Changes in the Muskellunge Fishery and Population of Lake St. Clair after an Increase in the Minimum Size Limit

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In response to high harvests and indications of stock declines in the late 1970s and early 1980s the minimum size limit for muskellunge *(Esox masquinongy)* for Lake St. Clair was elevated from 76 to 102 cm (30 to 40 inches) in 1987. This regulation change was implemented to protect female muskellunge through two repeat spawnings and to support a muskellunge management objective for a high quality trophy fishery based on natural reproduction. Changes in the muskellunge stock and fishery of Lake St. Clair were demonstrated by calculating length group specific indices of relative abundance. This analysis indicated that an immediate and dramatic increase had occurred in the newly protected 76 to 102 cm length group (an average annual increase of 15% with a doubling of the stock in seven years). Elevation of the minimum size limit afforded important protection to this segment of the stock which represents the prime breeding muskellunge. It also enabled a buildup of the spawning stock over the next four year period (1987-1990), with subsequent enhancements to recruitment based on strong year-classes occurring in 1991 and 1994. The dramatic turn-around in the Lake St. Clair muskellunge fishery emphasizes the need for, and benefit of, appropriate size-based regulations and effective angler catch-and-release initiatives. An angler diary program can make an extremely valuable contribution to management of muskellunge through the provision of comprehensive and cost-effective stock monitoring data. Favourable changes to musky habitat occurred during the same period but the habitat contribution to musky production and abundance, relative to changes in angling regulations and angler attitudes is unknown.

Introduction

Lake St. Clair is part of the Great Lakes interconnecting waters with a surface area of 127,000 ha (1,110 km^2), 75,000 of which are in Ontario (Fig. 1). It has a mean depth of only 3.0 m, is generally meosotrophic, and has many marshes and wetland areas. The habitat of Lake St. Clair supports a varied fish community of coolwater (primarily percid and esocid) and warmwater (centrachid) species.

Lake St. Clair is one of the most intensively utilized lakes in North America. The human population adjacent to the St. Clair system is estimated at about 6.0 million. The recreational fishery is the most intensive in southwestern Ontario with a summer (June-August) mean angler-effort of 300,000 rod-hrs or 4.0 rod-hrs ha^{-1} (1978-1992 angler surveys, Ontario waters). Muskellunge (Esox masquinongy) in the angler fishery represents the fourth most sought species and one tenth of all summer angler effort, with an average annual angler effort of 30,000 rod-hrs or 0.4 rod-hrs ha^{-1} (1978-1992) and an annual catch of over 2,500

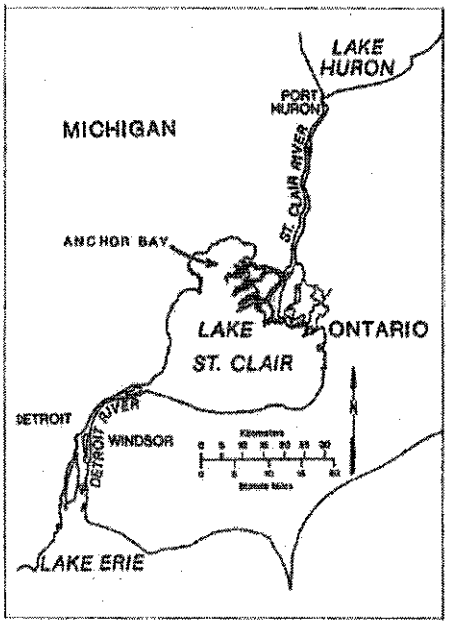

Fig. 1. Map of Lake St. Clair.

fish or 0.03 fish ha^{-1} (9.9 kg/fish) (1992 angler survey).

Status and Management of Muskellunge in Lake St. Clair Prior to Elevation of the Minimum Size Limit

A 76 cm minimum size limit regulation for muskellunge had been in place for the Ontario waters of Lake St. Clair for many years prior to 1987. In the early 1980s concern was mounting over the status of muskellunge in Lake St. Clair. Angler fishery survey data from 1978 and 1979 indicated a substantial level of harvest with annual catches of about 1000 fish and harvests of 700-800 fish (Fig. 2). About 80% of the angler catch was kept. Relatively high harvests continued into the 1980s. These harvests represented annual yields of one muskellunge or 10 kg 100 ha^{-1}.

