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AN EVALUATION OF LAKE TROUT (SALVELINUS NAMAYCUSH) HOOKING MORTALITY IN THE UPPER GREAT LAKES[1]

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ABSTRACT

During 1984 and 1985, to help assess the effectiveness of restrictive fishing regulations on lake trout stocks, lake trout hooking mortality was measured in lakes Michigan, Huron, and Superior. Fish were collected by charter boat operators and sport fishermen. Short-term mortality was measured using an aerated, chilled tank system on board the boat. Long-term mortality was estimated by returning hooked fish back into the water, tethered to a line-buoy system. Overall hooking mortality was determined to be 14.9%. Significantly higher mortalities were noted in fish not immediately discovered to have been hooked. In addition, lake trout hooked in internal regions produced a mortality of 71.4% while those hooked in the upper or lower jaw exhibited a mortality of only 6.9%. A significant difference was also seen in the mortality between length classes of fish, with the smallest size class producing the highest mortality. The depth from which the fish was caught, the temperature differential from this depth to the surface, gear type, and handling times had no significant effect on survival. These results appear to support the use of size limits, creel limits, and season restrictions as effective methods to reduce sport harvest of lake trout.

INTRODUCTION

Lake trout (Salvelinus namaycush) were once abundant in the Great Lakes and constituted one of the major predators in this system (Christie 1974). Until the 1950's, naturally reproducing stocks of this fish helped to support a thriving commercial fishery in the Great Lakes. Historically, lakes Michigan and Huron each consistently produced in excess of 500,000 pounds of lake trout annually while Lake Superior reached over 400,000 pounds per year (Baldwin et al. 1979). Intensive overfishing, environmental degradation, and the invasion of the sea lamprey (Petromyzon marinus) through the Welland Canal have often been cited as the causes of the total collapse of the lake trout stocks in lakes Michigan and Huron and the near collapse of the stocks in Lake Superior (Christie 1974).

With the development of a chemical lampricide (3-trifluoromethyl-4-nitrophenol) and subsequent reductions of the sea lamprey populations, along with extensive limitations on commercial fishing, it was felt that a suitable environment for the reestablishment of lake trout stocks had been created (Peck 1984). Stocking of fingerlings began in Lake Michigan in 1965 with the intention of establishing self-sustaining stocks of this fish. However, to date, only Lake Superior shows signs of significant natural recruitment (Rybicki 1983).

Many theories have been advanced regarding the failure of reproduction in the planted lake trout stocks. Degradation of spawning habitat through changing land use practices, increased contaminants in the Great Lakes, lack of abundant spawners, and failure of lake trout to locate and deposit eggs successfully on suitable reefs have all been cited as possible reasons for this failure (Rybicki and Keller 1978, Peck 1979). Currently though, attention has shifted to achieving the necessary critical mass of reproductive-age fish in the population.

To achieve this necessary critical mass, the Great Lakes Fishery Commission, Lake Michigan Lake Trout Technical Committee (1983) advised that total annual mortality not exceed 40%. Mortality currently exceeds this in most statistical management districts of Lake Michigan (Rybicki 1983). Records available from the Michigan Department of Natural Resources indicate that the majority of lake trout in Lake Michigan do not reach maturity until the age of 6 years, and as a result the biomass of fish reaching a mature age constitutes a relatively small percentage of the total biomass of the stocks.

In an attempt to increase spawner abundance, the Michigan Department of Natural Resources established regulations aimed at reducing the mortality of adult fish. The creel limit for individual anglers was reduced from five to three lake trout per day. Additionally, Lake Michigan received further reductions to the current two lake trout per angler per day. In another attempt to decrease the adult mortality and increase the number of spawners, the Michigan Department of Natural Resources in 1984 imposed a season limit of May 1 to August 15 on the lower two lakes.

The ultimate success of these regulations depends upon the degree of mortality experienced by lake trout that have been caught and released by anglers. Previously, an estimate of this hooking mortality was not available. Controversies arose among managers and between managers and anglers as to the effectiveness of regulations in reducing lake trout mortality. Prior hooking mortality studies on salmonid species indicated highly variable results ranging from 3.3% for Atlantic salmon (Salmo salar) (Warner 1976) to 90% for rainbow trout (Salmo gairdneri) (Mason and Hunt 1976). Hooking mortality of lake trout was reported to be 6.98% in Great Slave Lake, Canada (Falk et al. 1974).

