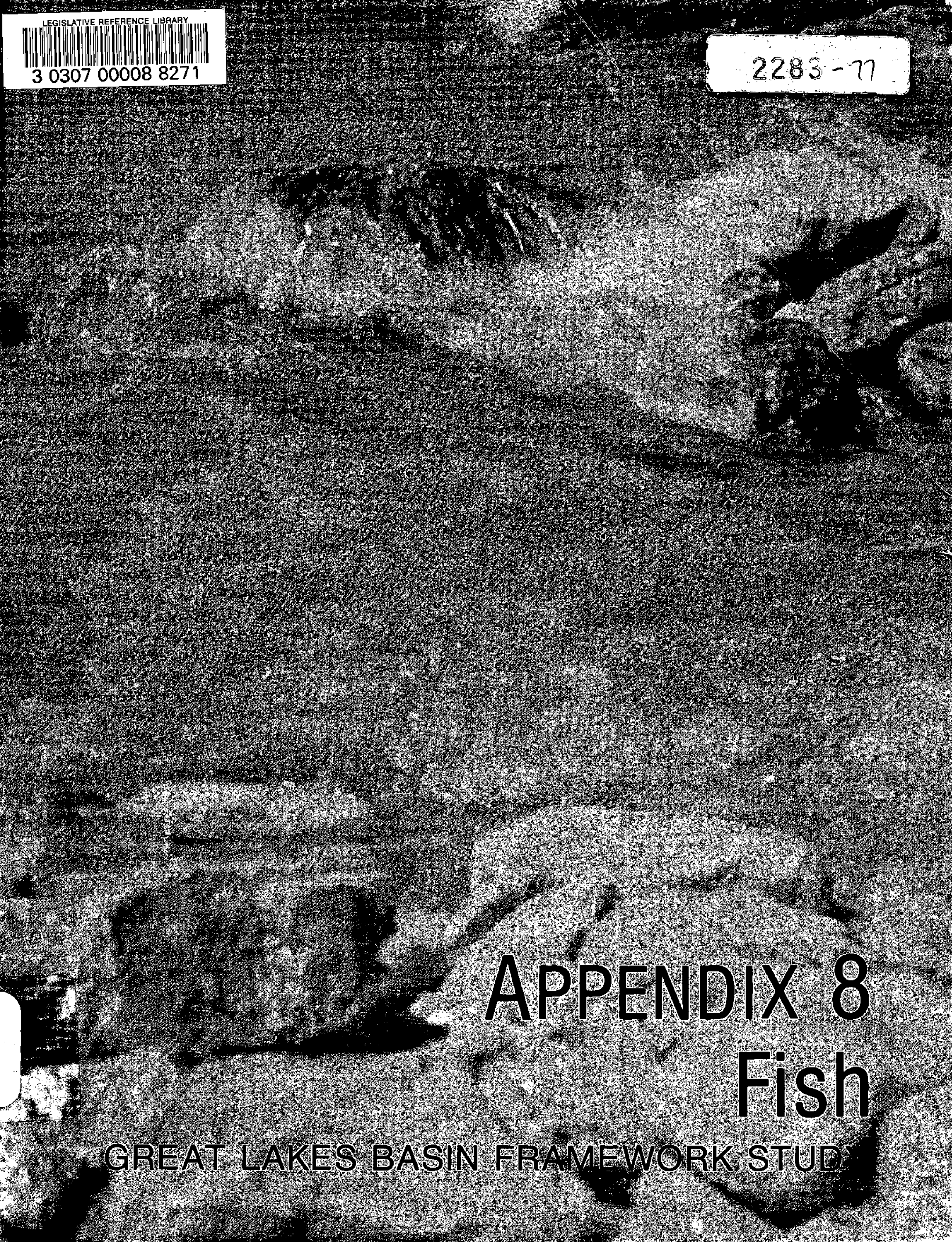

APPENDIX 8
Fish

GREAT LAKES BASIN FRAMEWORK STUDY

Great Lakes Basin Framework Study

APPENDIX 8

FISH

GREAT LAKES BASIN COMMISSION

Prepared by the Fish Work Group

Sponsored by Michigan Department of Natural Resources

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Cover photo by Kristine Moore Meves.

This appendix to the *Report* of the *Great Lakes Basin Framework Study* was prepared at field level under the auspices of the Great Lakes Basin Commission to provide data for use in the conduct of the Study and preparation of the *Report*. The conclusions and recommendations herein are those of the group preparing the appendix and not necessarily those of the Basin Commission. The recommendations of the Great Lakes Basin Commission are included in the *Report*.

OUTLINE

SYNOPSIS

This report provides information on the past, present, and future demand; analysis of the present and future capacity of the resource base to meet these demands; assessment of the problems involved; and general approaches to achieve solutions that will contribute maximum public benefits.

The information is presented according to the planning subareas established for the study as a whole. Because of the special nature of the fishery resource, much of the information is presented on a lakewide basis. However, it can be analyzed on a State-by-State basis to facilitate administration of programs.

In the preparation of this report, heavy reliance was placed on available data, inputs from ongoing programs, and reasoned approximations. Report preparation required a minimum number of new basic investigations and the judgment of experienced planners and administrators.

Fishery management needs have been analyzed and include the philosophy of management up to the present time. All considerations were made on the assumption that fish were the primary crop of all waters of concern. Whenever possible, management measures took into account the jurisdictional responsibilities of the participating agencies.

While the inland basins of the Great Lakes Region are included in this report, the major emphasis is placed on the Great Lakes themselves because their sheer size and fishery potential will dominate the future sport and commercial fishery of the Basin. The Great Lakes also require the highest degree of cooperative management.

This report will discuss the rapidly changing conditions on the Great Lakes. During the last twenty years tremendous changes in fish populations, management practices, management philosophy, and fish habitat have occurred. Recent common fishery crises and management successes have promoted high degrees of cooperation at the international, national, and State levels, and have created a public awareness of the potential value of the Great Lakes fishery resources.

FOREWORD

This appendix was prepared by the Fish Work Group under the chairmanship of Dr. Wayne H. Tody, Michigan Department of Natural Resources. The Fish Work Group included representatives from each of the Great Lakes States and the United States Departments of Agriculture, Army, and Interior.

The following individuals and the agencies they represented contributed to this appendix.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Study Objectives

Appendix 8, *Fish*, has changed continuously throughout the study period to coincide with the planning requirements of the Great Lakes Basin Commission and the available manpower and money at the disposal of the Fish Work Group. However, the basic objectives have remained the same.

The objective of this report is to examine long-range fishery development programs for the waters of the Great Lakes Basin, predicated on the historical development of the fishery, present status and problems, and projections of future supply and demand. Alternative approaches have been considered in response to various physical, ecological, social, economic, and institutional conditions that are expected in future years.

Fish and Fisheries

The Great Lakes Basin contains a wide variety of fish. Most of the important families of North American freshwater fish are represented in the Great Lakes Basin. More than 237 species and subspecies of fish are now present in the waters of the Basin.

While many species of fish have been purposefully or accidently introduced by man, most are indigenous, having entered the Great Lakes area during various glacial stages. Water migration routes once existed from the Hudson Bay and upper Mississippi River in the northwest; the Ohio River and Mississippi on the south; and the St. Lawrence, Mohawk-Hudson, and Susquehanna Rivers on the east. Each of these separate basins now has certain species of fish in common with the Great Lakes Basin. The temperate climate of the Great Lakes Region has provided for the northern extension of the natural range of several warmwater species and the southern extension of the natural range of many coldwater species.

Commercial fishing has been important for over a century in the Great Lakes. The decline of certain important commercial food fish in the 1860s was in large part responsible for the creation of the various State fish commissions in the 1870s. Since the turn of the century, the Great Lakes States inland fishery resources have been generally reserved for recreational use by the public.

In the last decade, many States have turned to the Great Lakes to provide recreational fishing. The development of selective sea lamprey control chemicals in the late 1950s laid the groundwork for the rehabilitation of the traditional fisheries and led to the introduction of new species to fully utilize the tremendous potential of the Great Lakes to produce fish valuable both as food and as a source of high quality recreation.

This report details the investments necessary to fully develop the vast potential of the public fishery resources of the Great Lakes Basin.

Methodology

The methodology used for calculation of fishing demand, as summarized at the end of each section, was relatively straightforward. Attempts were initially made to project demand using formulas developed in the Ohio River Basin study by the Bureau of Sport Fisheries and Wildlife. While input data for this formula were available for the Great Lakes Basin (i.e., population, habitat base, fishing license sales), the unusually high habitat base in the Great Lakes Basin and the distribution of population in the Basin undermined the basic assumptions utilized to construct the formula.

Fishing trends were projected strictly on the basis of population in this study. The assumption was made that fish managers should plan to maintain the same ratio of fishermen in the population in 1980, 2000, and 2020 as occurred during the base years 1966–67. Therefore, the projections represent the minimum demand. Where current observations or professional judgment indicated that future fishing demand would be significantly different than that projected, the narrative in the text suggests how and why the demand is different from that projected solely on population trends.

Section 1

DESCRIPTION OF BASIN

1.1 Geology

The Basin occupied by the Great Lakes (Figure 8–1) was created by glaciation and its physical features and hydrology differ greatly from those of regions not glaciated or only modified by glaciation. Its construction was only recently completed in terms of earth history. The five Great Lakes, with their outlets and approximate Lake levels as they are today, date back less than 5,000 years. The processes of stream and shoreline erosion hardly changed the original topography.

Prior to the Pleistocene age the Great Lakes were nonexistent and the area was traversed by well-drained valleys and divides of several large rivers. When the continental ice cap developed to a thickness of several thousand feet over all of what is now Canada, it spread southward into this lower area, completely covering the Great Lakes-St. Lawrence Basin. Tremendous amounts of bedrock were eroded and the debris was entrained in the ice mass. As the ice sheet slowly melted and retreated progressively northward, it released the entrained debris in the form of vast irregular deposits of overburden.

The Pleistocene topography was entirely changed. Parts of the major pre-glacial valleys were deepened by glacial scouring, while other parts that were filled by glacial deposits formed the basins of the five Great Lakes. The pre-glacial, well-drained divides also were scoured and buried under glacial deposits. Present land areas have an irregular and varied topography. They are characterized by depressions occupied by small lakes or marshes, level or sloping local plains, and low rolling hills or ridges. The varied overburden ranges from clays to sand or gravel.

Temporary occurrences of large glacial lakes contributed to development of topography and overburden conditions in areas bordering present shorelines. During the final northward recession of the ice front there was ponding of melt waters between the ice and exposed glacial deposits. This resulted in a gradually enlarging lake, rising in some cases hundreds of feet above present lake levels and overflowing into outlets across present watershed divides. As the ice border receded, the pattern and levels of those lakes were repeatedly changed by new lower outlets. The effect of these glacial lakes on present shorelines is illustrated by the perched wave-cut cliffs of Mackinac Island, the lake-deposited clay flats of Chicago and Toledo, the variable stratified sands and silts constituting or overlying the bluffs along the Ohio shore of Lake Erie, and the sand tracts of the dune areas. Concurrent with the shrinking of the ice mass, a differential uplift of the earth surface occurred and the tilted positions of the present shore features of the glacial lakes were created.

The outlets of Lakes Superior and Erie are controlled by bedrock uncovered by erosion at shallow depths under the glacial overburden at Sault Ste. Marie and the Niagara River below Buffalo. Although bedrock occurs at shallow depth in the Detroit River, the Lake Huron outlet control is still overburden for the entire length of the St. Clair River.

The configuration of the Great Lakes has been only slightly altered since its glacial development. However, shoreline overburden is still vulnerable to erosion.

1.2 Topography

The Great Lakes Basin ranges in elevation from more than 4,500 feet in the Adirondack Mountains to 152 feet above sea level at Cornwall, Ontario, near the International Boundary. The mean surface elevations of the Great Lakes during the past 100 years have been: Lake Superior, 602.20; Lakes Michigan-Huron, 580.54; Lake Erie, 572.34; and Lake Ontario, 246.03. Maximum recorded depths of the Great Lakes range from 1,333 feet in Lake Superior to 210 feet in Lake Erie.