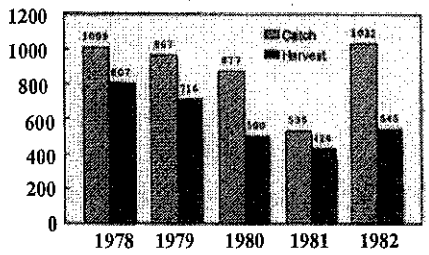

Fig. 2. Number of muskellunge in the angler catch and harvest, Lake St. Clair angler survey data, 1978-1982.

Angler fishery survey data from 1979 to 1983 (Fig. 3) showed a consistent trend of progressively declining muskellunge angler catch rates (average number of fish caught per rod-hr of effort by muskellunge anglers, or CUE). The consistency of the trend in angler CUES indicated that the abundance of muskellunge in Lake St. Clair might be declining significantly.

At about the same time (1985-1986) an Ontario Ministry of Natural Resources (OMNR) committee was reviewing angling regulations appropriate to meet established objectives for the management of muskellunge fisheries across Ontario (OMNR 1986). This committee expressed concerns about the reduction in the number and size of angler-caught muskellunge,

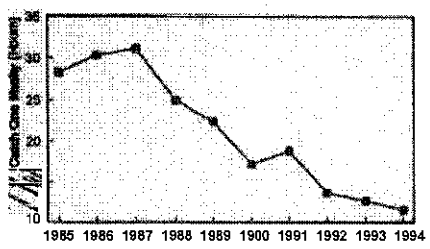

Fig. 3. Muskellunge angler catch-per-unit-effort (CUE), Lake St. Clair angler survey data, *1978-1983.*

the relatively high growth rates and the truncated population structure (i.e., an almost total absence of older fish) in Lake St. Clair. These characteristics suggested heavy exploitation, perhaps overexploitation.

The committee recommended establishing a muskellunge management objective for a high quality trophy fishery based on natural reproduction. They concluded that to provide adequate reproduction to maintain or enhance muskellunge resources, it would be important that regulations be directed at protecting prime breeding fish and particularly in providing repeat spawners. Data from Lake St. Clair indicated that female muskellunge started to mature at age five, or a total length of 87.6 cm. To allow two repeat spawnings, Lake St. Clair female muskellunge would require protection to age seven, and a total length of 100.2 cm.

In 1987, the OMNR revised muskellunge regulations for the Ontario waters of Lake St. Clair by elevating the minimum size limit from 76 to 102 cm and reducing the daily bag limit from two to one per day (possession limit remained at two). These changes were instituted to protect female muskellunge through two spawning seasons and thus support a management objective for a high quality muskellunge fishery based on natural reproduction.

Previously, the Michigan Department of Natural Resources had elevated the minimum size limit for muskellunge in the U.S. waters of Lake St. Clair from 76 to 91 cm in 1976, then to 97 cm in 1981 and, in a bilateral move with Ontario, to 102 in 1987. In the early to mid 1980s, Michigan anglers, primarily members of the Michigan-Ontario Muskie Club (MOMC), lobbied for a minimum size limit increase to 102 cm and voluntarily observed a 102 cm minimum size as they promoted a catch-andrelease fishing ethic.

Response of the Muskellunge Fishery and Population After the 1987 Elevation of the Minimum Size Limit

Elevation of the minimum size limit from 76 to 102 cm was implemented in 1987. After this regulation change, angler fishery harvests of muskellunge decreased from previous levels of 400-800 fish to 100-200 fish (Fig. 4a) and catch retention rates from 40-80% to 5-15% (Fig. 4b).

The increase in the minimum size limit and attendant reduction in harvest was expected to result in increased muskellunge abundance and angler catch rates over the long term. The

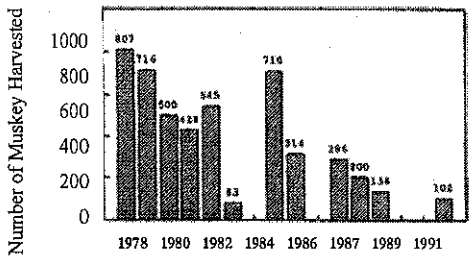

Fig. 4a. Muskellunge angler annual harvest (number of fish) before and after elevation of the minimum size limit in 1987, Lake St. Clair angler survey data, 1978-1992.

