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## MANAGEMENT RECOMMENDATIONS FOR LAKE TROUT STOCKING AND CATCH IN THE WISCONSIN WATERS OF LAKE MICHIGAN

By

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### ABSTRACT

The effect of fishing mortality (sport and commercial) and stocking on the population dynamics of hatchery origin lake trout in the Wisconsin waters of Lake Michigan was examined with a computer simulation model. The model simulated the population dynamics within three lake trout management zones: the southern Kenosha-Kewaunee Zone, the Mid-Lake Reef Zone, and the northern Clay Banks Zone. The management goal in each of these zones has been the re-establishment of naturally reproducing populations. Population characteristics related to reproduction were predicted by the model and were compared to those exhibited by naturally reproducing self-sustaining lake trout populations in other North American lakes. Reference scenarios that simulated current stocking and fishery removals for 20 years suggested that in no management zone would a population develop that exhibited characteristics similar to naturally reproducing populations elsewhere. In each zone, the hatchery populations had higher total mortality and fewer mature trout and fertilized eggs/spawning reef acre. Alternative management recommendations were developed that, based on the model's predictions, would cause hatchery origin populations to become established that have minimum spawning densities of 4 mature trout/reef acre, a minimum of 7 mature age classes, a minimum deposition of 3,000 eggs/reef acre, and a total annual mortality not exceeding 45% for the first 12 age classes. For the Kenosha-Kewaunee Zone, a management strategy was recommended that reduced catch levels by 75% and approximately doubled stocking. The recommendation for the Mid-Lake Reef Zone was to increase stocking by more than 4 times and to allow the fishery catch to remain the same. For the Clay Banks Zone the management recommendations were to reduce catch levels by 75% and to reduce stocking by 8%. Implementation of these recommendations would require that an additional 1,458,000 lake trout be stocked, the sport catch decline by 102,000 fish, and the commercial catch be reduced by 56,000 fish.

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## CONTENTS

INTRODUCTION.....	3
LAKE TROUT POPULATION CRITERIA.....	4
LAKE TROUT MANAGEMENT ZONES.....	4
Kenosha-Kewaunee Zone.....	4
Mid-Lake Reef Zone.....	4
Clay Banks Zone.....	6
No Rehabilitation Zone.....	7
MODEL DESCRIPTION.....	7
MODEL PREDICTIONS.....	9
Kenosha-Kewaunee Zone.....	11
Mid-Lake Reef Zone.....	11
Clay Banks Zone.....	12
MANAGEMENT RECOMMENDATIONS AND DISCUSSION.....	12
LITERATURE CITED.....	15

## INTRODUCTION

Since the early 1960s, a management program has been conducted to re-establish naturally reproducing lake trout (Salvelinus namaycush) populations in Lake Michigan. The program has depended on three management tools: 1) the annual stocking of yearling lake trout, 2) sea lamprey control, and 3) fishery regulation. In the Wisconsin waters of Lake Michigan, lake trout stocking has averaged approximately 1 million fish each year from 1965 to 1985. The U.S. Fish and Wildlife Service has been responsible for the hatchery propagation of lake trout and sea lamprey control. The Wisconsin Department of Natural Resources (DNR) has been responsible for stocking distribution policy and fishery regulation.

The lake trout stocked in the Lake Michigan waters of Wisconsin have survived sufficiently well to develop an important sport fishery (estimated 1984 catch of 117,000 trout) and to generate an incidental catch in the commercial fishery. Although survival of lake trout to spawning sizes has occurred, naturally produced year classes of lake trout have not been observed after more than 15 years of stocking. Several causes have been suggested as contributing to the lack of significant natural reproduction including, for example, pesticide contamination (Stauffer 1979, Berlin et al. 1981), the predation of eggs and fry (Stauffer and Wagner 1979), an insufficient number of spawners (Brown et al. 1981, Dorr et al. 1981), wrong stocking locations and fish sizes planted (Brown et al. 1981, Horrall 1981), and an inappropriate genetic background of the fish stocked (Loftus 1976, Brown et al. 1981, Krueger et al. 1983).