The purpose of this study was to evaluate the degree of hooking mortality of lake trout in lakes Michigan, Huron, and Superior. In addition, relationships between mortality and various physical and biological factors were investigated. With these estimates an evaluation of harvest regulations, which are designed to insure lake trout rehabilitation, was possible.

METHODS

Investigation of lake trout hooking mortality was conducted primarily with the cooperation of Great Lakes charter boat operators and sport fishermen. In addition, research personnel augmented angler fishing time in 1985.

Three of the upper Great Lakes were sampled in 1984 and two in 1985. Eight ports (New Buffalo, South Haven, Holland, Grand Haven, Pentwater, Ludington, Charlevoix, and Petoskey) were visited along the eastern shore of Lake Michigan and one port each on lakes Huron (Harrisville) and Superior (Marquette). In 1985 Lake Superior was excluded due to inclement weather at the scheduled time of sampling. Different ports were visited in order to obtain samples from different fish stocks and also to sample a cross section of the "typical" Great Lakes angler and fishing techniques.

Lake trout were caught by both fishermen and research personnel using traditional Great Lakes fishing methods. The majority of fish were caught by trolling artificial lures attached to downriggers. However, in rare instances, alternate methods such as wire line fishing were used by fishermen. At the time that the fish was brought on board, information was recorded on depth of capture, water temperature at the depth of capture, anatomical site of hooking, lure type, time required to land the fish (playing time), time the fish was on board (deck time), and surface water temperature.

Two different methods were utilized to assess hooking mortality. The tank method involved immediate placement of the landed fish into a 2 ft x 2 ft x 3 ft tank filled with lake water. Dissolved oxygen levels were maintained at saturation with compressed oxygen while temperatures were kept between 10°C and 13°C with non-chlorinated ice. The lake trout were observed for the duration of the fishing trip, usually 2 to 6 hours. This method was used only in 1984 and represented mortality under ideal conditions.

The buoy-and-line method involved placing a metal clip through the center lower mandible of the lake trout. This was connected via a two-way swivel to 75 yards of 15-pound test monofilament line which was in turn attached to a crab pot buoy. The fish, line, and buoy were returned to the water where the lake trout could seek out its preferred temperature and depth strata. Observation times for this method ranged from 1 to 7 hours in 1984.

Since unanchored buoys drifted with the current, the line-buoy method was modified in 1985 to allow for longer observation times. The lake trout, after having the metal clip placed through its mandible, was tethered via a two-way swivel to 50 yards of 30-pound test monfilament line. The fish was then released back into the water and all of the line was played out. The opposite end of this line was attached, via another two-way swivel, to the anchor rope of the buoy. The fish was thus tethered to the anchor line but was free to move to its preferred depth strata. Horizontal movement was restricted to a 50-yard radius of the buoy. Ideally fish were released for a minimum of 48 hours since 90–95% of hooking mortality in salmonids had been shown to occur within 48 hours of capture (Mongillo 1984). However, fishermen who came too close to this system often became entangled in the line. For this reason release times were often shortened during times of heavy fishing pressure.

After fish were retrieved from the buoy system or the fishing trip was completed (1984), lake trout were classified as alive or dead. Total length, weight, sex, and evidence of lamprey scars were recorded for each fish. Age was determined with Michigan Department of Natural Resources fin clip records and verified with scale aging techniques.

STATISTICAL ANALYSIS

All factors or classifications of factors were compared to determine their impact on observed mortality. Since data were distributed binomially, nonparametric chi-square contingency tables were used in all cases. Some data were categorized into groups for analysis. In these cases the group intervals were the smallest which incorporated a sufficient number of observations in each cell that allowed for accurate testing using chi-square. In all tests a 95% level of probability was used to determine significance.

RESULTS AND DISCUSSION

Over the 2 years of sampling a total of 90 fish were observed. Of these, 23 fish were placed in the aerated tank and the remaining 67 fish were returned to the water on the line-buoy system.

In 1984 the use of the aerated tank system resulted in a mortality estimate of 4.3%. This estimate is believed to be below the actual mortality experienced by angler caught and released lake trout. Fish that were returned to the water often experienced surface water temperatures that were 11°–14°C higher than the temperature from which they were caught. However, when fish were placed in the tank system, the water temperature was approximately 10°C and the oxygen levels were at saturation. In addition, released fish were subject to sea gull predation, as witnessed in two cases, whereas fish held in the tank were not. The tank system thus provided an estimate of lake trout survival under optimal conditions and may not reflect the actual angler induced mortality. For these reasons, along with the small number of mortalities, analyses on the possible factors related to mortality (size, depth, lure type, etc.) were not conducted on these data.