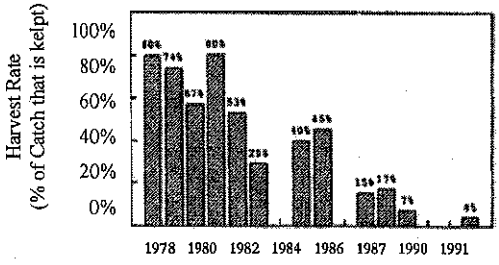

Fig. 4b. Muskellunge angler harvest rate (% of catch kept) before and after elevation of the minimum size limit in 1987, Lake St. Clair angler survey data, 1978-1992.

process of stock rebuilding and improvements to the fishery were expected to be in the order of one or two muskellunge life-cycle generation periods, that is, in six to ten years or by 1993 to 1997. It was estimated that the process would involve an initial gradual buildup of the spawning stock over three to six years which would increase the stock's reproductive potential. The enhanced reproductive potential would elevate recruitment, which in turn would show up as a higher abundance of fishable stock (age three to four-year-old fish) in about six to ten years (1993 to 1997).

Instead, an immediate and continuous increase in angler fishery muskellunge catch rates occurred. Angler diary data from 1985 to 1994 (Fig. 5), indicated that angler catch rates for muskellunge declined modestly prior to the regulation change (1985-1987), then increased dramatically after the regulation change with an average increase of 16% per year over the seven years from 1987-1994. The effort (length of time in hours) needed to catch one muskellunge (EUC) (Fig. 6) declined from over 31 hours in 1987 to 11 hours in 1994, a reduction of nearly two-thirds. Interpreting angler CUE and its reciprocal, EUC, as indicators of relative abundance, it was apparent that muskellunge numbers had increased significantly and quickly in Lake St. Clair.

It was first thought that the dramatic increase in angler catch rates for muskellunge, after Ontario

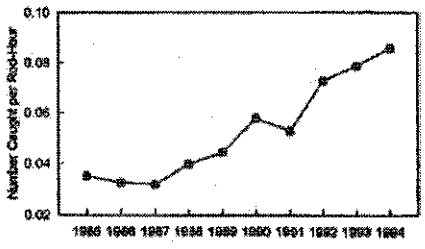

Fig. 5. Muskellunge angler CUE, Lake St. Clair sport diary program data, 1985-1994.

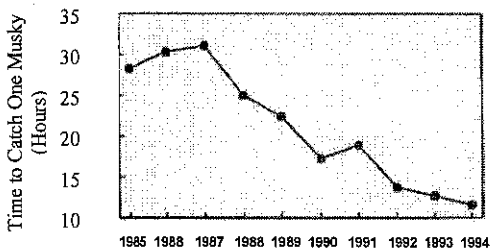

Fig. 6. Time needed to catch one muskellunge (EUC), Lake St. Clair sport diary program, 1985-1994.

had implemented an increase in the minimum size limit, may have merely coincided with increases in the muskellunge stock expected from Michigan's previous minimum size limit regulation changes of nine years and six years earlier (i.e., in 1976 and 1981 the minimum size limit was elevated from 76 to 91 cm and 91 to 97 cm respectively). However, this may not have been true as harvest levels of 400-800 fish and catch retention rates of 45-80% remained high in the Ontario waters of Lake St. Clair after elevation of the Michigan minimum size limit for muskellunge.

OMNR wanted to determine if it was possible to demonstrate that the increase in the Ontario minimum size limit was responsible for these dramatic changes in muskellunge angler CUE and apparent stock abundance. Perhaps changes in the stock related to the potential effects of the regulation could be interpreted through a detailed analysis of length group specific changes in CUE as an indicator of relative abundance changes in the protected and unprotected segments of the stock.

Analysis of angler fishery data involved partitioning the angler catch rates for muskellunge (CUE) into the following three length groups:

1) 76-102 cm - became protected by the increased minimum size limit

2) > 102 cm - never protected (trophy fish)

3) < 76 cm - always protected

Considerable length sampling data had been provided in association with angler diary catch and effort data making it possible to determine reliable length group specific CUE.