This document examines the effect of fishing mortality (sport and commercial) and stocking on the population dynamics of hatchery origin lake trout in the Wisconsin waters of Lake Michigan. The analyses were conducted through the use of a computer simulation model (Dehring and Krueger 1986) and had 4 objectives:

- 1) To determine whether the current levels of stocking and catch would permit the development of a hatchery population with characteristics capable of achievement of the rehabilitation goal.
- 2) To determine allowable catches by fishery if stocking levels remain the same.
- 3) To determine the number of lake trout that should be stocked if catch remains the same.
- 4) To propose both new stocking levels and allowable catches by fishery and area that will permit the re-establishment of lake trout populations.

## LAKE TROUT POPULATION CRITERIA

Population parameters (e.g., number of mature trout/reef acre) were chosen as criteria to compare lake trout populations predicted to develop from various management strategies (different combinations of catch and stocking). The parameters used were based on the characteristics of naturally reproducing self-sustaining lake trout populations elsewhere in North America. The criteria were to represent the minimum population characteristics that hatchery populations should possess for significant natural reproduction to occur. The criteria were:

- 1) A spawning density of 4 mature trout/reef acre.
- 2) A minimum of 7 mature age classes.
- 3) A minimum annual deposition of 3,000 fertilized eggs/acre of spawning reef.
- 4) A total annual mortality not exceeding 45% for the first 12 age classes.

Criteria #1-#3 were based on data from the lake trout population that uses Gull Island Shoal as a spawning reef in Lake Superior (Bruce Swanson, pers. comm.; Swanson and Swedberg 1980). The total annual mortality criteria (#4) was established based on a review of mortality rates reported for populations across North America (Healey 1978, Schneider et al. 1983).

## LAKE TROUT MANAGEMENT ZONES

Separate simulation models were developed for geographically specific zones within the Wisconsin waters of Lake Michigan (Fig. 1). The zones were established based on differences in past stocking levels, sport and commercial catches, and the availability of spawning reefs (Table 1). Within these zones, commercial incidental catches of lake trout occur in small mesh gill nets (2.50 - 2.75 inch stretch mesh) set primarily for chubs (Coregonus sp.) and yellow perch (Perca flavescens) and in large mesh gill nets (4.50 - 4.63 inch stretch mesh) set for whitefish (Coregonus clupeaformis).

### Kenosha-Kewaunee Zone

This zone includes most of Wisconsin's Lake Michigan waters from the City of Kewaunee south to the Wisconsin-Illinois boundary (Fig. 1). This zone received approximately 31% of the total lake trout stocked and accounted for 72% of the total annual fishing mortality in recent years (Table 1). The lake trout spawning reef area in this zone was estimated to be 43,714 acres or 22% of the total reef area in the three lake trout management zones combined. This zone has a secondary priority within the DNR for lake trout rehabilitation due to the high sport harvest and limited spawning reef area.

### Mid-Lake Reef Zone

This zone includes reef areas known as the Northeast, Sheboygan, and Milwaukee Reefs located offshore from the City of Milwaukee (Fig. 1). These reef areas are thought to formerly be some of the most productive

