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**GROWTH, SURVIVAL, AND STRAYING OF THREE LAKE TROUT STRAINS
STOCKED IN THE REFUGE OF NORTHERN LAKE MICHIGAN¹**

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¹ A contribution from Dingell-Johnson Project F-53-R, Michigan.

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Abstract.—Although some twenty year classes of lake trout (*Salvelinus namaycush*) have been stocked in Lake Michigan since 1965, significant reproduction has not occurred anywhere in the lake. A shortage of mature lake trout was a suspected cause of reproductive failure. Consequently, in 1986, a 2,330 km² refuge was established in northern Lake Michigan to permit the lake trout stock to build spawner biomass. The objective of the study was to evaluate survival, growth, and straying characteristics of three strains of lake trout stocked in the northern refuge. No significant differences were found in the relative survival rate, growth, or straying among Apostle Island outcross, Marquette domestic, and the Wyoming strains of lake trout as 4-year-old fish. Straying from the refuge occurred, but all strains were found outside the refuge in similar proportions of 12-15%. Twenty-four percent of the anglers' catch of 4-year-old lake trout from the Little Traverse Bay-Grand Traverse Bay area and 14% from the Leland-Frankfort area consisted of strays from the northern refuge. Based on this study I make three recommendations. First, the Marquette domestic strain should continue to be used for this project because of its many years of successful performance and availability. Second, the numbers of lake trout planted in the offshore northern refuge should not be used to estimate the catch quota of inshore lake trout, because to do so would grossly inflate the harvest quota. Third, strays from the northern refuge should not be included when estimating survival rate of other lake trout stocks by catch-curve analysis, because a disproportionately large representation of the former in the catch will tend to bias the survival rate estimate.

A long-standing goal of fishery management in Lake Michigan has been recolonization of the lake by self-sustaining populations of lake trout. To that end, the stocking of hatchery-reared lake trout (*Salvelinus namaycush*) in Lake Michigan began in 1965, and annual stockings have ranged from 837 thousand to 2.3 million in Michigan's waters alone. Nevertheless, in Lake Michigan, achievement of a self-sustaining population of lake trout has been a colossal failure. The lack of meaningful reproduction by lake trout

anywhere in Lake Michigan has been attributed to causes ranging from contaminated lake water (Willford et al. 1981) to a critical shortage of spawning trout (Dorr et al. 1981).

Two lake trout refuges were established in Lake Michigan to accommodate a long-term, multi-agency research study designed to evaluate the growth, survival, and straying characteristics of three strains of lake trout, to permit the lake trout stock to build spawner biomass, and ultimately to quantify the stock-recruitment relationship (Brown 1984).

The localities of the refuges in Lake Michigan were chosen by the Lake Trout Technical Committee (affiliated with the Lake Michigan Committee of the Great Lakes Fishery Commission) and sanctioned by the jurisdictions which have management authority. The mid-lake refuge, which was not a part of this investigation, was located approximately in the center of Lake Michigan east of Port Washington, Wisconsin; the mid-lake refuge project has been under the direction of the Wisconsin Department of Natural Resources. The location of the lake trout refuge in northern Lake Michigan was selected because some reefs within the refuge were known historically to have been prime spawning grounds for lake trout (Organ et al. 1978), and the lake's water is relatively low in contaminant concentration. The northern refuge study began in 1986. However, the Michigan Department of Natural Resources (MDNR) withdrew from the project in 1990 because commitment of its research capabilities was urgently needed in other problem areas. It is anticipated that the U. S. Fish and Wildlife Service and the Indian tribes will continue the study. The purpose of this project completion report is to document the growth, survival, and straying of three strains of lake trout stocked in the northern refuge in 1986 from data collected by the MDNR during 1986-89.

Methods

The northern lake trout refuge in Lake Michigan is located in the northeastern sector of the lake and has an area of 2,330 km² (Figure 1). Angling for lake trout and commercial fishing with gill nets for any fish species are prohibited in the refuge.

In June 1986, 703 thousand yearling lake trout of three strains were stocked on three, closely grouped reefs in the refuge (Table 1). The Marquette domestic strain of lake trout originated from Lake Superior and the broodstock was maintained at the state fish hatchery near Marquette, Michigan. Genesis of the Apostle Island outcross strain was from a cross between feral, male lake trout from the

Apostle Island area of Lake Superior and females from the Marquette domestic broodstock; no broodstock of the Apostle Island outcross strain is maintained in hatcheries. The Wyoming variety was derived from a cross between feral lake trout from Lewis and Jenny lakes, Wyoming, and the brood trout are maintained in the Federal fish hatcheries at Jackson Hole and Saratoga, Wyoming; originally, the lake trout in Jenny and Lewis lakes were imported from northern Lake Michigan in 1889.