In general the tributary topographic relief varies slightly. Major stream profiles are relatively flat. Such tributaries as the Maumee and Grand have reversed their flows in recent

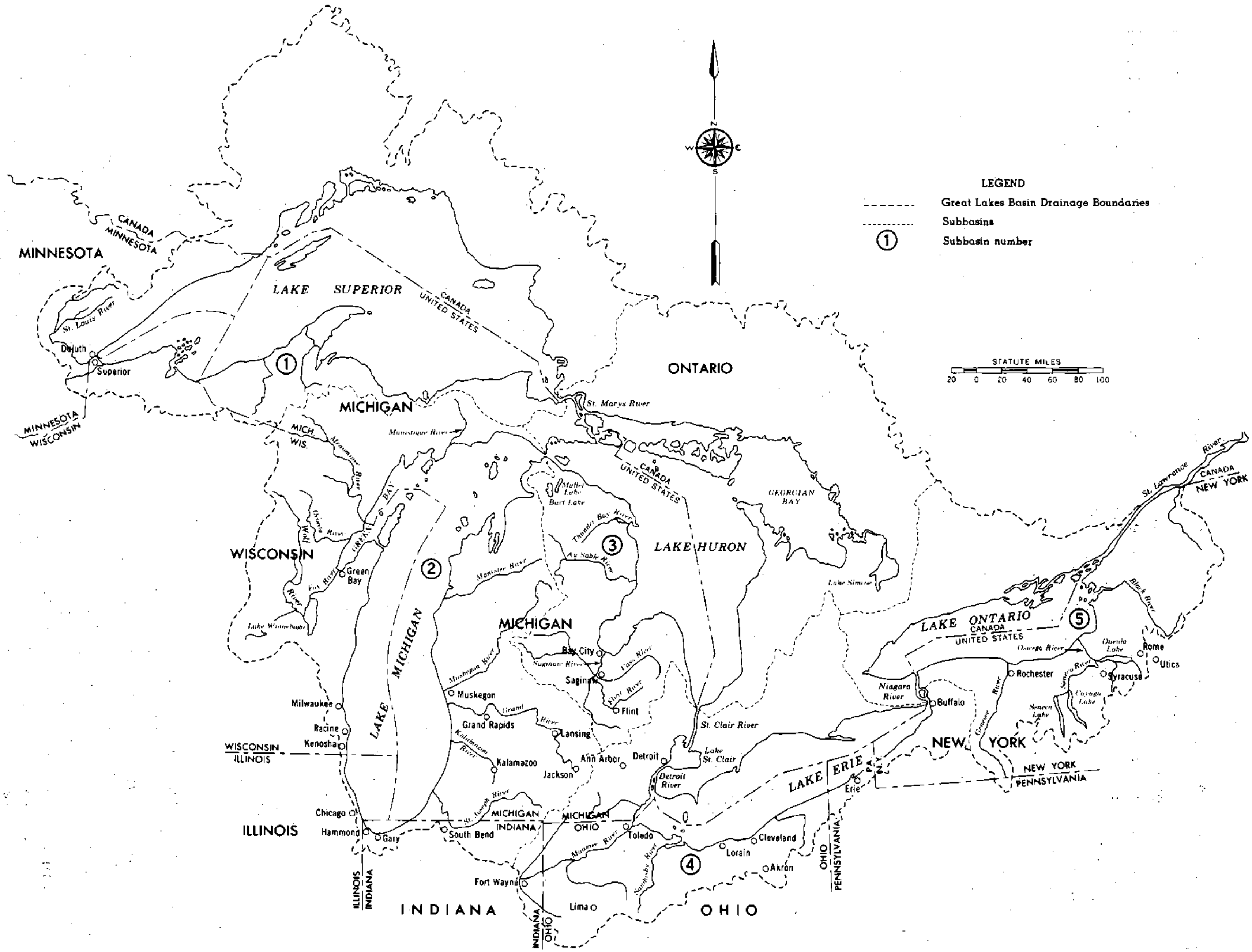


FIGURE 8–1 Lake Basins, Great Lakes Basin

geologic times as the outlets of the Great Lakes became lower. Although there are thousands of natural lakes in the Basin and hundreds of small power plant storage reservoirs, there are few suitable reservoir sites for surface storage available for water resource development. Of the few sites available, the Oswego and Genesee basins flowing into Lake Ontario, the Cuyahoga and Sandusky basins flowing into Lake Erie, and the Fox River flowing into Lake Michigan offer the most suitable topography for water storage.

Because there exists no well-developed main and tributary valley systems, the tributary surface drainage system is rudimentary. With few exceptions the main valleys are low places in the glacial topography into which melt waters escaped from the ice front leaving the valleys partly filled with silts, sands, and gravels. Their downstream reach runs in many cases across the clay or sand flats of glacial lake bottoms. The few tributary valleys are small and tend to follow the lows of the glacial topography. Except in minor areas at the east and west ends of the watershed, the divides separating basins are characteristically broad and vary from almost level plains to rolling hills. The overall topography, which has large areas of sandy and gravelly tracts, is favorable to infiltration and unfavorable to rapid surface runoff. The numerous lakes, marshes, and peat bogs further reflect the poor development of surface drainage.

1.3 Soils

The soils of the Great Lakes Basin are of glacial origin. For 60,000 years the Basin was dominated by the Wisconsin glacier. Ice thickness varied from a few thousand feet to several miles, and thickness of drift varies from a few inches to more than 400 feet. By the oscillating movement of its ice and melt water, the glacier finely ground, mixed, transported, and distributed the rock material.

The soils that developed from this material include the Iron River and Gogebic soils in Minnesota, Wisconsin, and the Upper Peninsula of Michigan. These soils occur in thin glacial till over igneous bedrock. Also in this area are the Ontonagon and Trenary soils, which are calcareous clays and loams. The Rubicon, Au Gres, and Roscommon soils occupy areas in Wisconsin and Michigan. These are level-to-rolling, well-drained-to-poorly-drained sands. The Sims, Kawkawlin, Toledo, and Vergennes soils are fine and moderately fine textured deposits. In southern Michigan, Indiana, western Ohio, and eastern Wisconsin soils occur in rolling, calcareous glacial till and sandy outwash materials. These include the Miami, Hillsdale, Fox, Boyer, and Spinks soils. The Brookston, Conover, Crosby, and Blout soils are also found in this area, mainly in nearly level regions. The Wooster-Mahoning soils occur in rolling, acid glacial till in eastern Ohio and Pennsylvania. The Ontario and Lordstown soils occupy much of western New York. The Ontario soils are in deep, calcareous glacial till and the Lordstown soils are in thin, acid glacial till over sandstone and shale. Other areas of upper New York have Gloucester, a rough stony soil prevalent in the Adirondack Mountains.

1.4 Climate

Because of their large surface area and depth, the Great Lakes have a decided tempering effect upon the severe climate associated with their shores. Based on the period 1883 to 1957, average annual temperature in the Great Lakes Basin ranges from 39.0 degrees on Lake Superior to 48.7 degrees on Lake Erie. Minimun and maximum monthly temperatures occur in February and July.

The mean annual precipitation for the entire Basin for the same period is approximately 31 inches, with a minumum of 25 inches in 1930 and a maximum of 37 inches in 1950. The annual snowfall within the Great Lakes Basin ranges from approximately 40 inches to 120 inches.

Estimates of the annual rate of evaporation on the surface of the Great Lakes range from a minimum of approximately 1.5 feet on Lake Superior to approximately 3.0 feet on Lake Erie. The Lakes are generally ice-free from May to the early part of November. In general an ice cover does not form on the Lakes except in bays and in sheltered areas between islands in the northern regions.

1.5 Human Population Status and Trends

The Great Lakes Region covers approximately 4 percent of the United States land area and has 14.4 percent of the nation's population. The 1960 population of the counties in the Region was 25.5 million. Of this total, 19.4 million were classified as urban residents.

The Region's population classified as urban is projected to increase to 85 percent urban by

2000. This urbanization is attributed to the expansion of the following major metropolitan areas with a 1960 population in millions: Chicago-Northwestern Indiana, 6.8; Detroit, 3.8; Cleveland, 1.9; Buffalo, 1.3; Milwaukee, 1.2; Rochester, 0.7; Syracuse, 0.6; Akron, 0.6; Toledo, 0.6; Grand Rapids, 0.5; Flint, 0.4; Utica-Rome, 0.3; Lansing, 0.3; Duluth-Superior, 0.3; South Bend, 0.3; Erie, 0.3; and 11 other Standard Metropolitan Statistical Areas of 100,000 to 250,000 population.

1.6 Transportation Facilities

The 95,000 square miles of water surface, extending over 2,000 miles, makes the Great Lakes system the world's largest body of fresh water. One hundred billion ton-miles of water-borne freight per year is transported over the Great Lakes-St. Lawrence navigation system.

The Great Lakes are connected by rivers and related waterways such as the St. Marys River, Lake Superior to Lake Huron; the Straights of Mackinac, Lake Michigan to Lake Huron; the St. Clair River, Lake Huron to Lake St. Clair; the Detroit River, Lake St. Clair to Lake Erie; the Niagara River, Lake Erie to Lake Ontario; and the St. Lawrence River, Lake Ontario to the Atlantic Ocean. As a result these connecting waterways provide a low-cost means of transporting major resources in the Basin.

1.7 Agriculture

The widely varying factors of climate, soils, and topography foster a diverse agriculture that ranges from truck and fruit crops to general farming. The Basin is very important for its dry bean production, "hothouse" rhubarb, sugar beets, and soft white wheat used in flour blending. Dairy farming is found throughout the Region. Cash crops, such as corn, soy beans, and vegetables, predominate in the more productive southern portion. Due to the favorable climate along the Lakes, one of the nation's most important fruit and vegetable areas has developed and is contributing to an expanding fresh and processed fruit and vegetable market. Large quantities of feed grains are grown in the Basin both for local use in the livestock industry and for export.

New forest growth followed the heavy logging of the second decade of this century. Natural reproduction has been encouraged by improved fire protection and reforestation. This created an improved forest resource of high potential and gradually increasing productivity which is being used by forest-based industries such as sawmills and pulp and paper mills. In view of the long-term prospects for forest products, this resource will serve as a basis for new economic development. Production of pulpwood, saw logs, veneer logs, and miscellaneous industrial timber products is substantial and is expected to increase.

Many people in northern Minnesota, Wisconsin, Michigan, and New York depend upon the resources of forested areas for a livelihood. Increasing population, rising income, and more leisure time have greatly stimulated the demand for recreational facilities and related services in the Basin. Forest and water areas provide scenery and a favorable environment in which people can enjoy outdoor recreational activities. These same areas also provide good habitat conditions for fish and wildlife.

1.8 Industry

From the viewpoint of economic development, the dominant characteristics of the Great Lakes Region and adjacent areas are the large bodies of fresh water in the Great Lakes, the Region's location within the highly industrialized North Central United States, and the presence of natural resources for manufacturing.

The Great Lakes Region provides approximately 50 percent of the nation's steel. Within 100 miles of the Great Lakes are significant concentrations of various types of United States manufacturing industries. The Great Lakes Region employs the following percentages of the nation's work force in these industries: primary metals, 42; instruments, 36; nonelectrical machinery, 31; fabricated metal products, 30; transportation equipment, 29; electrical machinery, 26; rubber and plastics, 20; printing and publishing, 20; furniture and fixtures, 18; food, 17; chemicals, 16; stone, clay and glass products, 16; petroleum and coal products, 14; and paper and allied products, 13. Most of the industries serve national or major subnational markets. In 1963 manufacturing activity exceeded 40 billion dollars, almost one-fourth of the nation's total.

There are approximately 160 existing hydroelectric plants in the Basin, which supply both private and public needs. A small portion of these needs is also met by nuclear-fired generation.

The mineral industries are a vital and important segment of the economy of the Basin as well as of the nation. For example, the area's mineral production totaled $1,418 million in 1965. Principal minerals contributing to this total were metals including iron ore, copper, zinc, and silver, $633 million; stone, $156 million; sand and gravel, $105 million; salt, $100 million; and lime, $90 million. Other important minerals produced in the Basin included ilmenite, gypsum, magnesium, petroleum and natural gas, clay, coal, and calcium-magnesium compounds. The western Great Lakes area produces approximately two-thirds of the nation's output of iron ore and five percent of its domestic copper output.

The 1964 commercial fishing catch in the United States totaled more than 53 million pounds, one-half of which was taken from Lake Michigan.

Section 2

GREAT LAKES FISHERY RESOURCES

This portion of the appendix addresses those problems and needs of the fisheries of the Great Lakes and does not concern itself with considerations of planning subareas.

The first portion of this two-part section discusses general problems and needs of Great Lakes' fisheries and fish resources. Problems of oil spills and thermal pollution are included. The second part, which addresses problems of individual Great Lakes, is subdivided into the five sections followed by inland planning subarea discussions.

2.1 Habitat Base

The more important physical and chemical characteristics of the Great Lakes are summarized in Table 8–1 and Figure 8–2 through Figure 8–5. Although water quality conditions differ significantly between Lakes and even between different areas of the same Lake, a generalized summary of the more important chemical changes that have taken place in them was possible. More detailed discussions of these and other changes will be found in the individual Lake reports herein contained and in Appendix 4, *Limnology of Lakes and Embayments*.

2.1.1 General Problems, Needs, and Solutions

Obvious changes in the fish and plankton populations of the Great Lakes have already been discussed. There are other more subtle changes such as those exhibited by changing benthos and chemical characteristics. The latter changes manifest themselves only after long periods of time (Figures 8–6 through 8–9). The solid lines on these figures represent Beeton's (1965) suggested trends, dashed lines represent Weiler and Chawla (1969) suggested trends, and data are from Beeton, Kramer (1964), and Weiler and Chawla.