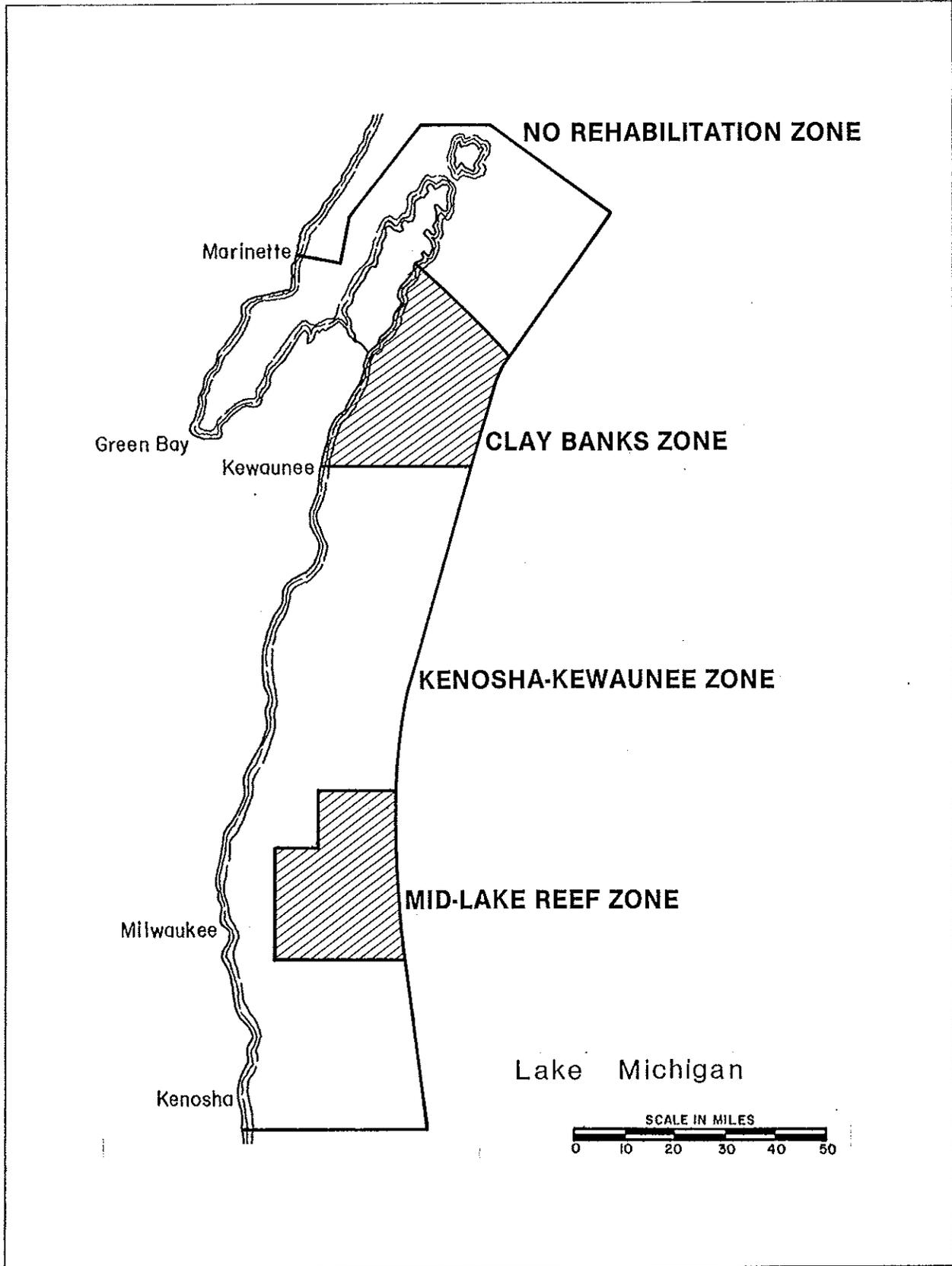


FIGURE 1. Lake trout management zones in the Wisconsin waters of Lake Michigan.

lake trout spawning grounds in Lake Michigan (Brown et al. 1981). In the past, this zone has received approximately 36% (345,000) of the total lake trout stocked (Table 1). Lake trout fishing mortality has been limited to an incidental catch in small mesh gill nets set by the commercial chub fishery (Table 1). No sport fishing or large mesh gill net fishing occurs in this area. This zone contains 71% (140,486 acres) of the total reef area available for lake trout spawning in the three lake trout management zones. This zone has been given a high priority for lake trout rehabilitation by the Lake Michigan Committee organized by the Great Lakes Fishery Commission (Lake Mich. Lake Trout Tech. Comm. 1983) and by the DNR.

TABLE 1. Lake trout stocking, catch, and reef area for the three lake trout management zones in the Wisconsin waters of Lake Michigan.

Management Zone	Stocking <sup>1</sup> (numbers)	Catch (numbers) <sup>1</sup>			Reef Area acres) <sup>3</sup>
		Sport	Small Mesh <sup>2</sup>	Large Mesh	
Kenosha- Kewaunee	296,000	99,000	29,000	0 <sup>4</sup>	43,714
Mid-Lake Reef	345,000	0	3,000	0 <sup>4</sup>	140,486
Clay Banks	326,000	38,000	8,000	39,000	14,451
TOTAL	967,000	137,000	40,000	39,000	198,651

<sup>1</sup> Average 1981-1983.

<sup>2</sup> Mortality caused by commercial gill nets represent an incidental catch while fishing for other species. All trout, dead or alive, are to be returned to Lake Michigan. Mortality estimates given here may actually be higher, since trout presumed alive may suffer a delayed mortality after release.