The 76-102 cm length group became protected from harvest by the minimum size limit change in 1987. Prior to the 1987 elevation in the minimum size limit, muskellunge in this length group were the most vulnerable to the fishery and typically represented about 65% of the angler catch. The relative abundance of muskellunge in this length group based on angler CUE had been decreasing prior to 1987. After becoming protected by the increase in the minimum size limit in 1987, this trend reversed and this length group exhibited a substantial annual increase in CUE. The annual increase averaged 15% per year which steadily continued through to 1994 (Fig. 7), suggesting a doubling of the stock in seven years. This group was the first to show such a significant change. The large and steady increase observed in the 76 to 102 cm length group indicates elevation of the minimum size limit must have afforded effective and important protection to this segment of the population.

This would, however, be reasonable if the annual rate of exploitation in this segment of the population was reaching 20% or more. Such an estimate of the rate of exploitation would be valid with harvests of 700 fish per year from an estimated population of 3,500 fish, which would have been plausible based on a muskellunge density of just under one muskellunge ha^{-1} over an area of about half the lake.

The rapid rate of increase of muskellunge in this length group is predicated on some important, and hitherto, unrecognized conditions:

1) muskellunge that were caught, but not harvested support future captures, that is, the possibility of multiple captures of individual muskellunge existed; and

2) the decline in harvest under catch-and-release regulations, with future multiple captures that directly supported the observed increase in angler CUE.

The increase in the abundance of muskellunge and angler CUE in this length group could not have occurred as a result of increased recruitment this soon after the regulation change. Thus, the increase observed in angler CUE represents a decline in fishing mortality and the attendant increased probability of multiple recaptures taking place.

The length group exceeding 102 cm represents muskellunge that were available to harvest removal before and after the minimum size limit regulation change. The relative abundance of muskellunge in this group based on angler CUE was below that of the 76-102 cm group reflecting incremental losses from both fishing and natural mortality. The > 102 cm length group shows a very slow degree of increase up to 1987, then a slightly faster, but still modest, rate of increase from 1987 to 1990-91 (Fig. 7). In 1991-92, an additional increase in the rate appeared (despite some nonconformityiin the data points). I interpret the elevation in the rate of increase as representing the spillover of fish

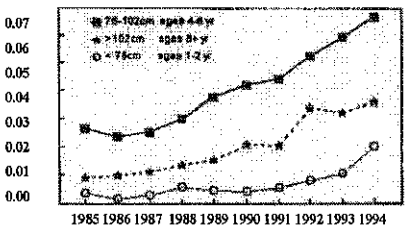

Fig. 7. Muskellunge relative abundance by total length group based on muskellunge angler CUE, Lake St. Clair sport diary program, 1985-1994.

moving first slowly then more rapidly up from the 76-102 cm group into the > 102 cm group (i.e., recruitment). The sequence of smaller but escalating increases in muskellunge abundance occurring in the > 102 cm length group relative to the 76-102 cm length group agrees with the observed and interpreted changes in the 30-40 in length group of the stock previously discussed.

Although it was apparent that recruitment into the > 102 cm group was occurring, their numbers were still quite small based on angler diary scale sample submissions. This group was mostly age eight and older, with some age seven fish and represented only 15% of the catch in 1993-94, with only 3% being age ten and older (Fig. 8). MOMC records show the number of muskellunge above 127 cm has only recently been increasing. With this level of increase expected to continue, the number of fish in this largest length group should increase considerably over time, ultimately providing the basis for a noteworthy trophy angler fishery.

The last group of muskellunge with fish < 76 cm and ages of one to three years, had the lowest angler CUE relative to the other two length groups, despite their obvious higher abundance, as a result of low selectivity by the fishery. There was little or no change in relative abundance based on angler CUE from before the change in the minimum size limit (1985-87) through 1991. In 1992 and 1993, five and six years after the change in the minimum size limit, there was a modest increase in angler CUE with a large increase in 1994 suggesting additions from recruitment (Fig. 7).

Muskellunge scale samples submitted by angler diary participants indicated a large increase in the relative number of three year-old fish in 1994 (Fig. 8), suggesting a strong hatch and recruitment from the 1991 year-class. At age three, these fish would have been just below 76 cm and thus would show up in this length group.

This interpretation of a strong year-class in 1991 based on angler diary data was corroborated by OMNR young-of-year (YOY) survey data. Although the survey does not provide a continuous data series (Fig. 9), no YOY muskellunge were caught in any of the surveyed years from 1979 to 1994 except for 1991 and 1994. These two years may have produced strong year-classes.