The Lakes which have exhibited the most profound changes in water chemistry over the past three or four decades are those whose basins have fostered the greatest population growths. Because population growth in the Lake Erie basin has exceeded that of other Great Lake areas, changes in its water chemistry and benthos have been substantial. Lake Ontario, which receives its waters from Lake Erie, has exhibited similar changes in water quality without the associated population growth.

Waters of the southern Lake Michigan basin, which is also experiencing the effect of increased population pressure, have displayed unmistakable signs of accelerated eutrophication. The rate of this process is slightly slower because of Lake Michigan's large volume. This undeniable trend is discouraging because most of the major tributaries of the Lake are heavily polluted. We can expect parallel though diluted changes in Lake Huron, which receives approximately 30 percent of its waters from Lake Michigan. The possible dilution benefits of Lake Huron waters upon Lake Erie are considerably reduced because they pass through the Detroit metropolitan complex. The entire volume of the Lake can be replaced in three years while that of Lake Michigan requires at least thirty.

Although changes have taken place in the chemical characteristics of Lakes Ontario, Erie, and Michigan, and in Saginaw Bay of Lake Huron, the truly significant changes are taking place in the sediments because of the tremendous amounts of allochthonous materials that daily enter the Lakes. For example, 1.4 million pounds of suspended solids are discharged daily into the Detroit River by municipal and industrial concerns. Changes in the quantity, diversity, and species composition of benthic organisms and dissolved oxygen levels testify to the changes taking place in the sediments as the result of these discharges. Because all Great Lakes fish except the sheepshead have demersal eggs, changes in their populations may also be related to waste inputs.

Changes in the benthos of Green and Saginaw Bays as well as isolated areas such as the Harbor Beach area in Lake Huron indi-

TABLE 8–1 Physical Data of Great Lakes System

	Lake Superior	Lake Michigan	Lake Huron	Lake St.Clair	Lake Erie	Lake Ontario	Totals
Length (miles)	350	307	206	26	241	193	------
Breadth (miles)	160	118	183	24	57	53	------
Water area (sq.mi.)							
United States	20,700	22,400	9,110	200	4,990	3,600	61,000
Canada	11,120	------	13,900	290	4,940	3,920	34,170
Total	31,820	22,400	23,010	490	9,930	7,520	95,170
Average surface elevation since 1860 (ft.)	602.20	580.54	580.54	574.88	572.34	246.03	------
Maximum Depth (ft.)	1,333	923	750	21	210	802	------
Mean Depth (ft.)	487	276	195	10	58	283	------
Drainage area (sq.mi.)	80,000	67,860	72,620	7,430	32,490	34,800	295,200

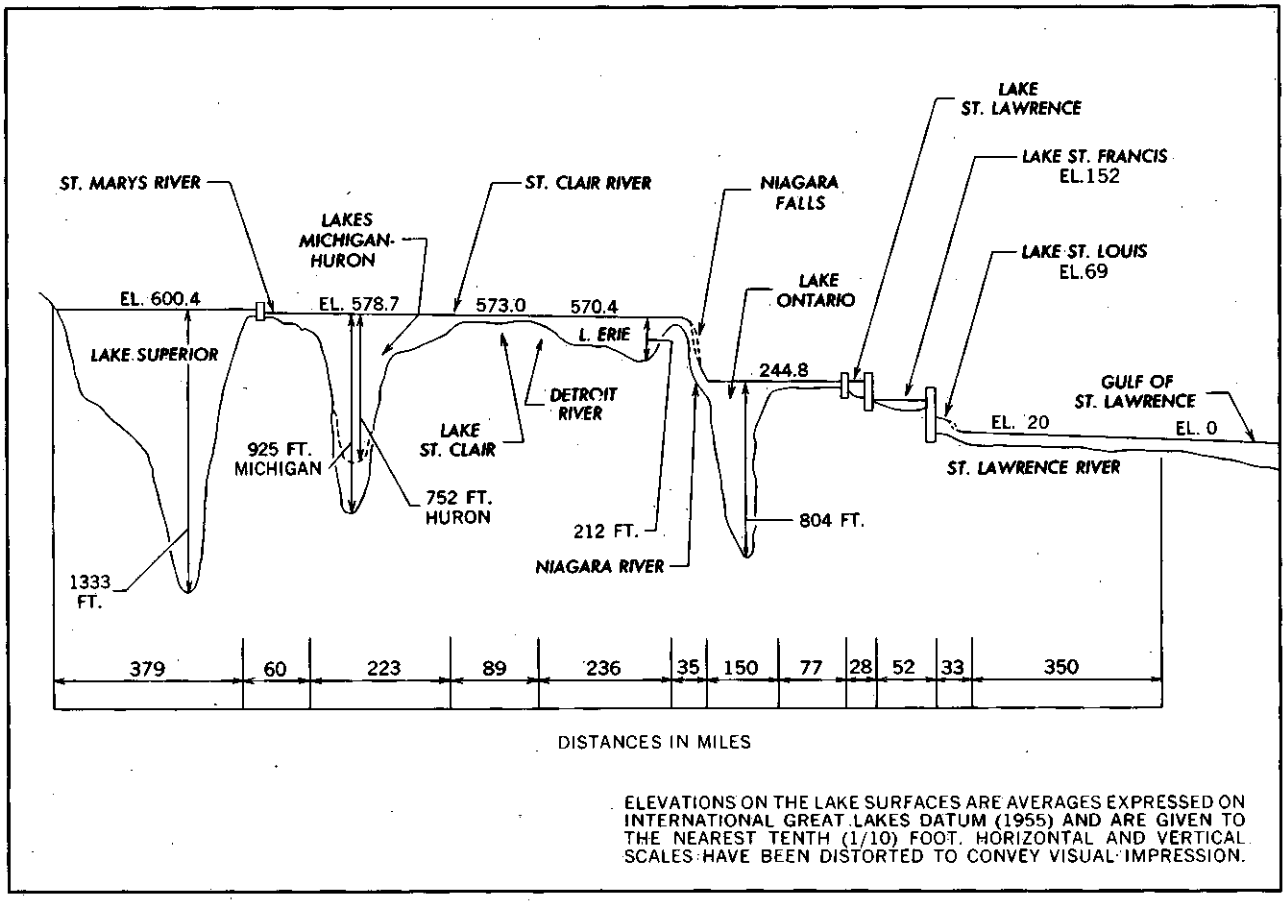


FIGURE 8–2 Great Lakes Profile

cate organic enrichment of the sediments. Oligochaete species, which are associated with enrichment conditions, are also important in the benthic communities of the littoral zones of Lake Ontario.

Because the successful establishment or reestablishment of high-value predator species in or throughout the Great Lakes Basin will depend heavily upon the existence of a suitable environment, the Fish Work Group supports any effort geared to the stabilization and improvement of water quality of the Lakes. In Lakes Superior and Huron existing water quality exceeds recently adopted State and Federal water quality standards for the Lakes. Degradation of these waters should not be permitted. Until careful research demonstrates that degradation of existing water quality to State and Federal levels will not result in harmful effects upon fish and aquatic life resources, the Fish Work Group will argue that pollution abatement is best served by retention of the existing standards including that of non-degradation. The success of these programs, which include maintenance of all Lake water quality standards, requires vigorous State and Federal enforcement programs.

In addition to encouraging vigorous law enforcement, the Fish Work Group recommends:

(1) that current enforcement authority be amended so that the Federal government can take action on pollution affecting inhabitants of a State without requiring the consent of the Governor

(2) that because Federal water quality standards do not presently apply to intrastate waters, the Refuse Act be employed as an additional tool to enforce the Federal Water Pollution Control Act and to extend Federal regulatory authority

(3) that existing water quality legislation be amended to limit effluents

(4) that the development of policies in waste handling and treatment to avoid water pollution be carried out with the realization that effective waste disposal must involve integrated consideration of air and water pollu-