<sup>3</sup> From Coberly and Horrall (1980).

<sup>4</sup> Large mesh gill net use prohibited.

### Clay Banks Zone

This zone includes the area from the Baileys Harbor Line (135° bearing from the mid-channel marker buoy of Baileys Harbor) south to the City of Kewaunee (Fig. 1). In the past, this zone has received approximately 34% of the total annual lake trout stocking (Table 1). Lake trout fishing mortality occurs as a result of sport angling, and small and large mesh gill net fisheries. Fishing mortality estimates for this zone, in terms of numbers, included lake trout caught north of the Baileys Harbor Line. Trout caught in this northern area were assumed to originate from stocking within the Clay Banks Zone because no lake trout in recent years have been stocked north of Baileys Harbor. Spawning reef areas within the Clay Banks Zone include Jacksonport Reef, Whitefish Point Reef, Black Can Reef, and the Clay Banks.

This zone contains 7% (14,451 acres) of the total spawning reef area in the three lake trout management zones. This area has been given a high priority for lake trout rehabilitation by the Lake Michigan Committee and by the DNR similar to the Mid-Lake Reef Zone.

#### No Rehabilitation Zone

This zone includes all Wisconsin waters north of the Baileys Harbor Line and Green Bay. This zone supports an active large and small mesh commercial fishery that is considered incompatible with lake trout restoration. This area has received no lake trout stocking in recent years. Lake trout catches in this zone were included as part of the catch estimates for the Clay Banks Zone (Table 1).

#### MODEL DESCRIPTION

A simulation model was developed to predict the characteristics of hatchery populations that would occur under different regimes of stocking and catch. The outputs from the model were the characteristics of a hatchery population that would occur after 20 years of constant stocking and catch. The outputs included the number of mature trout/reef acre, number of mature age classes, number of fertilized eggs/reef acre, and natural, fishing, and total annual mortality rates by age class. The model assumed that no year class recruitment occurred due to natural reproduction. Complete documentation of the model has been given by Dehring and Krueger (1986).

Catch by each fishery was distributed by age-class based on known catch-age distributions. These distributions were developed based on data collected by a sport creel survey, and the monitoring of gill net lifts in the small and large mesh commercial fisheries (Fig. 2). The largest percentage contribution to the catch within each fishery was age VI fish for the sport fishery, age III fish for the small mesh fishery, and age IV fish for the large mesh fishery. The model assumed that age XV and older trout did not contribute to the fisheries. The importance of the differences in catch-age distributions among fisheries may be illustrated by the model scenario where 1 million lake trout are stocked and there is a 50,000 annual lake trout sport catch (hypothetical example with no other fisheries). At the end of 20 years, the model predicted a spawning population of 214,040 trout. Approximately the same number of trout in the spawning population can be produced if instead of a much larger commercial catch by small mesh gill nets of 100,000 fish is allowed (no sport catch). In this alternative case, the model predicted 214,008 spawning trout. Based on this example, one trout caught by a sport angler is on the average approximately equivalent to 2.0 trout caught by small mesh gear in terms of the effects on spawning numbers.

Total annual mortality rates were computed using the equation:

$$A = m + n - mn$$

where:    n = conditional natural mortality rate,  
          m = conditional fishing mortality rate,  
          A = actual total mortality rate (Ricker 1975).