Looking at the dynamics of the muskellunge stock by length groups (Fig. 7), the increase in angler CUE and muskellunge abundance in the < 76 cm length group in 1994 represents recruitment of the strong 1991 year-class into the fishery. This would coincide with temporal expectations. The regulation was implemented

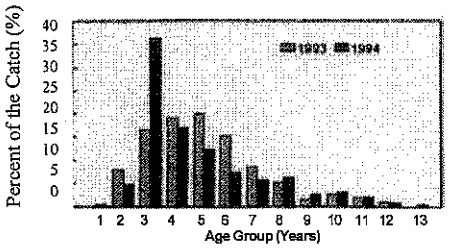

Fig. 8. Muskellunge age composition (%) in the angler catch, Lake St. Clair sport diary program, 1993-1994.

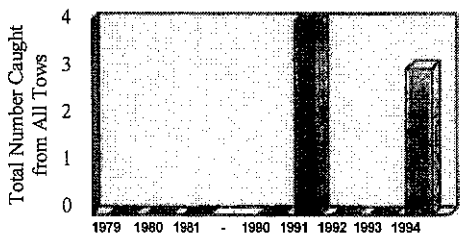

Fig. 9. Total number of YOY muskellunge caught during the Lake St. Clair index netting program, 1979-1994.

in 1987, building of spawning stock biomass occurred over the next four year period, 1987-1990, then dividends in terms of enhanced reproductive potential leading to increased recruitment occurred.

Assessment of Achievement of the Muskellunge Management Objectives for Lake St. Clair

In 1985, the musky review committee (OMNR 1986) was concerned about the high growth rate of Lake St. Clair muskellunge (Fig. 10). Length-at-age data in 1993-94 indicated little apparent change in the muskellunge growth rate (Fig. 10). Thus, the population increase, while dramatic, has not largely altered growth. This may suggest either that food has not been limiting in this system or that the population had been considerably depressed from exploitation to a point that, after a doubling in stock abundance over seven years, the population has not begun to exhibit any of the density dependant effects that would be associated with equilibrium conditions.

Based on angler CUE (Fig. 11), the relative abundance of muskellunge below and to a lesser extent above the minimum size limit has shown a steady increase over the seven years since elevation of the minimum size limit. The apparent increase in the stock both below and

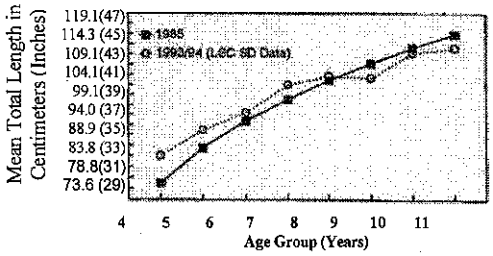

Fig. 10. Muskellunge mean length at age before and after size limit change. OMNR *(1986)* and Lake St. Clair sport diary data *(1993-1994)*.

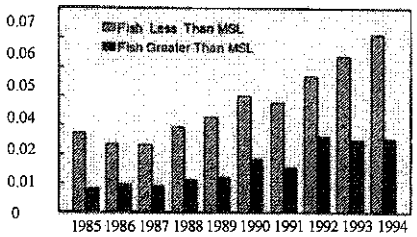

Fig. 11. Muskellunge angler CUE above and below the 102 cm (40 inch) minimum size limit (MSL), Lake St. Clair sport diary program data, 1985-1994.

above the minimum size limit, in contrast to declining indices of abundance for muskellunge prior to 1987, along with YOY data showing improved recruitment in recent years, would indicate that the muskellunge stock of Lake St. Clair has not only been sustained by this management regulation, but has been increasing through natural reproduction.