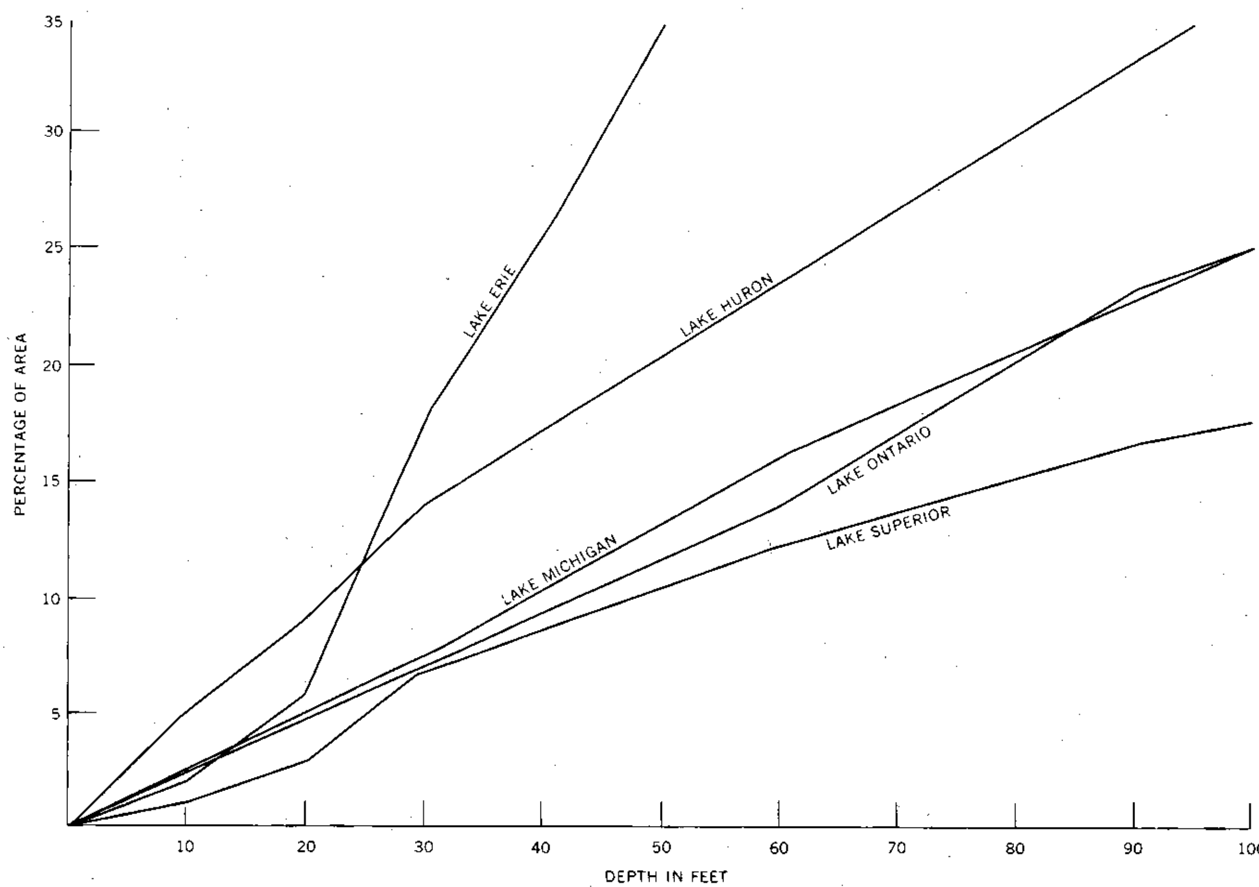


FIGURE 8–3 Great Lakes Depth Area Curves, 0–100 Feet

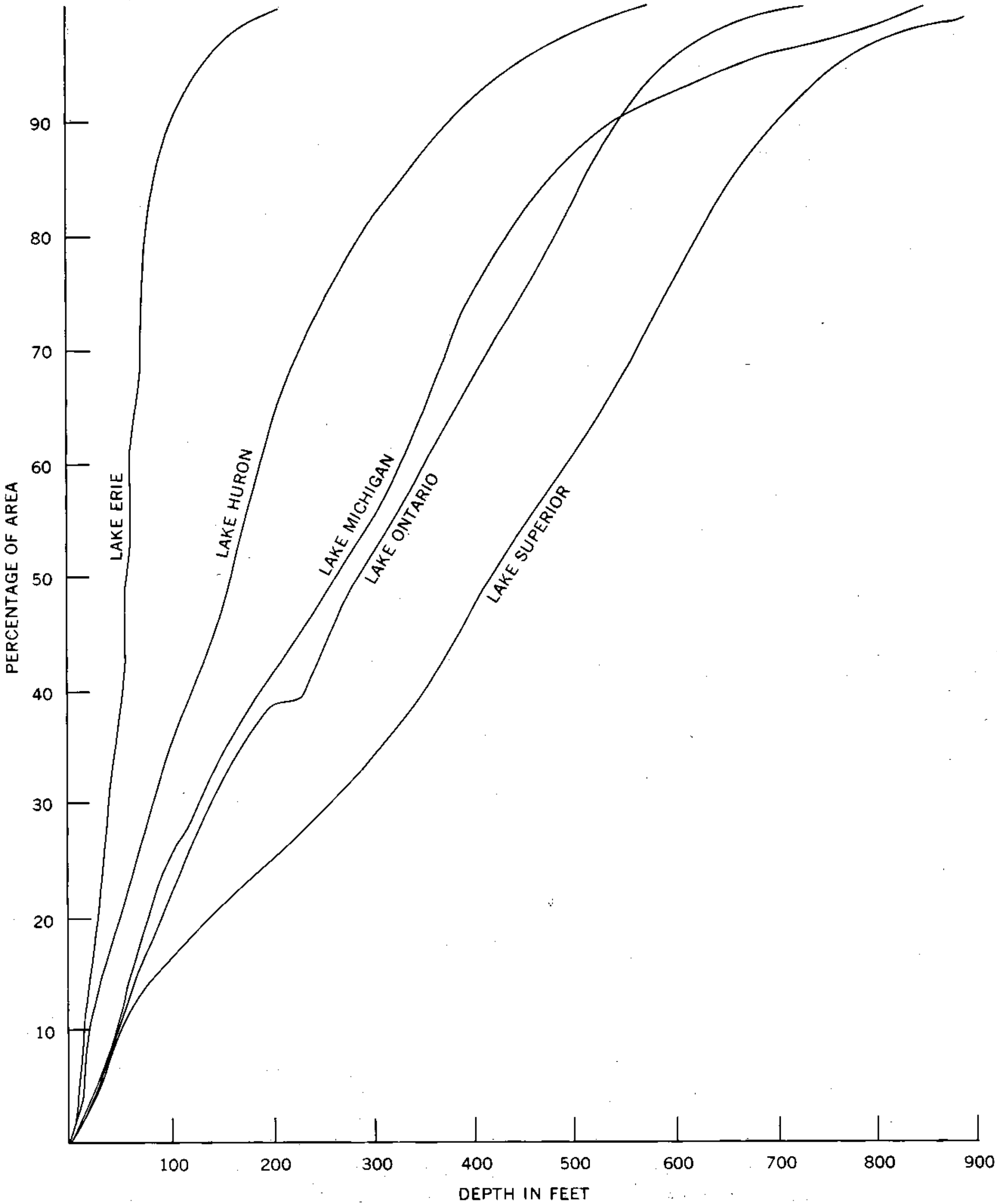
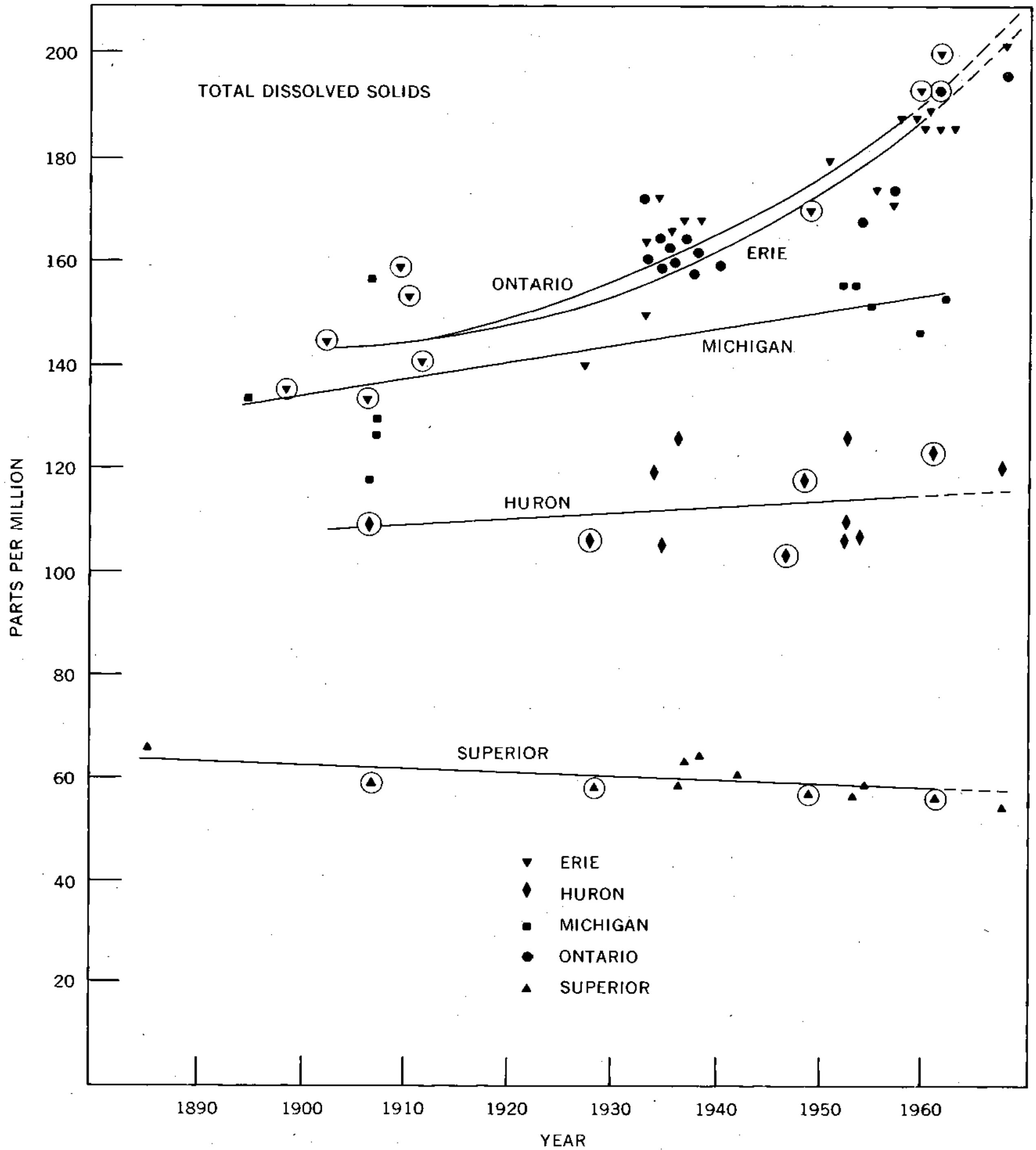
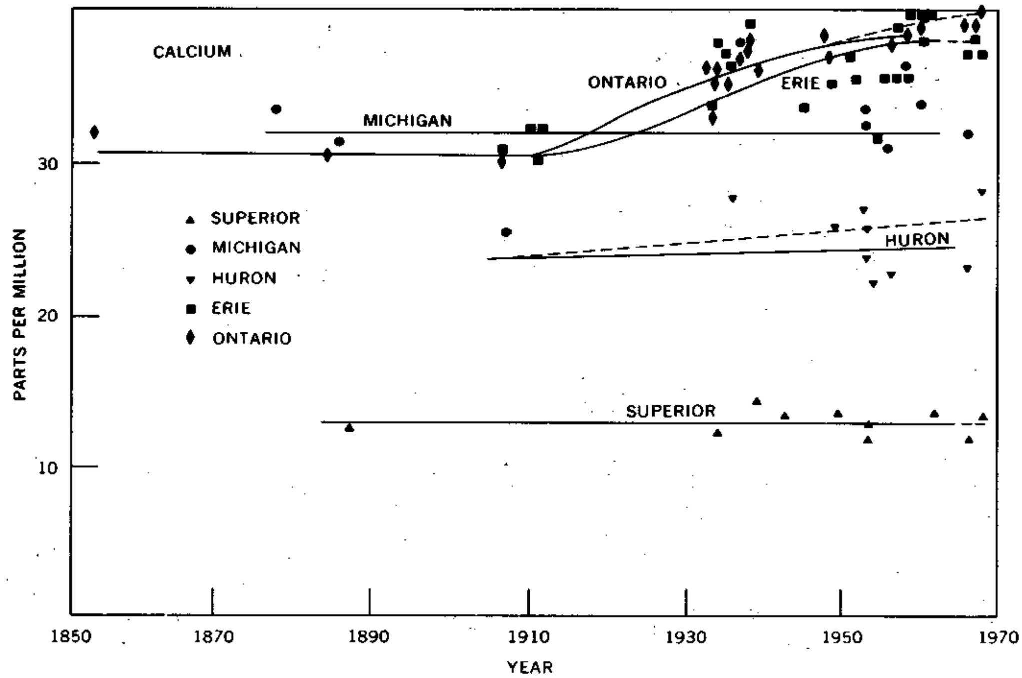


FIGURE 8–4 Great Lakes Depth Area Curves, 0–900 Feet



AFTER BEETON (1965), KRAMER (1964), AND WEILER AND CHAWLA (1969).
CIRCLED POINTS ARE THE AVERAGES OF 12 OR MORE DETERMINATIONS.

FIGURE 8–5 Changes in Total Dissolved Solids of the Great Lakes



SOLID LINES REPRESENT BEETON'S (1965) SUGGESTED TRENDS. DASHED LINE REPRESENT WEILER AND CHAWLA (1969) SUGGESTED TRENDS. DATA ARE FROM BEETON, KRAMER (1964), AND WEILER AND CHAWLA.

FIGURE 8–6 Historical Calcium Concentration Trends in the Great Lakes

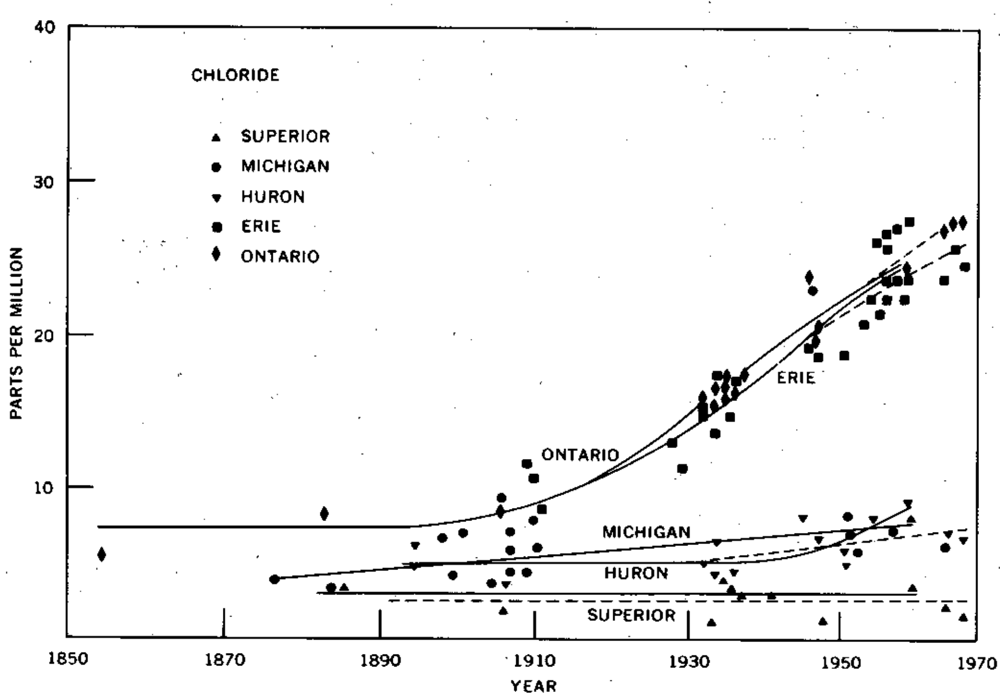


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FIGURE 8–7 Changes in Chloride Concentration in the Great Lakes