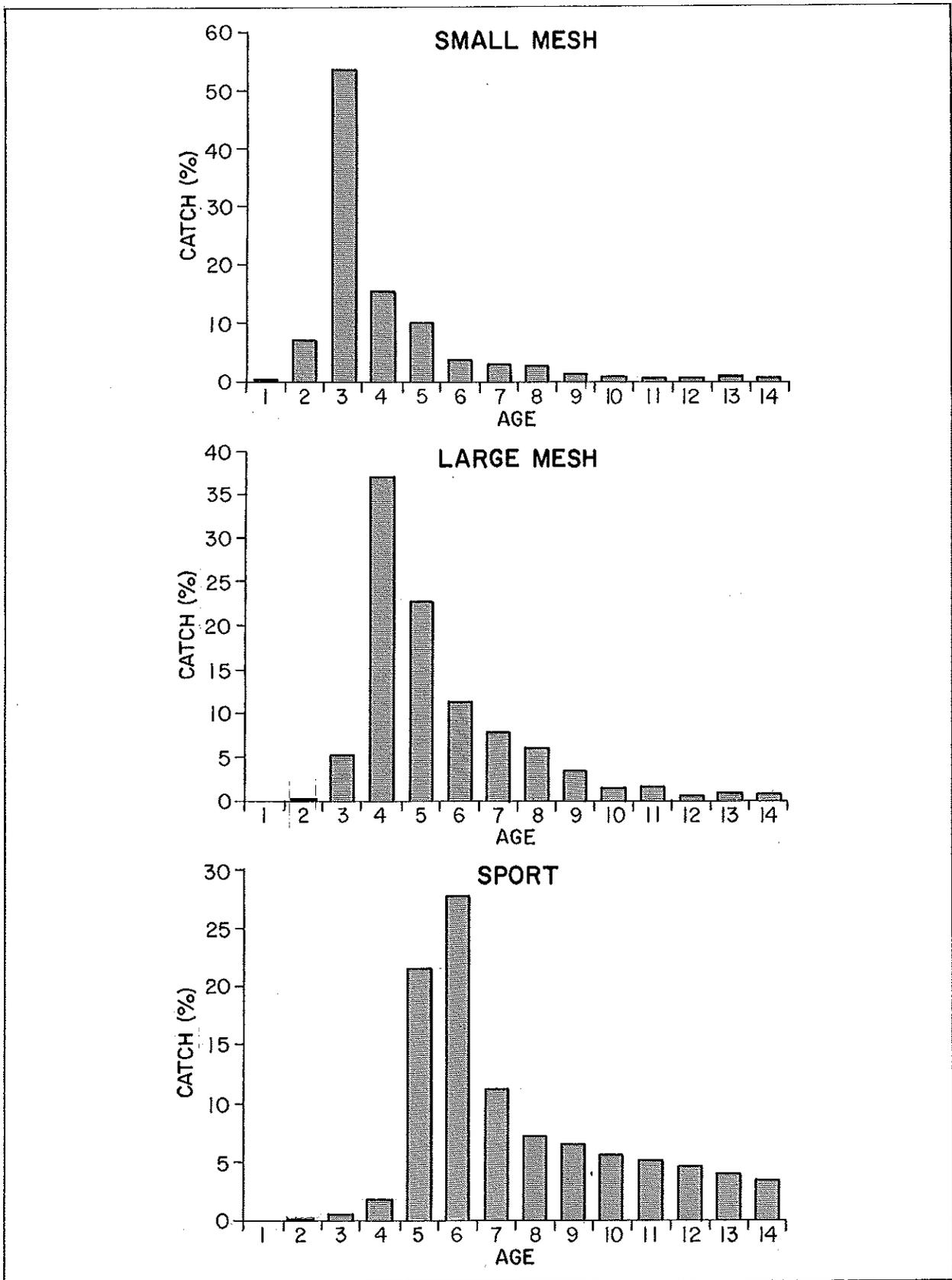


FIGURE 2. Lake trout catch-age distributions for commercial incidental and sport fisheries in the Wisconsin waters of Lake Michigan.

Several assumptions were required in order to develop the model. Particularly sensitive model variables were natural mortality rates and the percent return of mature trout to reef areas at spawning time. The model used natural mortality rates ( $n$ ) of 0.37 for ages I-IV and 0.25 for ages V-XX based on data from hatchery trout in Lake Michigan (Rybicki and Keller 1978). The percent of adults returning to spawning reef areas was assumed to be 0.60 for the Kenosha-Kewaunee and Clay Banks zones and 0.80 for the Mid-Lake Reef Zone (Ross Horrall, pers. comm.). Trout in the Mid-Lake Reef Zone were assumed to stray less due to isolation by deep water surrounding these reefs although few data were available to support these return rates.

The model also assumed that all individuals of both sexes were mature at age VII. Fecundity per trout was based on the age-fecundity relationship observed for lake trout from the Gull Island Shoal area of Lake Superior (Bruce Swanson, pers. comm.). Lake trout older than age XV were assumed to spawn every other year as occurs for Gull Island Shoal trout. The model also assumed no immigration or emigration between Wisconsin waters and Lake Michigan waters of other states. Spawning reef areas were determined for each zone based on the maps published in Coberly and Horrall (1980).

