We hypothesize that Soldier Lake would continue to benefit from future manual removals of yellow perch, which may continue to increase the size structure and condition of this sport fish population.

The increase in relative weight that was observed in Soldier Lake following the manual removal indicates that yellow perch were in better condition than prior to the manipulation. An increased weight gain in yellow perch has the potential to impact individual fitness (Keast & Eadie 1985; Ludsin & DeVries 1997; Sammons et al. 1999). As a result, aggressive and successive manual removals may be required to maintain continued positive increases in growth. Because weight is strongly correlated with fecundity in yellow perch, the effects of a reduction in the adult population in Soldier Lake may be only measurable over a single season. In subsequent years, large year classes could return the population to its pre-manipulation abundance and biomass levels as suggested by the strong year class that we observed the year following the manual removal in Soldier Lake (W. Bauer unpubl. data). Similar results have also been observed by Amundsen et al. (1993) for Arctic char (*Salvelinus alpinus*) in Norway. Additional examinations will be required to determine whether the differences in size structure that we observed continue or revert to pre-manipulation conditions due to multiple strong year classes.

Lack of the appropriate size and type of prey available for yellow perch has been shown to limit growth and cause stunting in other systems (Wootton 1990; Hayes et al. 1992). In Soldier Lake, we determined that the diet of yellow perch was comprised primarily of macroinvertebrates, with few yellow perch consuming piscine prey (W. Bauer unpubl. data). Lott et al. (1996) found that yellow perch maintained rapid growth on diets that were dominated by large macroinvertebrate prey. However, odonates were the most common macroinvertebrate by number and weight in the diet of yellow perch in Soldier Lake. If fish are available as prey, the diet of yellow perch will typically shift from macroinvertebrates to fish when yellow perch reach between 150–200 mm in length (Clady 1974). In Soldier Lake, yellow perch rarely reach lengths that allow them to consume piscine prey. Further, piscine prey were not readily available as forage in this system (W. Bauer unpubl. data). Therefore, stunting of yellow perch in Soldier Lake appears to result from intraspecific competition for limited resources, particularly for fish prey within predator ingestibility limits.

Manual removal was chosen over other types of population-manipulation approaches due to the ease of implementation and cost effectiveness. In contrast, the large-scale stocking of predators (in this case, largemouth bass) would have been costly and most likely met with little success (Diana 1987; Wydoski & Wiley 1999). Maintaining a predator base that is effective at reducing high densities of yellow perch may be difficult in small impoundments due to high angling pressure and a lack of suitable habitat (Olson et al. 2001). Increased recruitment as a response to decreased fish density from manual removal does suggest that the fish population could return to a stunted condition following cessation of this manipulation (Amundsen et al. 1993). For this reason, we recommend that additional manual removals should be implemented in subsequent years as it has been reported that at least two consecutive years are required for lasting affects (C. Bassett, USDA Forest Service - Hiawatha National Forest, pers. commun.). As a result, we predict that the size structure and condition of yellow perch will continue to increase due to the reduction in population abundance and intraspecific competition for trophic resources in Soldier Lake. In addition, the production of strong year classes should provide large yellow perch with a piscine prey base. Piscine prey, as an important component in growth for yellow perch, will enable the population to maintain larger sizes and move toward a more balanced size structure. Therefore, we recommend manual removals as a management tool for alleviating slow growth of yellow perch populations in small inland lakes and impoundments.

ACKNOWLEDGMENTS

We thank the USDA Forest Service and Michigan Department of Natural Resources for their collaboration during this project. We also thank the Lake Superior State University Fish and Wildlife Club, the Soo Area Sportsman's Club, and K. Pangle and K. Kruckeberg for their assistance in data collection. Constructive comments on an earlier draft by S. Scott, C. Bassett, J. Reattoir, M. Siepker, D. Daugherty, A. Kennedy and A. Benson improved this manuscript.

LITERATURE CITED

Amundsen, P.A., A. Klemetsen & P.E. Grotnes. 1993. Rehabilitation of a stunted population of Arctic char by intensive fishing. North American Journal of Fisheries Management 13:483–491.

Anderson, R.O. & R.M. Neumann. 1996. Length, weight, and associated structural indices. Pp. 447–482, *In* Fisheries Techniques, Second edition. (B.R. Murphy & D.W. Willis, eds.). American Fisheries Society. Bethesda, Maryland.

Anderson, R.O. & A.S. Weithman. 1978. The concept of balance for coolwater fish populations. American Fisheries Society Special Publication 11:371–381.

Chapman, D.G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. University of California Publications in Statistics 1:131–160.

Clady, M.D. 1974. Food habits of yellow perch, smallmouth bass, and largemouth bass in two unproductive lakes in northern Michigan. American Midland Naturalist 91:453–459.