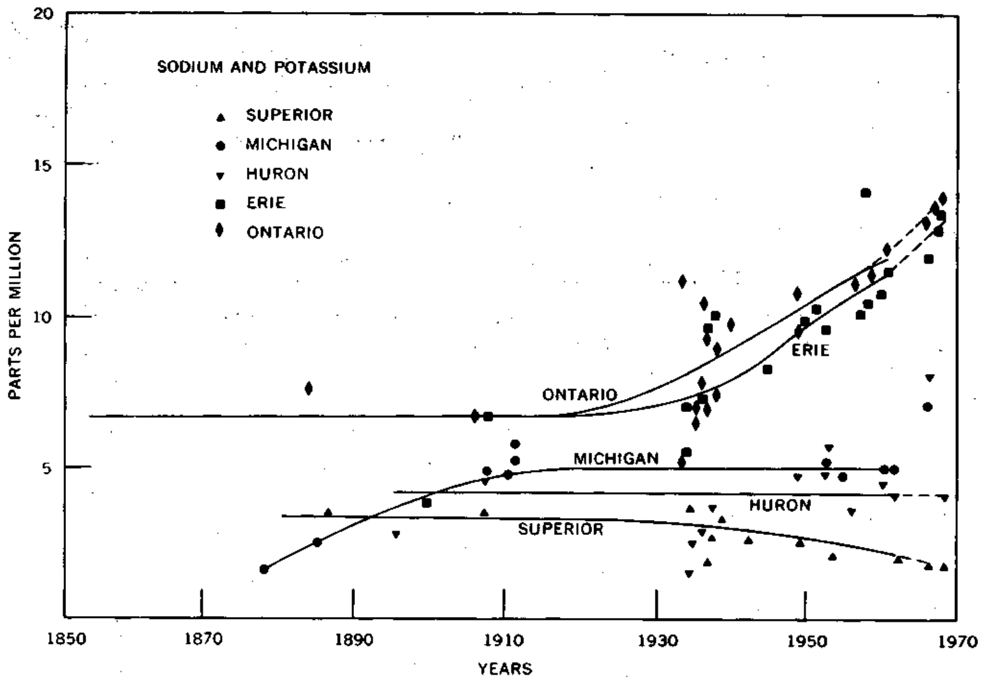

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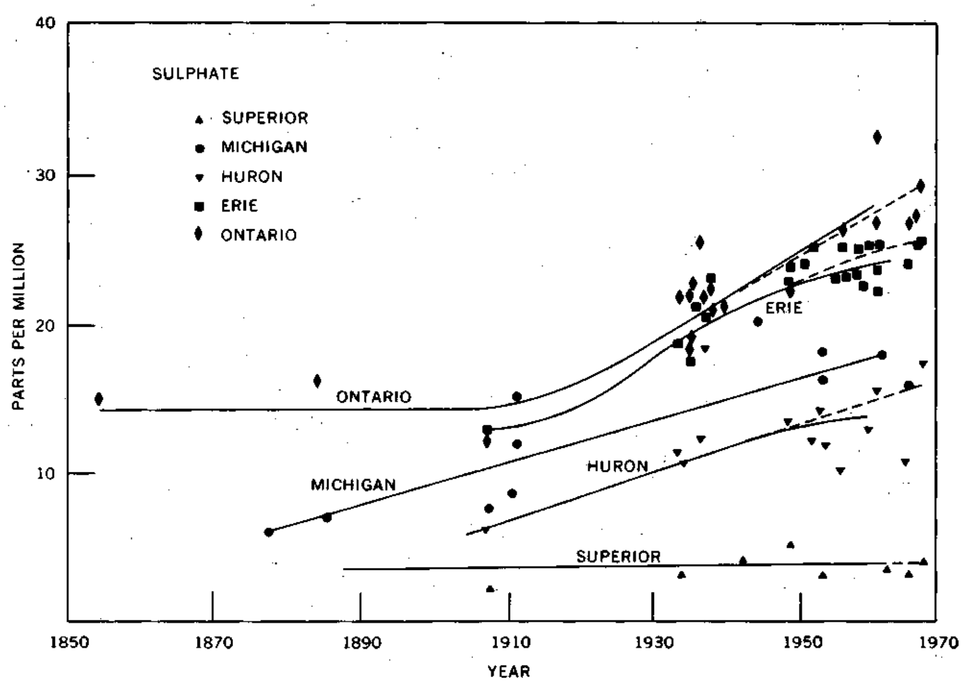
FIGURE 8–8 Changes in Sodium and Potassium Concentration in the Great Lakes



SOLID LINES REPRESENT BEETON'S (1965) SUGGESTED TRENDS. DASHED LINES REPRESENT WEILER AND CHAWLA (1969) SUGGESTED TRENDS. DATA ARE FROM BEETON, KRAMER (1964), AND WEILER AND CHAWLA.

FIGURE 8–9 Changes in Sulfate Concentration in the Great Lakes

tion control and solid waste management. Waste pollution control policies must avoid creating air pollution or solid waste problems. Greater emphasis should be placed on effective waste management through recycling, recovery, and reuse.

The Fish Work Group also recommends that research aimed at determining the amounts and sources of various system inputs (pesticides, fertilizers, heavy metals) be continued. This research should also explore the effect of these inputs on such varied system components as food chains, reproductive capacities of various organisms, and fish spawning and nursery areas. It is also necessary to determine the concentration characteristics that different species display for these various inputs.

2.2 Biology of the Individual Species

Prior to 1950 U.S. commercial fishing relied heavily on eleven species: lake sturgeon, lake trout, blue pike, lake herring, chubs, lake whitefish, carp, suckers, catfish, yellow perch, and walleye. Only the last eight have played a substantial role in the commercial fishery of the last two decades. However, lake herring is no longer important in the commercial fishery. Invasion by sea lamprey, smelt, and alewife, and, in some cases, overfishing has led to the virtual elimination of the first four from the commercial fishery. However, they still remain as considerations for future restored fishery. Four other species, northern pike, bullhead, sheepshead, and quillback, contribute to the commercial fishery, but their total combined catch has represented only 1.56 percent of the total over the last 20 years. Three introduced or invading species, the smelt, alewife, and sea lamprey, have become significant to the fishery over the last twenty years, and four others, the coho, chinook and kokanee salmons, and the splake are expected to play a part in the future fishery.

Except for the practical elimination of the sturgeon and the decrease in yellow perch landings since the early 1920s, relatively few changes were recorded in species composition and total landing until the late 1930s. The commercial fisheries then witnessed drastic declines in lake herring, lake trout, and whitefish landings and steady declines in the walleye and sucker catches through 1969. There was a significant increase in the chub fishery from 1958 to 1965. These changes can be attributed to many factors including the biological characteristics of the individual species.

Management techniques should exploit the biological and behavioral characteristics of individual fish species. For example, coho salmon can be successfully introduced into the Great Lakes only if massive artificial propogation is employed. This program is required because of the lack of natural spawning opportunities. Biological and behavioral factors must also be considered when trying to control a species. The fact that the lamprey is semimobile during its lengthy ammocoete stage makes eradication or extreme reduction by larvicide application difficult.

Sport or commercial fishing may be essentially irrelevant to species with short life spans, early sexual maturity, high reproductive potential, broad and easily satisfied spawning requirements, and vulnerability to fluctuations in their environment. However, moderate exploitation may have substantial effects on species with long life spans, late sexual maturity, limited reproductive potential, demanding spawning requirements, and relative immunity to fluctuations in their environment.

Numerous types of biological and behavioral characteristics may be germane to management and exploitation decision making: longevity, time needed to attain sexual maturity, year class structure, rate of growth, spawning requirements, vulnerability to changes in the environment, behavioral characteristics, discreteness of stocks, and capacity to accumulate contaminants. Under natural conditions, these characteristics often interact. However, they should be considered separately as a preliminary analytical step.

2.2.1 Longevity

The length of a fish's life defines the period during which it is vulnerable to predation and changes in environment. Its lifespan also affects the options open to management.

Longevity defines the period that a fish is available to the entire fishery. The coho salmon, for example, usually only spawns at the end of its third year. After spawning, it dies. Because it dies after spawning, the coho should be utilized by the fishery before becoming a wasted resource. The following species are arranged in descending order from long-lived to short-lived: lake trout, carp, lake whitefish, splake, walleye, catfish, suckers, smelt, alewife, and the salmons.

2.2.2. Sexual Maturity

Age at which a fish attains sexual maturity can have a significant implication for management. Late sexual maturity in a desired species usually requires considerable management efforts to insure adequate self-sustained reproduction. The classic example is the current problem of assuring that lake trout, which are threatened by residual sea lamprey population, survive through sexual maturity. Early-maturing fish are often more adaptable than slow-maturing species. This adaptability can take the form of resiliency, which allows the species to maintain itself even if subjected to heavy predation. If the alewife, a species which possess these characteristics, were classified undesirable, this acquired resiliency would make population control very difficult.

Changes in age of sexual maturity can reflect the effects that varying levels of exploitation have on a specific population. This provides management with information useful in decision making. Recent studies have shown that heavy exploitation of the Lake Huron whitefish has resulted in earlier sexual maturity. Because it matures earlier, the whitefish also acquires an improved degree of adaptability and resiliency associated with early-maturing species. This flexibility prevents stock depletion while still providing an adequate supply to the commercial fishery.

Attainment of sexual maturity also affects the timing of exploitation. Harvest of late-maturing species prior to maturity can have considerable repercussions on the abundance of a species. In the face of exploitation early-maturing species usually have a distinct advantage over late-maturing fish by sustaining proportionally greater levels of removals.

Examples of late-maturing species would include the lake trout, lake whitefish, and the walleye, whereas those attaining maturity earlier are the salmons, alewife, and smelt.

2.2.3 Year Class Structure

This biologically determined characteristic varies from species that normally have several sexually mature age classes to species that normally exhibit a structure dominated by one or two sexually mature age classes. Other species exhibit various intergradations between these two extremes. In spite of marginal environmental conditions that can distort a normally multi-age class adult population, population structure of the alewife and coho salmon is inherently dominated by a single adult reproducing-age class. The yellow perch, normally an intermediate example, has been reduced in Lake Erie to dependence on one or two year classes due to adverse changes in the environment.

The multi-age class adult structure is the most stable. Loss of an occasional year class has only minor impact on the basic status of the stocks. Steady optimum harvest rates by the sport and commercial fishery are relatively easy to calculate. Because this type of population age class structure is usually characterized by steady but modest annual recruitment, exploitation at more than the sustainable rate by either the sport fishery, the commercial fishery, or predators results in rapid, even crash, declines.

Species which are normally characterized by only one or two sexually mature adult age classes are unstable, being vulnerable to failure of the dominant year class. Measures should be taken either to protect or deplete the key age class prior to spawning. In practice, however, effective management measures are seldom available. Once adequate spawning has taken place the entire age class becomes available for exploitation. Species whose year class structure falls between a multi-age class adult structure and an essentially single-age class adult structure pose more complex problems. Theoretically, measures such as remedial stocking and adjustment of exploitation rates could be employed to maintain a satisfactory age class distribution. However, such measures require adequate knowledge and regular monitoring of possible shifts of age class structure. Realistically, adequate knowledge and monitoring capabilities are a long way off. Some day a well-regulated commercial fishery may provide this capability for Great Lakes species in this intermediate group.

Species normally characterized by a multi-age class structure, while exhibiting a fluctuating age class structure due to long range environmental deterioration, cannot be effectively managed or exploited. Unless something is done about the environmental causative factor, our only recourse is to preserve the species.

2.2.4 Rate of Growth

A fish's growth rate defines its susceptibility to predators, especially those that are size specific. A slow-growing species is considerably more vulnerable to piscivores than one that is fast-growing, but the latter becomes available at an earlier age to predators such as the sea lamprey.

Growth rates can also reflect changes in the environment and in the structure of the fish's population. The fact that a species is now relatively slow-growing usually indicates a change in the abundance of food or an overabundance of individuals in its population.

Rate of growth is the determining factor in defining the time at which a fish becomes available to both the commercial and sport fisheries. A fast growth rate means that a fish is vulnerable to specific mesh sizes earlier than a slow-growing species. Accelerated growth often accompanies increased exploitation.

Under normal conditions, species that are characteristically fast growers are: the coho salmon (extremely fast), splake, walleye and carp. Slow-growing fish include the smelt, alewife, chubs, and yellow perch. Fish whose growth rates have characteristically reflected changes in levels of exploitation or increasing deleterious effects of environmental changes are the lake whitefish, lake herring, smelt, and yellow perch.

2.2.5 Spawning Requirements

Species that have spawning requirements dependent on time, place, and environmental conditions are susceptible to management and vulnerable to exploitation.

Fish whose preferences for time and location are restrictive and easy to identify are more susceptible to concentrated management and exploitation than those with more generalized requirements. These preferences increase the species' vulnerability to predators and to loss of narrowly restricted spawning grounds. On the other hand, these restrictive characteristics allow creation of additional spawning habitats or substitution of hatchery and stocking operations for natural reproduction. Control options are also increased for this group. For example, the sea lamprey control program is dependent on the very restrictive requirements of spawning habitat.

Some Great Lakes species with restricted spawning location requirements are whitefish, discrete shallow inshore spawning areas; coho salmon, streams of a character not generally occurring in the Great Lakes; and sea lamprey and smelt, streams of a character occurring widely in most of the Great Lakes. Examples of species with very generalized spawning location requirements are lake trout, lake herring, and alewife.

All Great Lakes species have timing limitations with regard to spawning, but some are more restricted. This has relatively few implications for management and exploitation unless the timing characteristic is combined with narrow location requirements so that spawning must take place in an area made inaccessible by ice or strong winds.

The smelt's spawning activities are restricted to a two-week period. Other fish with fairly short spawning periods are the coho salmon, walleye, sucker, and the catfish. The alewife has a long spawning period.

Certain Great Lakes fish, for example, the whitefish, also require exacting environmental conditions such as a specific range of water temperature to insure the success of reproduction. Such species are more susceptible to changes in their environment, especially if they are already near their tolerance limits.