#### MODEL PREDICTIONS

As many as 6 different management options were simulated for each management zone. The first two simulations were the Reference Scenarios of current management (stocking and catch), and current stocking levels but no fishing (Table 2).

The first simulation (Current Management) provided an evaluation as to whether current management will allow significant natural reproduction to occur. The second simulation (No Fisheries), when compared to the first, provided a determination of the effect of current fisheries removals on hatchery population development.

The third through sixth scenarios were alternative management options where catch, stocking, or both were changed from current levels and inputted to the model (Table 2). The third simulation (Reduce Fisheries) determined the level that fisheries catch must be reduced, if stocking remained the same, in order for a hatchery population to develop that would meet the population criteria established.

The fourth scenario (Increase Stocking) determined the increase in stocking that would be required to develop the appropriate hatchery population if catch levels remained the same. The fifth scenario (Strategic Plan) determined the level of stocking required to support the catch levels proposed by the DNR Lake Michigan Fish Management Plan (LMFMP) for 1986-1991 (Wis. Dep. Nat. Resour. 1986). A sixth simulation (Reduce Fishery by 75%) was tested for the Kenosha-Kewaunee and Clay Banks Zones which reduced fisheries catch levels by 75% (substantially greater reduction than proposed by the strategic plan) and increased stocking. This sixth simulation was evaluated because the stocking requirements for this scenario were much less than those required for the strategic plan. The sixth scenario was not developed for the Mid-Lake Reef Zone because the fisheries catch level was not an important determinant of the population characteristics at this offshore location.

TABLE 2. Predicted lake trout population characteristics after 20 years given annual stocking and catch levels for three management zones in the Wisconsin waters of Lake Michigan.

Management Zone Scenario	Model Input				Simulation Results						
	Annual Stocking (numbers)	Catch (Numbers)		Sport	Adults/ Reef Acre	Number Mature Classes	Fertilized Eggs/ Reef Acre	Total Annual Mortality at Age VII	IX	XII	
		Small Mesh	Large Mesh								
<b>Kenosha-Kewaunee Reference</b>											
Current Management	296,000	0	0	99,000	0	0	0	0	No Survivors at These Ages	0.25	0.25
No Fisheries	296,000	0	0	0	2	14	4,018	0	0.25	0.25	0.25
<b>Alternative Management</b>											
Reduce Fisheries --											
Increase Stocking	2,000,000	0	0	99,000	9	8	13,665	0	0.33	0.33	0.46
Strategic Plan	1,200,000	0	0	59,000	5	14	8,260	0	0.33	0.33	0.46
Increase Stocking and Reduce Fishery by 75%	700,000	0	0	25,000	4	14	6,056	0	0.30	0.30	0.36
<b>Mid-Lake Reef Reference</b>											
Current Management	345,000	0	0	0	1	14	1,874	0.25	0.25	0.25	0.25
No Fisheries	345,000	0	0	0	1	14	1,942	0.25	0.25	0.25	0.25
<b>Alternative Management</b>											
Reduce Fisheries	1,450,000	0	0	0	4	14	8,098	0.25	0.25	0.25	0.25
Increase Stocking	1,425,000	0	0	0	4	14	7,980	0.25	0.25	0.25	0.25
Strategic Plan	1,425,000	0	0	0	4	14	7,980	0.25	0.25	0.25	0.25
<b>Clay Banks Reference</b>											
Current Management	326,000	39,000	0	38,000	0	0	0	No Survivors at These Ages	0.25	0.25	0.25
No Fisheries	326,000	0	0	0	8	14	13,386	0.25	0.25	0.25	0.25
<b>Alternative Management</b>											
Reduce Fisheries	326,000	13,000	0	12,000	4	8	5,263	0.35	0.37	0.52	0.52
Increase Stocking	1,000,000	39,000	0	38,000	11	8	15,978	0.35	0.37	0.54	0.54
Strategic Plan	550,000	23,000	0	23,000	5	7	7,792	0.36	0.39	0.68	0.68
Decrease Stocking and Reduce Fishery by 75%	300,000	10,000	0	10,000	4	14	5,708	0.33	0.34	0.43	0.43

## Kenosha-Kewaunee Zone

The lake trout population in this zone was first simulated based on the current management of stocking 296,000 lake trout and allowing a fishery removal of 128,000 trout (99,000 sport and 29,000 small mesh) (Table 2). The model predicted that after 20 years at this level of stocking and removal, the age class structure would not include trout older than age VI and that no fertilized eggs would be deposited. A particularly important result of this simulation was the prediction that the sport fishery catch would be forced to decline by 68% (67,000 trout) over the 20-year period. None of the population criteria for rehabilitation were met by this simulation.