All of the yearling lake trout were marked with an adipose fin clip and a macroscopic wire tag bearing a binary-coded number, which identified each strain, planting site, and date (Table 1).

During late summer and early fall in 1986-88, the northern refuge lake trout were fished with an otter trawl (24 m long, 12 m headrope, and mouth 2 m deep) at numerous locations inside and outside the refuge. These lake trout were fished with graded-mesh gill nets (mesh sizes of 64-152 mm, on a 13 mm interval) in 1989. Other sources of recoveries of northern refuge lake trout in 1989 were from the MDNR's index-fishing stations located along Lake Michigan's eastern shoreline (Rybicki 1990) and the MDNR's Lake Michigan creel census (Rakoczy and Rogers 1990a,b). Numbers of each strain of northern refuge lake trout caught in graded-mesh gill nets in 1989 were standardized for stocking rate and fishing effort, which facilitated analyzing the relative rate of straying among the three varieties. The instantaneous rate of growth in total length (y^{-1}) was computed by dividing the natural logarithm of the ratio of mean lengths at age by the difference in age.

Results and Discussion

Survival

Relative survival indices, defined as the proportion of the number planted of each strain that was subsequently caught, were similar among the three strains at each age (Table 2). Survival indices, computed on total

catch of each variety, did not differ significantly ($P > 0.05$) among strains. Substantially larger numbers of northern refuge lake trout were caught as 4 year olds because, as older fish, the lake trout were more readily available to the graded-mesh gill nets than they were to the trawl at the younger ages.

Growth

When averaged over age groups, the three strains grew in total length at identical instantaneous rates of 0.35 y^{-1} (Table 3). However, the length-at-age relationship differed among the three strains. Although the slopes of the regression lines did not differ significantly ($P = 0.17$; common slope of 126.46), the regression intercept for the Wyoming strain (47.6) was significantly larger ($P < 0.05$) than that for either the Apostle Island (43.8) or Marquette (44.6) varieties. This difference (about 6 mm) reflects the Wyoming strain's slightly larger average length of 139 mm at the time of stocking versus 132 mm for the Apostle outcrosses and 133 mm for the Marquette domestics.

Straying

Few yearling lake trout in the northern refuge had migrated beyond the immediate area of stocking up to 4 months after planting in June 1986. From 88-98% of the yearling trout were captured in the proximity of the reefs where they were stocked. By the fall of 1987, the 2-year-old lake trout had dispersed southward to South Fox Island (38 km), northward to High Island (19 km), eastward to Little Traverse Bay (72 km), and southwest to Baileys Harbor, Wisconsin (120 km). As 3 and 4 year olds the northern refuge trout had migrated in every direction (Figure 1). An apparently significant, albeit unquantified, number of those lake trout had migrated into Wisconsin's waters. Sixty-one northern refuge lake trout were observed in the commercial chub fishery off Wisconsin's Door Peninsula in 1988 (M. Holey, Wisconsin Department of Natural Resources, personal communication).

One northern refuge lake trout was reported caught in Illinois waters of Lake Michigan. Along the eastern shoreline, the Leland-Frankfort area appeared to be the southern terminus for lake trout that had strayed from the northern refuge. No lake trout stocked in the northern refuge were reported caught from any of the other Great Lakes.

The relative rates of straying from the refuge among the three strains of 4-year-old lake trout were comparable. Fifteen percent of the Wyoming strain, 14.6% of the Apostle Island outcross, and 12.4% of the Marquette domestic variety were captured outside the northern refuge along the northern and eastern shorelines of Lake Michigan (Table 4); thus, the relative rate of straying was independent of strain ($P > 0.05$). Percentages of the total catch taken in general locations outside the northern refuge (Table 1) were: 1% from the area roughly north of a line extending from Dahlia Shoal to Pt. Aux Barque, 7% from the area south of Dahlia Shoal to Grand Traverse Bay, and 6% from the Leland-Frankfort region; none were caught south of Frankfort, except for the single fish caught in Illinois waters.