2.2.6 Behavioral Characteristics

Biologically determined behavioral characteristics exert influence in many ways. In addition to time and location preferences, a tendency to school or annually occupy specific parts of the Lake may have repercussions. This habit may cause interaction and competition for food between species. Location preference also means that a fish is more susceptible to specific predators at certain times.

These behavioral characteristics may strongly influence certain management decisions relating to timing and geographical restriction of exploitation. Steps might be taken to protect those species that school during spawning because they are more vulnerable to predation and sport and commercial harvesting.

Conversely, the preference of the alewife and bloater chub for mid-water depths during juvenile stages makes them relatively immune to commercial fishery. This protects them from harvest prior to sexual maturity. Schooling species include the coho salmon and alewife.

Smelt and alewife compete with other species because of location and depth preferences. Although its effect has not been well documented, the alewife seems to exert considerable influence on young chubs. The fact that the alewife occupies mid-depth zones during the fall and winter months might also contribute to the reduction of lake herring populations.

2.2.7 Vulnerability to Changes in the Environment

Some Lake Huron species are extremely sensitive to sudden fluctuations in various environmental parameters such as water quality, water temperature, and food supply. These species reflect these sensitivities by incurring an erratic and rapidly changing number and species distribution. Other less sensitive species tend to exhibit a more stable and predictable pattern of population dynamics.

These fluctuating environmental parameters can have sudden large-scale effects on sensitive stocks and are beyond the control of management. The only options are estimating population and growth, adjusting species utilization to an uncontrolled supply, and stocking and protecting the affected species during the recovery phase. Conversely, species not particularly sensitive to these fluctuations tend to be more amenable to conscious management and programmed harvests. For the same reasons they are more vulnerable to overexploitation.

Alewife and whitefish are intolerant to abnormal water temperature changes. The mortality rate of alewife tends to be high following unusually cold winters. The erratic population fluctuations of whitefish may be caused by the sensitivity of the eggs and fry to abnormal water temperature changes. On the other hand, this environmental parameter has little effect on chub population.

The whitefish and walleye are extremely sensitive to both sudden and long-range increases of pollution, while the carp and sucker are, within limits, essentially unaffected by these factors.

All species are susceptible in some degree to changes in food availability. Shifts in this environmental parameter do not take on critical importance to nonspecific generalized feeders like the yellow perch. On the other hand, the sea lamprey is strongly affected by changes in food availability, which, in this case, is a function of prey size. Prior to initiation of control measures, sea lamprey population in Lake Huron had dropped significantly because of the virtual elimination of the desired-size prey species.

2.2.8 Concentration of Contaminants

The capacity of a species to concentrate insecticides, pesticides, trace elements, and heavy metals is of major importance to both the commercial and sport fisheries. The current concern with mercury and DDT accumulation reflects the impact this biological characteristic can have. Assimilation rates and concentration levels vary with the species, size, age, feeding habits, and fat distribution. Walleye assimilate mercury very efficiently, catfish and yellow perch show one-half this proficiency, while smelt are even less efficient. Generally, less predacious fish and nonbottom feeders concentrate less mercury than voracious predators or predominantly bottom feeders.

DDT and dieldrin reach higher levels in fish which have a relatively high percentage of fat such as chubs, lake trout, coho salmon, and yellow perch. Most of the fat and therefore the pesticide of the first three is uniformly distributed and remains in the dressed product, while approximately 97 percent of the fat of the yellow perch is concentrated in the viscera and other portions discarded as scrap.

Little is known of the direct effects these contaminants have on the fish themselves. In the case of DDT and dieldrin, relatively low levels have had a deleterious effect on reproduction in the lake trout. The Food and Drug Administration has imposed a maximum level of contamination permissible in fish flesh destined for human consumption. This imposition has had a massive impact on recreational and commercial fishing by closing certain commercial fisheries and restricting sectors of sport fishery.

Fish management agencies cannot control the input of contaminants into the Lakes. This prerogative rests with other State and Federal agencies. Unfortunately, these agencies have to contend with both environmental need and public opinion, and so must adjust their priorities accordingly.

2.3 Status of the Fisheries

2.3.1 Commercial Fishery—Historical Background

The historical development of the commercial fishing industry in each of the Great Lakes has followed the same general pattern:

(1) An initial period of development and

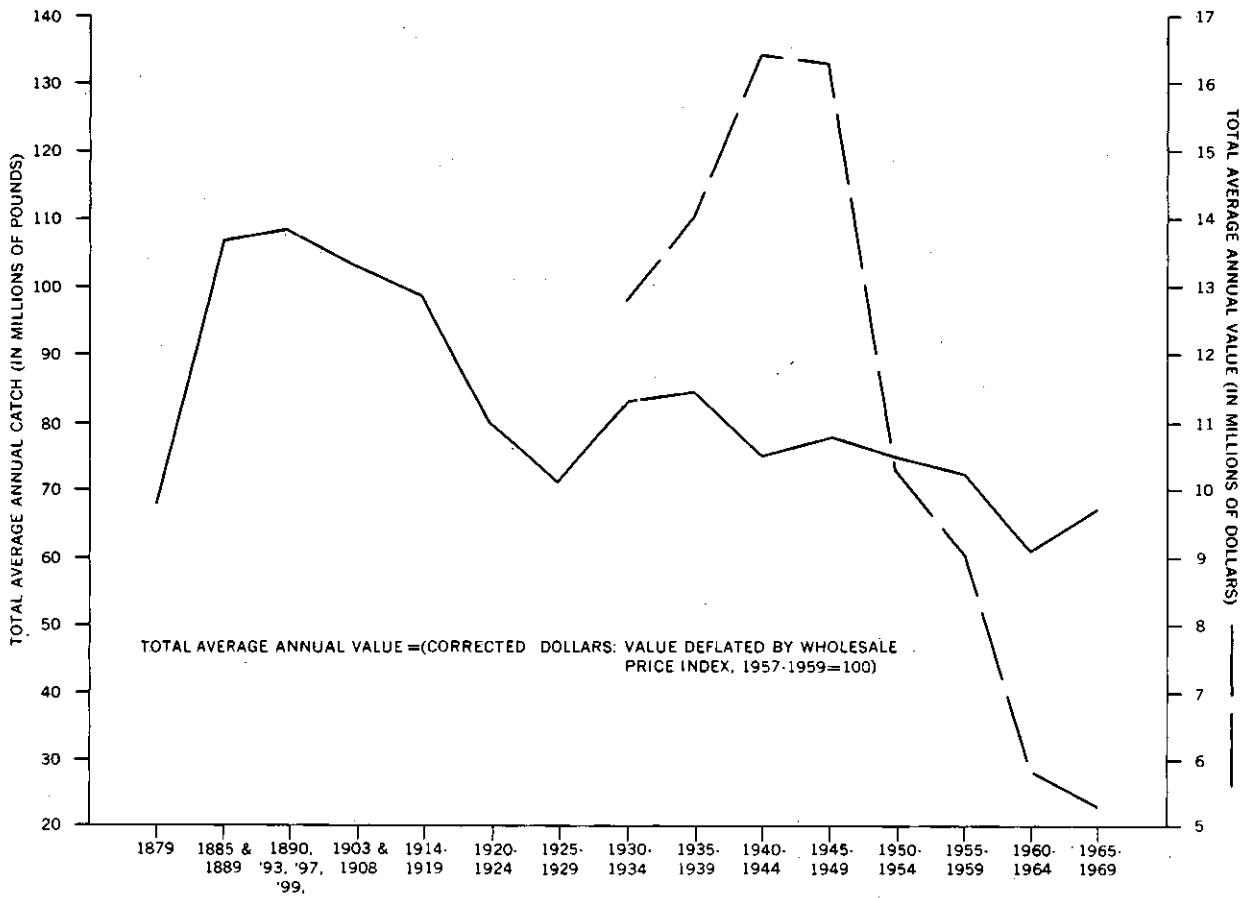


FIGURE 8-10 Total Average Annual Catch and Total Average Annual Value of the U.S. Great Lakes Commercial Fisheries

rapid expansion occurred during the middle and late 19th and very early 20th centuries. Approximately 50 percent of the total landings were high-value coldwater species such as lake trout, lake whitefish, lake herring, and blue pike.

(2) The middle period, 1910 to 1940, was characterized by an initial decrease in landings as the fishery started to stabilize. After the initial readjustment it was characterized by general stability of both fish resources and production. During this period the number of commercial fishermen decreased significantly. This trend has continued to the present.

(3) The period from 1940 to the present was characterized by intense instability of fish resources. Associated instabilities became prevalent in the fishery where the percent contribution of high-value species decreased markedly. The instability of this period can be largely attributed to the invasion and successful establishment of the sea lamprey and alewife in the three upper Great Lakes. Other contributing factors were significant overexploitation of certain species by the commercial fishery as well as general deterioration of the environment in Lake Erie and isolated portions of the other Great Lakes except Superior. Figure 8-10 summarizes the total average annual catch and the total average annual value of the U.S. Great Lakes commercial fisheries for the ninety-year period from 1879 to 1969. Figure 8-11 summarizes the average annual percent volume contribution of various fish species from 1890 through 1969.

In order to gain a better understanding of past and present trends of the commercial fishery of the Great Lakes, it is necessary to review some of the major changes in fish resources. Since its beginning over a century ago, the fishery of the Great Lakes has always shown a preference for species that were abundant and in high demand. Less than a dozen species were major contributors to the catch, and despite intensely selective fishing, the few major changes were localized until

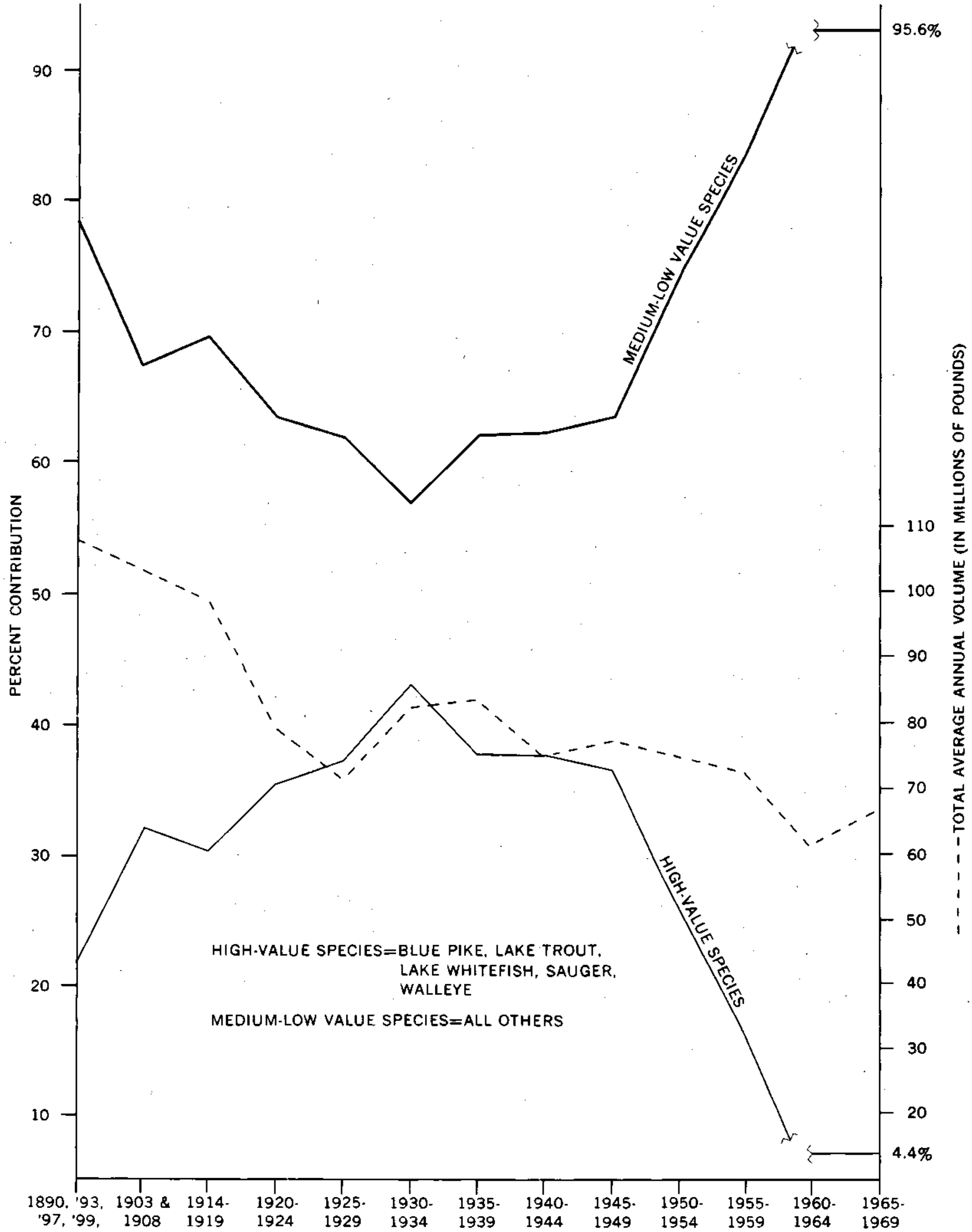


FIGURE 8–11 Average Annual Percent Volume Contribution of High and Medium-Low Value Fish Species to the Total U.S. Great Lakes

recent years. Species influenced greatly by the fishery before the late 1930s were the lake sturgeon, lake herring, and lake whitefish.