In 1984, 13.6% of the lake trout caught and released on the buoy system died. This estimate is comparable to 1985, when 15.6% of the fish died (Table 1). There was no significant difference in mortality between the 2 years (x^2 = 0.0429, df=1). For the 2-year period, overall hooking mortality was 14.9% (Table 1). Although the sample size was restrictive, it was felt that the concurrence of the estimates between the 2 years provides strong support for the overall mortality estimate. This rate is higher than that found by Falk et al. (1974). They determined that 6.98% of the caught and released lake trout died. However, several differences exist between Falk's work and this study. The work done by Falk was carried out in Great Slave Lake, Canada, where fish were taken under different conditions and using different angling methods. In addition, severe temperature changes as experienced by fish caught from the Great Lakes did not occur in Falk's study.

An evaluation of the relationships of selected physical and biological factors to observed mortality was conducted. These parameters were thought to have an influence on mortality or had been shown by previous researchers to affect mortality. As no significant difference in mortality was observed between the years of sampling, subsequent analysis of the factors possibly related to hooking mortality was carried out on the combined data set.

Size

Fish ranged in size from 461 mm to 801 mm with the average being 617 mm. Mortalities were noted over the entire size range. When fish lengths were placed into 51-mm (2-inch) size categories (Table 2) there was found to be a significant difference in mortality between various size classes (x^2 = 7.359, df = 6). The smallest size category of fish experienced the greatest mortality. Contrary to these results, Wydoski et al. (1976) concluded that larger rainbow trout, when caught and released, were stressed to a greater degree than smaller ones under the same conditions. However, Pelzman (1978) found no correlation between the size of largemouth bass (Micropterus salmoides) and mortality.

Handling times

The playing time, or the approximate time elapsed from the moment of initial hooking and the moment of landing the fish, ranged from 53 seconds to 5 minutes and 3 seconds. Grouping these times into 1-minute intervals, no significant difference was seen in mortality among the times ($x^2 = 0.7440$, df = 3). Marnell and Hunsaker (1970) working with cutthroat trout reported that mortality related to playing times of up to 10 minutes were not significantly different from their control group. However, Bouck and Ball (1966) found that 87% of rainbow trout that were angled to exhaustion died. Due to the relatively short playing times of lake trout in this study, it is doubtful that many were physically exhausted when landed.

Several fish were not immediately discovered after they were hooked. These fish were omitted from the analysis of playing times (but not overall mortality estimates) since accurate times could not be established. When the mortality estimates of these fish were compared to the estimates of other angled fish, a significant difference in mortality was observed ($x^2 = 6.3849$, df = 1). The fish which were not discovered immediately upon hooking produced a mortality estimate of 50% compared to 11.4% mortality for all other fish. This conclusion seems reasonable since fish that are not discovered immediately may be pulled behind the boat for some time, increasing mortality through a combination of factors. Fish fighting the drag of the boat may accumulate a lethal level of the by-products of anaerobic muscular activity (i.e., lactic acid). In addition, reduced respiratory efficiency occurs due to a reduced ability to pass water over the gills and may result in suffocation. This could be a result of an inability to manipulate the buccal or opercular pumps effectively due to the increased drag on the opercular surface. Also, the exposed surface area of the lamellae in the gills may be reduced by the force of water crushing individual lamellae together or water may take a non-respiratory path through the gill sieve. Joans and Randall (1978) described these possibilities as increased diffusion dead space and increased anatomical dead space. The typical response to these impediments to oxygen uptake is to redistribute blood flow through secondary lamellae so as to expose a greater surface area of blood vessels of each lamellae to water for a longer period of time. However, lake trout, being a sedentary fish, may not have evolved a sufficient system to cope with ram ventilation. Any reactions from secondary lamellae to compensate for reduced oxygen availability may be insufficient to provide oxygen at the rate required. Thus, these fish may be stressed from oxygen deficiency by the time that they are brought on board and the results would therefore coincide with those reported by Bouck and Ball. This is assuming that the fish are actively trying to pass water over their gills and have not ceased all attempts to respire.