There appears to be little influx into the northern refuge by lake trout stocked elsewhere. Only 10% of the lake trout of all ages and 6% of the 4 year olds caught within the northern refuge had not been planted there. Straying into the northern refuge by lake trout planted along the northeastern shoreline also was of minor proportion. In 1986, 92,600 coded-wire-tagged yearling lake trout were planted in Little Traverse Bay for a hatchery-diet study conducted independently of the refuge project. Of these fish captured in 1989, 1.7% were from the northern refuge, 95.8% came from the Little Traverse Bay-Grand Traverse Bay area, and 2.5% were caught in the Leland-Frankfort area. Migrants from the Little Traverse Bay plant accounted for 1.5% of all 4-year-old lake trout caught in the northern refuge in 1989.

Substantial proportions of the index catches of lake trout in graded-mesh gill nets fished in the spring of 1989 were northern refuge fish. In the Little Traverse Bay-Grand

Traverse Bay area, 28% of the index catch of 4-year-old lake trout were from the northern refuge, as were 54% of the those in the Leland-Frankfort index catch. A small percentage (0.5%) of the 4-year-old lake trout caught in the Leland-Frankfort area were from the 1985 year class stocked in the mid-lake refuge.

Lake trout from the northern refuge also have contributed substantially to the anglers' catches. Twenty-four percent of the 4-year-old lake trout creel from the Little Traverse Bay-Grand Traverse Bay area originated from the northern refuge. In the Leland-Frankfort area, 18% of the 4-year-old lake trout in the catch were from the northern refuge, and 1.5% of the 5-year-olds were from the mid-lake refuge.

Recommendations

1. Because of the similarities in growth, survival, and straying characteristics among the three varieties of lake trout, which strain is stocked appears to be of minor consideration. The Marquette domestic strain should continue to be used for this project because of its many years of successful performance and availability.

2. Since the contribution of northern refuge lake trout to a particular area was relatively small (0-7%) and there appeared to be only minor migration into the refuge, there is no justification for including the numbers of lake trout planted in the northern refuge to estimate catch quotas for lake trout outside the refuge. If numbers planted in the northern refuge were included in the computation of standing stock in an area outside the refuge, then the quota estimate would be grossly inflated.
3. Strays from the northern refuge were important in both the index and sport catches of lake trout and, therefore, should not be included when estimating survival rate by catch-curve analysis. Their disproportionately large representation in the catch will tend to negatively bias the survival rate estimate for several years after entering the fishery and positively bias the survival rate estimate at older ages.

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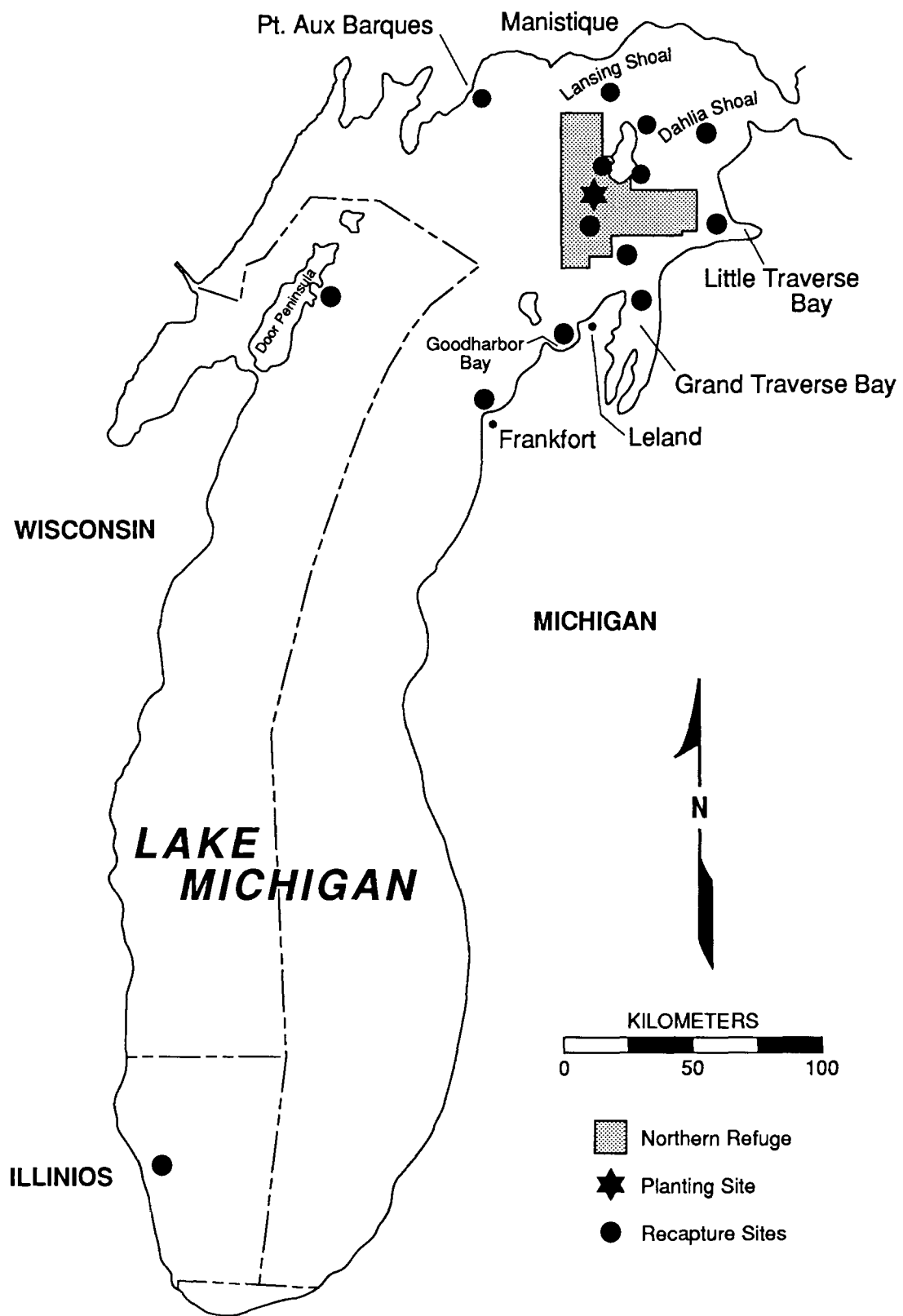