The sturgeon was abundant in all the Great Lakes before 1900 and was the first affected by intensive exploitation. Because of its large size, the sturgeon often damaged equipment intended for more valuable species. As a consequence it was fished heavily to remove it from the fishing grounds. At one time this species had a high annual production of more than one million pounds in each of Lakes Michigan, Huron, and Erie, and several hundred thousand pounds in Lakes Superior and Ontario. Today this species is represented by an annual, incidental catch of a few thousand pounds.

The collapse of the lake herring population in Lake Erie in the mid-1920s was the first precipitous change in the fish stocks of the Great Lakes. Historically the lake herring has been the most productive species in the Great Lakes. It frequently contributed one-third to one-half of the catch of the various Lakes. Lake herring in Lake Erie were particularly abundant and larger than in other Lakes. These factors, and the proximity of Lake Erie to markets in large eastern cities, caused intense exploitation. Before the collapse of the population, recorded catches were sometimes greater than 20 million pounds annually and ranged as high as 39 million pounds. The cause of the collapse of herring stocks in Lake Erie has never been settled because detailed biological, ecological, and fishing data were lacking. But in retrospect there are two pertinent factors to consider: intensive exploitation and interaction with environmental changes.

The Lake Huron whitefish was the second local fishery to collapse. The whitefish was the most preferred and heavily exploited species in the early days of the Great Lakes fishery, and significant declines occurred in whitefish stocks as early as the 1860s. However, the first collapse was recorded in the late 1920s when the deep trap net was introduced into the Lake Huron fishery. The whitefish was extremely vulnerable to this new equipment because of certain behavioral and morphological characteristics. Studies verified the extirpation of discrete stocks and the use of the deep trap net was consequently prohibited. Before the stocks could recover, they were hit by the invading sea lamprey. Recovery was arrested, and stocks have remained at a low level to the present time.

Temporary collapse of another fish stock in the early 1940s was unrelated to exploitation. The American smelt (*Osmerus mordax*), indigenous to Lake Ontario, was introduced into the Lake Michigan drainage in 1912 and underwent a population explosion in Lakes Michigan and Huron in the 1930s. The smelt population suffered severe mortality during the fall and winter of 1942-43 probably due to a bacterial or viral disease. The commercial production in Lake Michigan fell from 4.8 million pounds in 1941 to 4,500 pounds in 1944. However, the population recovered and contributed to a productive fishery in all the Lakes above Ontario. The fishery was particularly productive in Lake Michigan where the catch reached a record of 9.1 million pounds in 1958, and in Lake Erie where a peak catch of 19.2 million pounds was produced in 1962 by the Canadian fishery.

A selective fishery for the larger chubs or deepwater ciscoes (*Leucichthys spp.*) influenced the species composition during the late 1800s and early 1900s. The early stages of these changes could not be measured because various species of chubs were taken in the same net. These species were so similar that they were not sorted by fishermen nor listed separately in catch statistics. However, early records indicate clearly that the two largest species (*L. nigripinnis* and *L. johannae*) did in fact decline.

A rapid sequence of dramatic changes which started in the late 1930s led to a major alteration of the fish stocks. Despite loss of the sturgeon and the collapse of a few stocks in certain Lakes, until the early 1940s the fishery of the Great Lakes as a whole was relatively stable and productive. All preferred species continued in abundance somewhere in the Great Lakes. Although many showed varying degrees of cyclical fluctuation, the composition of the total catch showed few marked changes. The total production had stabilized at approximately 100 million pounds after declining from annual catches which often exceeded 140 million pounds before 1920.

The sea lamprey invaded the three upper Great Lakes in the late 1930s. The resulting succession of species resembled similar changes that had taken place earlier in Lake Ontario, but which had gone almost unnoticed because of the small and little-studied fishery.

Timing was the primary difference between these changes. One can trace the successive changes as they occurred first in Lake Huron, then Michigan, and finally, to a lesser degree, in Superior.

The sea lamprey selectively attacked the native predatory species and caused a collapse in their stock. The fisheries, in turn, shifted their emphasis to another species. Finally, because of the decline of these predators, species interaction changed drastically.

The lamprey first depleted the lake trout and burbot, both deepwater predators, and established itself in each of the Lakes. Chubs, normally prey for lake trout and burbot, were influenced differently depending on their size. The largest species of chubs now became both the focus of the fishery and the prey of the lamprey. Conditions were favorable for the increase of the bloater, a slow-growing chub. However, as the large chubs declined, the bloater was exploited by the new trawl fishery. The growth rate and size of the bloater had increased, making it more vulnerable to conventional gill-net fishing and the lampreys. This situation in Lakes Michigan and Huron was conducive to the growth of the small alewife, which had long been established in Lake Ontario. Like the lamprey it probably gained access to Lake Erie and the other Lakes through the Welland Canal, which bypasses Niagara Falls. The alewife increased rapidly and soon dominated the fish stocks of both Lakes Huron and Michigan. A fishery limited to Lake Michigan was developed for this tremendously abundant resource more than a decade ago.

Although the alewife in Lake Michigan and the chub in Lakes Michigan and Superior continue to be important, the present Great Lakes fishery is almost entirely supported by medium- and low-value species such as the yellow perch and carp.

2.4 Economic Contribution

2.4.1 Commercial Fishing Industry

The following economic evaluation of the commercial fishing industry is restricted because there is not enough information on the total Great Lakes fishery for a sound economic analysis. The value of Michigan's fishery will be discussed in general terms because of lack of information.

Although the relative annual value to Michigan's economy of the commercial fishing industry has declined significantly in the last several decades, specification of its present economic role is important for present policy decisions. This type of analysis is based on readily available data and has two important objectives. First, various classifications of economic value are defined, and an attempt is made to estimate the magnitudes of these values for a recent year. Second, analysis of the economic value of the present commercial fishing industry should facilitate discussion of its future economic role. We assume that the future fishery will have sound regulation and a more desirable species composition.

The first section of the analysis will be devoted to definition of the various estimated values. The definitions and the methodology employed in evaluation are taken from an economic analysis of Washington's saltwater fishery by Crutchfield and MacFarlane.[1] The second section will be devoted to estimating the values of interest.

We realize that a portion of the Michigan industry processes products from other States and countries. However, in this discussion we will focus on the possible annual loss to Michigan's economy were the State to lose its Great Lakes-based commercial fishery.

In assessing the annual economic importance to Michigan three different economic values are pertinent:

(1) Gross value is defined as the annual wholesale value of products processed from Michigan's landings.

(2) Net value is defined as the annual income, interest, salaries, rent, and profits earned by Michigan residents as a result of the commercial fishery. It is the value added to the Michigan economy by the commercial fishery. Value added is defined as the income paid at each stage of production to Michigan factors of production (land, labor, and capital). Net value is calculated by deducting the following items from gross value:

(a) A portion of Michigan landings are locally consumed, which creates demand for activities such as processing, transporting, and marketing of fishery products. These activities create income for Michigan residents who own the various factors of production employed. If the Great Lakes-based commercial fishery were eliminated, expenditures on Michigan-produced fish would probably be diverted to other sources of supply or to other products. In this case, the value added (income earned) by marketers and processors would probable not be significantly affected. If it were to lose the fishery, the maximum net loss to Michigan would be the income earned by fishermen for this portion of the catch. However, many of the smaller fishing enterprises process and market their catch locally. In this case, elimination of commercial fishery would result in loss to the Michigan economy of both fisherman income and the value added from processing and marketing. Where this is the case, the estimated net economic value to Michigan must include the value added by these enterprises.

(b) Some portion of the wholesale value of Michigan-produced fish exported from the State includes items or services purchased from other States. For example, shipping costs paid to a firm owned in another State for transporting fish to the Chicago market would be such a cost. Subtraction of estimated payments to firms outside of Michigan for services rendered in exporting fish would be necessary to calculate the net economic value of this portion of its annual landings.

(3) Net economic yield is calculated by subtracting annual Michigan fisherman production costs from the annual value of Michigan landings. Although it is an important analytical concept for sound management of any commercial fishery, lack of data precludes any attempt to estimate this value. The concept of net economic yield or rent accruing to the fishery is analogous in some ways to the rent that accrues to any factor of production fixed in total supply. The owner of a piece of agricultural land would expect to receive a payment for renting his land for agricultural purposes. Likewise, the Great Lakes ecosystem, which produces the landed fish, should be viewed as a fixed factor of production. Were it privately owned, a payment of rent would be expected. In this case, the resource is owned by the public and the concept of rent as applied to private property is not practical. In the theory of fisheries regulation, rent from the resource is assumed to accrue to a public regulatory body. Because it is difficult to measure, net economic yield will be mentioned only briefly in the following part.

Based on the concepts discussed above, the following procedure was employed to provide a rough estimate of the value of the commercial fishing industry to Michigan. Although an average of several years would be desirable, only one year, 1966, was used due to the lack of consistent data and time constraints on the analysis. Data were drawn primarily from the *Fishery Statistics of the United States*[2] and the Chicago and New York fish market report. Although other markets such as Baltimore receive shipments of Michigan fish, the shipments were either small or no published information was found.

Gross value was calculated by first estimating the 1966 wholesale prices for fish exported from Michigan to regional markets, as well as for those sold within the State. Price estimates were made based on an average of the median value of each month's price range for each of the various species. Total wholesale value was then calculated by multiplying the estimated pounds of each species received by their respective estimated average prices. This was not an ideal method because a correct estimate would involve valuing each shipment of fish by the price received and then summing these separate values. Estimates for gross value are shown in Table 8–2.

In order to determine net value, an assumption as to the final destination of the unrecorded production was made. Although a portion of the unrecorded production was processed and consumed within Michigan, only approximately three million pounds can be verified from published sources, *Fishery Statistics of the United States*.[2] Because detailed survey research techniques were not possible within this analysis, assumptions as to the destination of the remaining production were based primarily on the informed opinion of National Marine Fishery Service (NMFS) marketing specialists. It was estimated that in 1966 a significant portion of chub, lake herring, smelt, suckers, whitefish, and yellow perch was shipped from Michigan to various markets, including Cleveland, Columbus, Pittsburgh, Chicago, New York, Baltimore, and various cities in Wisconsin.

A similar problem arises in estimating the magnitude of imported services used for the export of Michigan fish. Because only the roughest estimate of net value can be made, there was no attempt to extrapolate this component from wholesale value of exported fish. To allow for these unknown values, a range was used for net value of the fishery to the Michigan economy. If none of the unrecorded production were exported, then the minimum net value would be the total wholesale value of the exported catch plus the value to fishermen of fish landed in Michigan ports. If certain processors or restaurants were dependent on Michigan-produced fish and were to go out of business if their supply source disappeared, that portion of the product would have to be valued at wholesale or even retail prices and would be counted as part of the net value. No available information exists for estimating this value, but it would probably be small. On the other hand, if most of the unrecorded production were exported, then net value would approach the estimated gross value. The pos-

TABLE 8–2 Estimated Wholesale Value of Michigan-Produced Fish for 1966

Total Production (lbs)	Exports (lbs)	Approximate Wholesale Value	Unaccounted For Production (lbs)	Approximate Wholesale Value	Total Gross Value to Michigan
21,284,000	6,341,000[1]	$1,764,000[2]	14,943,000	$1,902,000	$3,666,000

[1]Pounds listed received on the New York and Chicago markets are adjusted by conversion factors to reflect the estimated pounds landed before processing.

[2]The close approximation between the value of the six million pounds known exported and the fifteen million pounds unaccounted for is due to the large volume of high value species received on the Chicago and New York markets.

sible range of net values to Michigan is a minimum of $3,100,000 to a maximum of less than $3,600,000.

Because a majority of fish landed from Michigan waters were exported, the net value to Michigan would probably be closer to $3.6 million than $3.1 million, depending on the extent of out-of-State services used. These estimates are for 1966, and the fishery as well as the fish resources have undergone significant changes since that time. Nevertheless, the approximate magnitude of the values involved serves as a useful approximation of the present situation.