Diana, J.S. 1987. Simulation of mechanisms causing stunting in northern pike populations. Transactions of the American Fisheries Society 116: 612–617.

Diana, J.S. & R. Salz. 1990. Energy storage, growth, and maturation of yellow perch from different locations in Saginaw Bay, Michigan. Transactions of the American Fisheries Society 119:976–984.

Gabelhouse, D.W., Jr. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273–285.

Hanson, D.A., B.J. Belonger & D.L. Schoenike. 1983. Evaluation of a mechanical population reduction of black crappie and black bullheads in a small Wisconsin lake. North American Journal of Fisheries Management 3:41–47.

Hayes, D.B., W.W. Taylor & J.C. Schneider. 1992. Response of yellow perch and the benthic invertebrate community to a reduction in the abundance of white suckers. Transactions of the American Fisheries Society 121:36–53.

Herman, E., W. Wisby, L. Wiegert & M. Burdick. 1959. The Yellow Perch: Its Life History, Ecology, and Management. Wisconsin Conservation Department Fishery Biology Investigation Report 228. Madison, Wisconsin.

Jansen, W.A. & W.C. MacKay. 1991. Body composition and reproductive investment of stunted yellow perch, *Perca flavescens*. International Association of Theoretical Applied Limnology Proceedings 24:2356–2361.

Keast, A. & J. Eadie. 1985. Growth dispensation in year-0 largemouth bass: The influence of diet. Transactions of the American Fisheries Society 114:204–213.

Lott, J.P., D.O. Lucchesi & D.W. Willis. 1996. Relationship of food habits to yellow perch growth and population structure in South Dakota lakes. Journal of Freshwater Ecology 11:27–37.

Ludsin, S.A. & D.R. DeVries. 1997. First year recruitment of largemouth bass: Interdependency of early life stages. Ecological Applications 8: 88–103.

Noble, R.L. 1980. Management of lakes, reservoirs, and ponds. Pp. 265–296, *In* Fisheries Management. (R.T. Lackey & L.A. Nielson, eds.). Wiley, New York.

Olson, M.H., D.M. Green & L.G. Rudstam. 2001. Changes in yellow perch (*Perca flavescens*) growth associated with the establishment of a walleye (*Stizostedion vitreum*) population in Canadarago Lake, New York (USA). Ecology of Freshwater Fish 10:11–20.

Persson, L. 1983. Food consumption and competition between age classes in a perch *Perca fluviatilis* population in a shallow eutrophic lake. Oikos 40:197–207.

Ricker, W.E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Fisheries Research Board of Canada Bulletin 191. Ottawa, Canada.

Ridgway, L.L. & F. Chapleau. 1994. Study of a stunted population of yellow perch (*Perca flavescens* in a monospecific lake in Gatineau Park, Quebec. Canadian Journal of Zoology 34:1576–1582.

Roff, D.A. 1992. The Evolution of Life Histories: Theory and Analysis. Routledge, Chapman and Hall. New York.

Sammons, S.M., L.G. Dorsey, P.W. Bettoli & F.C. Fiss. 1999. Effects of reservoir hydrology on reproduction by largemouth bass and spotted bass in Normandy Reservoir, Tennessee. North American Journal of Fisheries Management 19:78–88.

Sandheinrich, M.B. & W.A. Hubert. 1984. Intraspecific resource partitioning by yellow perch (*Perca flavescens*) in a stratified lake. Canadian Journal of Fisheries and Aquatic Sciences 41:1745–1752.

SAS Institute, Inc. 1999. SAS Users Guide: Statistics, Version 7.0. SAS Institute. Cary, North Carolina.

Schnabel, Z.E. 1938. The estimation of the total fish population of a lake. American Mathematical Monographs 45:348–368.

Wege, G.J. & R.O. Anderson. 1978. Relative weight (W_r): A new index of condition for largemouth bass. Pp. 79–91, *In* New Approaches to the Management of Small Impoundments. (G.D. Novinger & J.G. Dillard, eds.). American Fisheries Society, North Central Division, Special Publication 5. Bethesda, Maryland.

Willis, D.W., C.S. Guy & B.R. Murphy. 1991. Development and evaluation of a standard weight (W_s) equation for yellow perch. North American Journal of Fisheries Management 11:374–380.

Wydoski, R.S. & R.W. Wiley. 1999. Management of undesirable fish species. Pp. 403–426, *In* Inland Fisheries Management in North America, Second edition. (C.C. Kohler & W.A. Hubert, eds.). American Fisheries Society. Bethesda, Maryland.

Wootton, R.J. 1990. Ecology of Teleost Fishes. Chapman and Hall. New York.

Zar, J.H. 1999. Biostatistical Analysis, Fourth edition. Prentice-Hall. New York.

Manuscript received 8 March 2004, revised 9 August 2004.