Figure 1.—Approximate locations of captures of northern refuge lake trout.

Table 1.—Number of yearling lake trout stocked in the northern refuge of Lake Michigan in 1986, by strain and release site, and the respective coded-wire tag number series.

Strain	Release site	Number stocked	Coded-wire tag number series
Wyoming	Richards Reef	58,433	431633
	Boulder Reef	56,735	431634
	Gull Island Reef	119,210	431635-36
	Subtotal	234,388	
Apostle Island outcross	Richards Reef	56,303	431637
	Boulder Reef	55,161	431638
	Gull Island Reef	110,553	431639-40
	Subtotal	222,017	
Marquette domestic	Richards Reef	61,829	431641
	Boulder Reef	61,451	431642
	Gull Island Reef	123,383	431643-44
	Subtotal	246,669	
Total		703,074	

Table 2.—Relative survival indices and catch of lake trout stocked in the northern Lake Michigan refuge in 1986, by strain and age.

Strain	Number stocked	Statistic	Age group				Total
			1	2	3	4	
Wyoming	234,388	Index (%)	0.033	0.003	0.015	0.079	0.129
		Number	77	7	34	184	302
Apostle Island outcross	222,017	Index (%)	0.038	0.002	0.019	0.053	0.112
		Number	84	5	43	117	249
Marquette domestic	246,669	Index (%)	0.035	0.002	0.019	0.061	0.117
		Number	87	5	47	150	289

Table 3.—Mean total length (mm) and growth rate (y^{-1}) of three strains of lake trout (1985 year class) stocked in the northern refuge of Lake Michigan, by index year.

Index year	Age	Statistic	Strain		
			Wyoming	Apostle Island outcross	Marquette domestic
1986	At June planting	Length	139	132	133
		Growth	0.25	0.25	0.23
		Sample N	—	—	—
1986	1	Length	178	169	168
		Growth	0.61	0.57	0.53
		Sample N	77	84	87
1987	2	Length	328	299	284
		Growth	0.27	0.33	0.44
		Sample N	6	7	5
1988	3	Length	428	417	441
		Growth	0.28	0.27	0.20
		Sample N	11	8	5
1989	4	Length	567	546	541
		Growth	—	—	—
		Sample N	105	91	74
Average		Growth	0.35	0.35	0.35

Table 4.—Number (and percentage) of three strains of 4-year-old lake trout captured in graded-mesh gill nets fished inside and outside the northern refuge of Lake Michigan in 1989.

General area of capture	Strain			Total
	Wyoming	Apostle Island outcross	Marquette domestic	
Inside refuge	153 (85.0)	135 (85.4)	99 (87.6)	387 (85.8)
Outside refuge	27 (15.0)	23 (14.6)	14 (12.4)	64 (14.2)
Total	180	158	113	451

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