The number of musky caught over 127 cm (50 inches) or 13.6 kg (30 pounds) may serve as a measure of a trophy musky fishery. Records maintained by MOMC anglers (Fig. 12) show the number of muskellunge caught that were 127 cm and over in total length averaged two fish through the 1980s, with an increasing trend

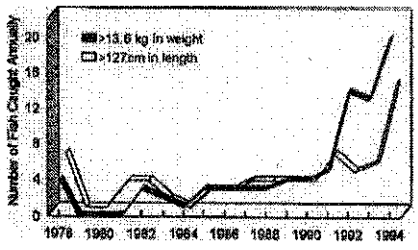

Fig. 12. Annual number of muskellunge caught above 50 inches in length and above 30 pounds in weight, Michigan-Ontario Musky Club, Lake St. Clair data, *1978-1994*.

in the 1990s and a 1994 value of 14. The number of muskellunge caught over 13.6 kg showed similar changes with a 1994 value of 20. By these measures, a trophy muskellunge angler fishery has clearly been developing in Lake St. Clair.

Conclusion

I conclude that the appropriate size limit regulations (which protected breeding female muskellunge) combined with a growing muskellunge angler catch-and-release ethic in Lake St. Clair resulted in realization of a management objective to provide trophy fishing opportunities from a stable self-sustaining muskellunge population. The dramatic turn-around in this muskellunge stock and fishery in Lake St. Clair underscores the need for, and the benefit of, appropriate size-based regulations and angler catch-and-release initiatives.

Sport Diary Program and Data

In 1984 it became apparent that neither a continuous nor intermittent annual source of angler creel survey data would be available. However, a continuous series of angler data is essential to monitor the status of muskellunge stocks and the effect of the change in the minimum size limit. Furthermore, a source of adequate biological data on the catch and harvest, better then that which could be obtained from creel surveys, was required.

An angler diary or sport diary program was considered a potential alternative and effective approach to creel surveys. It offered: (1) continuous data on angler catch and effort data from which CUE and biological data could be derived that could represent an index of the trends in the entire fishery; (2) increased opportunity to interact with sport fishery user groups via meetings with sport fishery clubs to recruit participants and provide program results; and (3) cost-effectiveness at less than 1/20th the cost of an OMNR implemented or contracted on-water creel survey.

The sport diary program for Lake St. Clair was set up by contacting primary muskellunge oriented fishermen via sport fishery clubs (e.g., MOMC) and charter boat operators. Although charter boat operators were potentially a good source of information, they were considerably less reliable than sport fishing clubs. In 1994, 43 participants in the Lake St. Clair sport diary program, expended 18,938 rod-hrs of effort, an average of 440 rod-hrs per angler; with a catch of 1,624 fish (an average of 38 fish each) and a harvest of only 22 fish (1% of all fish caught). This group represents very ardent and dedicated anglers who consistently contribute reliable information.

Obtaining biological samples from creel surveys has been difficult due to the low probability of encountering a successful muskellunge fisherman. Most muskellunge anglers spent many hours fishing then leave soon after being successful in catching a muskellunge. Lake St. Clair sport fishery diarists provided length data from almost all fish caught. For example, in 1994, sport fishery diary participants submitted length data for 1,418 of the 1,624 fish caught (typically over 90%). Recently the program had been expanded to include collection and submission of fish scale samples to support age assessment and more detailed stock monitoring (year-class and recruitment assessment, age structured population dynamics, and growth and condition assessment). Over 650 muskellunge scale samples were collected in 1993-94.

Conclusion

Based on my experience on Lake St. Clair, I believe that an angler diary program can make an extremely valuable contribution to muskellunge management by providing comprehensive and cost- effective stock monitoring data.

Habitat Considerations

Habitat may also make an important contribution to the management of muskellunge. A profound change in the habitat of Lake St. Clair occurred after 1989 in association with zebra mussel *(Dreissena polymorpha)* colonization and longterm water level changes. These factors have lead to a dramatic increase in water transparency and the biomass and distribution of macrophytes in Lake St. Clair. Surveys in 1985 and 1994 indicated that the density of muskgrass *(Chara* sp.) had increased 18 fold over an extensive area off the east shore of Lake St. Clair. Muskgrass has been reported to be a primary substrate for spawning muskellunge (Dombeck et al. 1984). Macrophyte density in general increased five fold, providing both nursery and adult habitat. Muskellunge were not only more abundant in the lake, but more ubiquitous in distribution.

These habitat changes, which are favourable to muskellunge, occurred almost simultaneously with changes to size-based angling regulations and changes in angler attitude. Although a strong case is made for the apparent positive effects of the latter, it must be tempered with the unknown and unquantified impacts that these habitat changes have undoubtedly had on the muskellunge population in Lake St. Clair.

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