The current management scenario may be compared to predictions based on the same level of stocking but no fishery removals, either sport or commercial (Table 2). In this case each of the population criteria were exceeded at the end of 20 years except adults/reef acre (2 adults/reef acre, 14 mature age classes, 4,018 eggs/reef acre).

Several alternative management scenarios were examined to determine the levels of catch and/or stocking rates that would be required to meet the population criteria established (Table 2). If catch levels in both fisheries were to remain the same then stocking would have to increase by 576% (to 2 million trout) in order to meet the population criteria established.

An alternative management strategy would be to increase stocking and decrease catch levels (Table 2). The alternative proposed by the LMFMP was to reduce catch in all fisheries by 40%. In order to maintain these catch levels and meet the population criteria, stocking would have to increase 305% from current levels (to 1.2 million). The last scenario to be evaluated was a reduction of catch levels by 75%. In this case stocking would have to increase by 136% (to 700,000 trout) in order to meet the population criteria. Choice of this last management strategy would require such a large reduction in the sport catch that most of the lake trout sport catch would probably occur from incidental harvest while angling for other species of trout and salmon.

The current sport fishery in the Kenosha-Kewaunee Zone may function as a buffer to lake trout removals in the other two zones, particularly the offshore Mid-Lake Reef Zone. A reduction of the lake trout fishery in the Kenosha-Kewaunee Zone could reduce this buffer effect, shift fishing effort, and therefore increase lake trout mortality in the other two zones.

## Mid-Lake Reef Zone

The current management, stocking 345,000 trout and allowing a small mesh fishery catch of 3,000 trout, was predicted to produce a population that did not meet the population criteria of adults and eggs/reef acre (Table 2). Elimination of the by-catch in the small mesh fishery produced a negligible change in the population characteristics (Table 2). These results indicated that current stocking levels, regardless of fishery removals, are too low to produce a population that meets the criteria established. In addition these results demonstrate that achievement of a total annual mortality criteria at 45% may not necessarily result in a population with the characteristics to permit significant natural reproduction to occur.

The alternative management strategies that were examined with the model focused on increases in stocking. Based on the model's results, stocking in the Mid-Lake Reef Zone should increase to 1,450,000 (820%) in order to minimally meet all spawning population criteria (Table 2). After 20 years this management would produce a population with the characteristics of 14 spawning age classes, 4 mature trout/reef acre, and an annual deposition of 8,098 eggs/reef acre.

If the commercial catch reductions proposed by the strategic plan were implemented, stocking would need to increase to 1,425,000 trout (Table 2). Based on the model's predictions, the proposed fishery reduction would only reduce stocking requirements by 25,000 fish from that required if fishery removals stay the same. Increasing stocking from 345,000 to approximately 1.4 million trout would require that the commercial incidental catch be carefully monitored. Under this management alternative, the lake trout catch rate in small mesh gill nets might increase by 4 times or more and thus new commercial regulations would be required to prevent an increase in the incidental catch.

### Clay Banks Zone

If current management of stocking 326,000 trout and a fishery catch of 85,000 fish continued for 20 years, the lake trout population that developed would not meet any of the population criteria established (Table 2). The model predicted for this scenario that no adult trout, mature age classes, or fertilized eggs would occur (Table 2). In contrast, if the fisheries catch was not allowed but stocking remained the same, all the population criteria would be met. In this case, the adults and eggs per reef acre exceeded the criteria levels by a factor of 2 (Table 2).

Several alternative management scenarios were examined to determine stocking and catch levels that could be used to develop hatchery populations that met the criteria (Table 2). If stocking remained the same, fisheries catch would be required to decrease by 66%. If catch levels remained the same, stocking would need to increase from 326,000 to 1,000,000. A reduction in catch of 40%, as proposed by the strategic plan, required that stocking increase by 53% to 550,000 trout.