The amount of time that the fish spent out of the water (deck time) did not significantly influence the survival of hooked lake trout ($x^2 = 5.508$, df =3). Deck times ranged from 1 minute and 10 seconds to 4 minutes and 30 seconds and were categorized into 1-minute intervals for analysis. This was apparently not long enough to cause severe physiological damage to the fish.

Gear type

There were three main lure types used by anglers. These consisted of small plug-like lures with small treble hooks (known as p-nuts), spoons with large treble hooks, and spoons with large single hooks. Although higher mortalities were observed with p-nuts (20.8%) and large treble hook spoons (20.0%) than large single hook spoons (5.9%), these differences were not found to be significant (x^2 = 1.905, 2 df). Smaller lures such as the p-nuts were often ingested more deeply by the lake trout. Thus, the potential for hooks to penetrate vital structures (esophagus, arteries, etc.) or become entangled in the gills might have been greater for smaller lures, although this was not statistically substantiated. These findings agree with Falk et al. (1974) and Dotson (1982). However, in a summary of hooking mortalities of salmonids, Mongillo (1984) concluded that the practice of using single hooks on lures causes slightly higher mortalities than treble hooks.

Anatomical hooking site

For statistical analysis, hooking sites were classified as being internal or external. Approximately 72% of the lake trout in this study were hooked in the upper or lower jaw (external). These fish experienced a mortality of 6.9% while fish which were hooked in one or more internal sites exhibited a mortality of 71.4%. A significant difference therefore exists in mortality between the two classifications (x^2 = 21.805, 1 df). This difference is a function of damage to internal structures and subsequent stress of the fish. Other investigators have similarly found hooking site to be important in determining mortality of hooked fish. Falk et al. (1974) concluded that the primary cause of death in hooked lake trout was attributable to hook placement and bleeding. Hook placement in the gill arches produced excessive bleeding and increased mortality. Pelzman (1978) found that significant mortality occurred among largemouth bass which had been hooked in the esophageal region. In addition, Warner (1979) indicated that hooking mortality of landlocked Atlantic salmon was more a function of hooking site (swallowing the hook) than gear type.

Temperature

The difference between the temperature at the depth at which the lake trout was hooked and the surface water temperature did not appear to have an effect on mortality (Table 3). When fish observations were placed into categories of temperature differential (0–5°C, 6–10°C, or 10–15°C), no significant differences were observed between the three categories

(x^2 = 1.347, 2 df). This conclusion is consistent with that of Marnell and Hunsaker (1970) who found that the survival of cutthroat trout after hooking and releasing was not affected by surface water temperatures between 37°F and 62°F. However, relationships have been established which suggest an increasing mortality with increasing water temperatures (Benson and Bulkley 1963, Klein 1965, Dotson 1982).

Depth

Lake trout were caught from depths ranging from 7.5 m to 49 m. No significant differences were observed among depth ranges in the probability of death (x^2 = 4.327, df = 4). When fish are raised from great depths, a decrease in pressure at the rate of 1 atmosphere for every 10 m allows gas in the gas bladder to expand. Since lake trout are physostomous, they possess the capability of releasing pressure from their expanding gas bladder via the esophageal connection. Often, when lake trout were brought to the surface, they could be heard releasing gas from the gas bladder. Several fish which ultimately survived were observed floating on the surface for periods of up to 10 minutes, possibly as a result of the extended gas bladder.

Management Implications

The primary objective of this study was to determine the degree of hooking mortality experienced by lake trout caught and released by Great Lakes anglers. This was in a effort to determine the effect of various fishing regulations upon the overall mortality of lake trout stocks and the ultimate plans for achieving their natural reproduction in the Great Lakes. Currently two types of restrictions are imposed on lake trout fishermen. A creel limit of two lake trout per angler per day is imposed on fishermen in Lake Michigan while the limit is three in lakes Superior and Huron. Based on the results of this study, the relatively low overall mortality appears to support the use of this limit as a method of reducing sportfishing mortality. Great Lakes fishermen are often able to target for alternate species (such as salmon) and therefore the incidental catch of lake trout after the daily limit has been reached may not be significant. However, lake trout that are incidental to the catch will exhibit a high survival when released, according to these results.