The last alternative examined was to reduce fishery catches by 75%. In this case stocking could decline from 326,000 to 300,000 trout (Table 2). Based on this level of catch and stocking, the model predicted that the hatchery population would meet the population criteria established after 20 years. This second alternative would provide a few lake trout (26,000) for redistribution to the other two zones.

## MANAGEMENT RECOMMENDATIONS AND DISCUSSION

We recommend that, for the Kenosha-Kewaunee and Clay Banks zones, the last alternative strategy (Reduce Fishery by 75%) be adopted and, for the Mid-Lake Reef zone, stocking be increased with no changes in the fishery (Table 3). For the Kenosha-Kewaunee Zone this recommendation would reduce catch levels by 75% and approximately double stocking. For the Clay Banks Zone catch levels would similarly be reduced by 75% but stocking would decrease by 8%. For the Mid-Lake Reef Zone stocking would increase by more than 4 times and the

fishery catch would remain the same. These strategies would allow the sport and commercial fisheries to exist, though at much reduced levels, and still permit an optimum population structure to develop for natural reproduction. Lake-wide the annual sport catch would decline to 35,000 trout. We did not recommend the strategic plan proposal, because the stocking required to develop suitable populations greatly exceeded (+228%) the typical allocation of lake trout from federal hatcheries to Wisconsin.

TABLE 3. Management recommendations for three lake trout rehabilitation zones in the Wisconsin waters of Lake Michigan.

(numbers) Management Zone	Annual Stocking (numbers)	Catch (numbers)			Change from Current Management			
		Small Mesh	Large Mesh	Sport	Stocking (numbers)	Sport	Small Mesh	Large Mesh
Kenosha- Kewaunee	700,000	8,000	0	25,000	+404,000	-74,000	-21,000	--
Mid-Lake Reef	1,450,000	3,000	0	0	+1,080,000	--	0	--
Clay Banks	300,000	2,000	10,000	10,000	-26,000	-28,000	-6,000	-29,000
Total (All three zones)	2,450,000	13,000	10,000	35,000	+1,458,000	-120,000	-27,000	-29,000

Implementation of these recommendations would require that an additional 1,458,000 (+151%) lake trout be stocked in the Wisconsin waters of Lake Michigan. The majority of these additional trout (1,080,000) would be placed in the Mid-Lake Reef Zone. If the lake trout available for stocking in a given year was less than the total required (2.4 million), the trout should be distributed on a proportional basis among the zones (Kenosha-Kewaunee 29%, Mid-Lake Reef 59%, Clay Banks 12%).

The predation impact on forage species caused by the increased stocking proposed here would need to be evaluated and, if excessive, lake-wide reductions in the stocking of other salmonid species would need to occur. Recent results from a predator-prey model for Lake Michigan, however, suggested that substantial increases in lake trout biomass may be possible without endangering the principal prey species, the alewife (Alosa pseudoharengus) (Eck and Brown 1985).

We recognize that the management actions proposed here, 75% catch reductions and doubling of stocking, are severe in terms of the potential effects on fisheries. Independently from this work, Clark and Huang (1985) developed a more complex lake trout model for mixed sport and commercial fisheries in the northern Lake Michigan waters of Michigan. In this case, rehabilitation was defined as the production of 25,000 age IV wild fish. Simultaneous regulations on both fisheries were required if rehabilitation was to be achieved in less than 25 years, although the predicted age IV natural recruitment was highly sensitive to the age 0 survival rate chosen. The only management action that achieved rehabilitation under levels of juvenile (age 0) survival between 0.05 and 0.005 was the complete closure of the sport and

commercial fisheries. If juvenile survival was 0.01 then the imposition of a 26-inch size limit and the doubling of stocking appeared to be the appropriate management action to implement. In terms of the severity of the management actions required to advance lake trout rehabilitation, these results were remarkably similar to those described here for the Wisconsin waters of Lake Michigan.

The development and use of the Wisconsin model revealed that the population predictions were particularly sensitive to the natural mortality rates and the percent adult return to reef areas used by the model. The use of empirical estimates of these parameters from each of the rehabilitation zones should substantially improve the accuracy of the model's predictions. In the future, studies should be conducted to obtain these estimates.

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