The recently imposed season limit by the Michigan Department of Natural Resources may also be effective in reducing fishing mortality. Although the current season closes on August 15 when surface water temperatures are often high, no evidence was found which indicated an increasing mortality with increasing differential in water temperatures. Lake trout still have a substantial chance for survival in the warmer surface waters. The basis for establishing opening and closing dates for lake trout fishing therefore would depend more on the evaluation of fishing pressure during different times of the year and socio-economic considerations. Tourism connected with Great Lakes fishing contributes substantially to the economy of Michigan. Many businesses would prefer to extend the lake trout season to Labor Day, the traditional end of the tourist season.

Imposing a size limit for lake trout has also been under consideration by management agencies. As was noted earlier, mortalities occurred over the entire size range of observed fish, but the smallest size classes of fish showed the highest mortality. Generally, significant maturity in lake trout is not reached until the age of 6 years, at which time the fish are approximately 660 mm in length (Rybicki and Keller 1978). If this was imposed as the minimum size for lake trout harvest, approximately 66% (42/64) of the fish caught in this study would have been returned to the water. Of these returned fish, 14.3% would have died. It should be noted that this estimate is actually below the estimate for overall mortality. This is due to the fact that the sample size for calculations on length was reduced to 64 fish due to missing length data caused by gull predation in one case and loss of live fish upon retrieval in two cases. Thus, a size limit designed to allow a greater number of fish to reach maturity may actually be an effective method to increase spawner biomass.

Clark and Huang (1985) provide a lake trout population model which incorporates varying fishing levels and mortality rates. With this model they simulated population changes in one statistical management district of Lake Michigan (Frankfort-Good Harbor Bay, statistical district MM5). Given that stocking remains at historical levels and that their mortality and maturity schedules are accurate, the model predicts that rehabilitation will not be achieved in 25 years. Rehabilitation was defined by the authors as the natural production of 25,000 4-year-olds, the approximate number now achieved by stocking. After 25 years with the size limit of 660 mm and the hooking mortality rate of 14.9%, approximately 13,000 4-year-olds will be produced.

CONCLUSION

The objective of this study was to estimate the mortality experienced by lake trout caught and released by anglers in the Great Lakes. Overall hooking mortality was found to be 14.9%. Fish hooked in one or more internal areas experienced significantly higher mortality (71.4%) than those hooked in the upper or lower jaw (6.9%). In addition, fish which were not immediately discovered upon hooking exhibited a mortality of 50.0% while those that were immediately landed exhibited 11.4% mortality, creating a significant difference between the two classifications. The smallest size classes of fish died at a slightly higher rate than larger ones, although this mortality is still relatively low. These conclusions support the use of season limits, size restrictions, and creel limits as a means of reducing sportfishing mortality of lake trout stocks in the Great Lakes. However, even with these restrictions, the rehabilitation of lake trout stocks in the Great Lakes may not be readily achieved.

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Table 1. Hooking mortality of lake trout (Salvelinus namaycush) returned to natural waters in the upper Great Lakes, 1984–85. Confidence intervals from Mainland et al. (1956).

Year	Number caught	Number of mortalities	Percent mortality	Confidence intervals (95%)
1984	22	3	13.6	3.2–37.9
1985	45	7	15.6	6.5–29.5
Combined	67	10	14.9	7.4–25.7

Table 2. Mortality by length of lake trout caught in the upper Great Lakes, 1984–85.

Total length (mm)	Number caught	Number of mortalities
457–508	7	4
509–559	8	0
560–610	13	1
611–660	14	1
661–711	15	2
712–762	6	1
763–813	1	0

Table 3. Number of lake trout caught at individual water temperature differentials in the upper Great Lakes, 1984 and 1985. Numbers in parentheses indicate mortalities.

Water temperature at depth (°C)	Surface water temperature (°C)																	
	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
4	1	—	—	—	—	—	—	—	—	—	—	—	2	1	4	—	—	—
5	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—
6	—	—	—	—	3	—	—	4	—	—	—	—	2 (1)	1	—	1	—	—
7	—	—	5 (4)	—	1	—	1	—	—	—	—	—	—	—	1	—	—	—
8	—	1	—	—	2	—	—	—	—	—	—	—	—	—	1	—	—	1
9	—	—	—	—	—	—	—	—	—	1	—	4	—	1	2	—	2 (1)	—
10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—
11	—	—	—	—	1	—	—	—	—	—	—	—	—	—	2	—	—	—
12	—	—	—	—	—	—	1	—	—	—	2	1	—	—	—	—	—	1 (1)
13	1	—	—	—	—	—	—	—	—	—	1 (1)	—	—	—	—	—	—	—
14	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	2 (1)
20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—

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