If cost and return estimates for various types of Michigan commercial fishing enterprises were available, it would be possible to approximate the net economic yield or rent that accrues to the fishery resource. Without such data one can only say that net economic yield based on Michigan fishery resource is typically very low or nonexistent. Because of the lack of good regional data, these estimates are not precise. However, they represent an attempt to specify the value to Michigan from its commercial fishery based on conceptually correct methods of economic analysis. The figures represent the estimated annual income that would have been lost to Michigan residents if the commercial fishing industry had been suddenly eliminated. The analysis has shown that Great Lakes-based commercial fishery is an export industry and a high proportion of annual earnings can be counted as net value to the Michigan economy. For the purpose of comprehensive planning, a similar analysis of actual net income accruing to Michigan residents from the sport fishery would be helpful.

2.4.2 Sport Fishing

The following economic evaluation of Michigan's salmon and steelhead fishery by Gale C. Jamsen and Paul V. Ellefson of the Michigan Department of Natural Resources will serve as an example for calculating the economic worth of recreational fishery. Comparable information is not available on all recreational fisheries in the Great Lakes, which limits the current application of the economic evaluation.

Determination of the financial output of Michigan's salmon and steelhead program is hindered because it is difficult to define exactly what the program is producing. Although the benefits of recreational programs have been labeled as intangible or not subject to measurement, recognition of their importance exists. Therefore, we should accurately determine such benefits so that they can be included properly in private and public decision-making.

The procedure used to evaluate Michigan's salmon and steelhead program has been applied to sport fisheries in the past. Willingness of the fisherman to forego money and time is used to measure the value of the natural resources.

Michigan's salmon and steelhead resources are evaluated by analyzing recreation demand curves. This method uses travel costs as an indicator of the willingness of the fishermen to pay for the salmon and steelhead resource. Such costs are used to define the relationship between price per day to the fishermen and the per capita attendance. This relationship is a conventional demand curve with a negative slope. As the price of fishing increases, we expect a decline in the number of days fished. By applying a range of added prices to the demand curve, one can define a second demand curve that represents the demand for salmon and steelhead. The value of the fishery is then measured by determining the area under the curve. This sum is an appropriate measure of the economic value of the salmon and steelhead resource being used to produce sport fishing opportunities.

Michigan's 1970 salmon and steelhead fishery was subjected to this demand curve analysis. The procedure followed three major steps. First, the demand curve for the entire sport fishing experience was determined. This represented the demand situation for the entire sport fishing package, anticipation and planning, travel, activity at the site, and the recollection that occurs once the fisherman returns home. Then a demand curve for the salmon and steelhead resource was determined from the demand curve for the entire recreation experience. Finally, the total value to the fishermen was determined from the latter demand curve. Data used in the analysis were obtained from licensed fishermen surveyed by mail during and after the 1970 season.

The value of Michigan's salmon and steelhead fishery to Michigan fishermen was interpreted as the sum or the area under the demand curve for the resource. This area totaled approximately $8.34 million. At an interest rate of 5.5 percent, the capitalized value of Michigan's salmon and steehlead sport fishery was estimated at $151 million.

The monetary value of the fishery could be used in forming opinions about the fishery resource and its future. However, caution is warranted because it does not include the value of the fisherman's time or the program's benefit to local communities in added income and new jobs. Because of these omissions the value is a conservative estimate of the fishery's worth.

Michigan's salmon and steelhead program was spectacular in terms of the total amount of sport fishing activity generated. Before the introduction of salmon in 1966, Great Lakes sport fishing was severely limited. By 1970 the salmon and steelhead fishery was producing nearly two million days of sport fishing for an estimated 200,000 anglers. In that year the catch of salmon (coho and chinook) and steelhead was estimated to be approximately 1.2 million. More than two-thirds of the catch was salmon. The net economic value of the salmon and steehlead resource was estimated to be $8.34 million.

2.5 Projected Demands

This subsection discusses the present and projected supplies and demands for species important to the commercial fisheries of the Great Lakes. It will also serve as an adequate consideration of the projected demands for each Lake.

2.5.1 Supply-Demand Relationships

Contrasted with beef, pork, and other meats, most species of fish have rather specific geographical, racial, religious, or cultural appeal that must be considered in describing past and future consumption. The following outline discusses the characteristics of 13 principal Great Lakes species contributing to the commercial fishery. The outline also indicates past and expected abundance, the relation of these trends to past and future market demand, and price movements resulting from these relations.

Aside from specific market characteristics of various species, certain broader factors will continue to affect the demand for Great Lakes fish. For example, since World War II consumption of fresh whole fish has declined while that of processed and frozen portions has increased. Consumers prefer these convenient forms to fresh whole fish. Handling is also easier and more economical. However, with the exception of the yellow perch and smelt, Great Lakes fish have not undergone modern processing and packaging. This has particular importance for high-value species such as walleye, lake trout, and whitefish. Because these species are again abundant, we should determine whether the fresh whole form is still preferred and whether this additional supply can be economically handled through traditional channels.

Two other important factors affecting demand are weakening of the wholesale and retail infrastructure in the freshwater fish industry since World War II, and the gradual dissolution of ethnic neighborhoods and changing composition of their populations. In addition to disappearance of such specialized outlets as the push-cart peddlers in New York City and Brooklyn, there has been a substantial decline in the number of wholesale and retail dealers which handle fresh fish. These changes relate somewhat to population redistribution in urban areas. The erosion of neighborhoods with preferences for freshwater species adversely affected the freshwater fish marketing structure. Dispersion of these groups, rising incomes, new life-styles, changing tastes, and loss of traditional values that influenced eating habits are related factors that influence demand for fish species with specific cultural, ethnic, and religious appeal. The net effect of these factors on future fish consumption is obviously difficult to foresee.

The following outline briefly describes past trends and future directions of supply, demand, and price. The projected trends are based on the assumption that commercial fishing will continue to occupy a significant role in utilization of the Great Lakes fishery resource and that management agencies will maintain fishing effort below the maximum sustainable yield (MSY) of any species. No specific assumptions were made in regard to possible technological changes. However, advances in harvesting and processing technology could greatly improve the prospects for increasing the production of several abundant, low-value species.

2.5.1.1 Alewife

(1) Supply

(a) 1945 to 1970: substantial stock increase in the upper Great Lakes associated with decline in predator species; some stock decline towards end of the period because of development of a commercial fishery in the early 1960s, stocking of salmonids and recovery of lake trout in the mid to late 1960s, and a massive die-off during the winter and summer of 1967 in Lake Michigan; commercial fishery production averaged about 35 to 40 million pounds annually in Lake Michigan between 1966 and 1970; predator species are estimated to consume more than 50 million pounds annually

(b) 1970 to 1980: wide, natural fluctuation in year class strength and abundance likely, but a general downward trend is expected with increase in predator populations; reduction of commercial alewife production by management agencies in order to allocate a larger portion of the forage base to predator species

(c) post 1980: uncertain; decline could level off

(d) other supply sources: none of freshwater origin

(2) Prices

(a) 1945 to 1970: prices available only since early 1960s; have fluctuated between 1.0 and 1.9 cents per pound; general downward trend

(b) current prices: approximately 1.1 cents per pound

(3) Market Characteristics

(a) general: used almost entirely for industrial purposes in production of fish meal and oil and pet food

(b) market area: Great Lakes Region

(c) market forms: ground for reduction purposes

(4) Consumption

(a) general: coastal alewife are marketed for human food but Great Lakes variety does not reach adequate size and is used entirely for industrial purposes. Some product research work is currently being carried out to develop a canned product for human food use.

(b) substitute species: any species available in sufficient quantity and density to permit harvesting with high volume and low unit cost methods. Only carp and sheepshead are possible substitutes in Great Lakes.

(c) expected trends: nationwide demand for fish meal is expected to continue rising and alternative marine supply sources are approaching MSY. Price increases are likely for fish meal. Product development work could create human food market.

(5) Future Outlook

The Great Lakes supply base is likely to decline from current levels. Demand for fish meal and prices paid to fishermen are expected to rise. Future outlook for the fishery will depend on the extent to which alewife populations remain in sufficient abundance to permit high-volume production methods. Management agencies are willing to allocate a significant portion of the resource to the commercial fishery.

2.5.1.2 Carp

(1) Supply

(a) 1945 to 1970: no overall trends in landings which have fluctuated between 4 and 9 million pounds annually; present abundance much greater than landings indicate; MSY estimated to be at least 36 to 40 million pounds, perhaps double this according to some estimates

(b) 1970 to 1980: some increase expected
(c) post 1980: may increase slightly if environmental conditions worsen for other species
(d) other supply sources: upper Mississippi River; inland lakes of Minnesota and Wisconsin
(2) Prices
(a) 1945 to 1970: generally downward trend; highest real prices reached during World War II and in mid-1950s
(b) current prices: approximately 2 to 8 cents (averaging 4 cents) to fishermen; retail prices in Chicago 25 to 39 cents (drawn)
(3) Market Characteristics
(a) general: historically sold principally on Jewish market in New York and other cities and also a low-priced substitute for buffalo fish in Chicago and other midwestern cities. Both these markets have declined since World War II. Greater quantities are now used for stocking fee fishing ponds and for fish meal and fish sausages.
(b) market areas: New York, Chicago, Detroit, Louisville, upper Mississippi River area, and recreational lakes in Ohio, Illinois, and Indiana
(c) market forms: fresh, whole; fillets or sides; smoked, live
(4) Consumtpion
(a) general: declining demand among low-income urban residents who are believed to have substituted buffalo fish and catfish for carp. There is a decline in demand for live carp in the Jewish market in New York, but increased demand for commercially-prepared gefilte fish has somewhat offset this trend. Overall consumption apparently drops with rising incomes. The demand is considered to be more price sensitive than for most freshwater species.
(b) substitute species: buffalo fish, suckers, and, to some extent, catfish
(c) expected trends: demand is expected to continue declining for fresh carp. Consumption of commercially prepared gefilte fish and smoked carp will remain at about current levels, although smoked carp consumption could increase with promotional work. Live market demand will increase slightly because of the demand for sport fishing opportunity.
(5) Future Outlook
Resource base should increase, while overall demand for carp will probably decline in the future. Efforts at increasing the production of carp for management purposes may generate new markets such as fish meal. The resource base will be sufficient to support 10- or 20-fold increase in landings over current levels.

2.5.1.3 Catfish

(1) Supply
(a) 1945 to 1970: generally steady but with a slight downward trend after 1960-61; current production slightly over 1 million pounds
(b) 1970 to 1980: no change in the resource base expected; MSY estimated at approximately 2 million pounds
(c) post 1980: no change anticipated
(d) other supply sources: Mississippi River; Florida; pond-reared production areas in the lower Mississippi River Valley; South America
(2) Prices
(a) 1945 to 1970: steady upward trend after 1955 amounting to a 70 to 80 percent increase in ex-vessel prices
(b) current prices: approximately 28 to 30 cents to fishermen; $0.95 to $1.20 per pound at retail markets in Chicago
(3) Market Characteristics
(a) general: historically a preferred species in the south-central U.S. and in the Mississippi, Missouri, and Ohio Valleys
(b) market areas: south-central States, the above-mentioned river valleys, and most midwestern cities with large populations of south-central U.S. origin. Most Great Lakes catfish are sold locally in Detroit, Chicago, and Cleveland areas, or live to fee ponds in Ohio, Indiana, and Illinois.
(c) market forms: fresh or frozen, skinned and dressed; live
(4) Consumption
(a) general: in the past, considered a southern species. Highest consumption is among low-income purchasers in the south-central States. The image of catfish elsewhere appears to be improving. Demand is increasing in restaurants and short-order, carry-out stores. Demand is somewhat price sensitive in certain areas where buffalo fish are considered a substitute. There is a large market for live catfish in pay lakes.
(b) substitute species: ocean catfish; buffalo fish in some areas
(c) expected trends: demand appears to be increasing. Nationwide supply and foreign imports are now beginning to greatly expand supply. Catfish are now available in restaurants and advances in processing technology

should enlarge the market considerably. Use of live catfish in pay lakes should increase but at a less rapid rate than in the past 10 years.

(5) Future Outlook

The Great Lakes supply base is relatively limited, and increasing supply competition is expected from the lower Mississippi Valley and foreign sources. Some increase in demand is expected, and past price increases are expected to level out over the 1970 to 1980 period. Afterwards prices should decline because of greater efficiency in production and processing in the catfish aquaculture industry.

2.5.1.4 Chubs

(1) Supply

(a) 1945 to 1970: no overall trend in landings although production rose substantially during 1960 to 1963; current landings approximately 10 to 11 million pounds, the estimated MSY at the present time

(b) 1970 to 1980: status of resource base uncertain; Lake Huron stocks will continue to be scarce; signs of collapse in Lake Michigan stocks (few young, extreme imbalance in sex ratio)

(c) post 1980: uncertain. Abundance will be affected by predator stocking program and, possibly, abundance of competing alewife.

(2) Prices

(a) 1945 to 1970: prices generally fluctuating with changes in supply. Overall nominal ex-vessel prices remained approximately the same over period with some rise in retail prices.

(b) current prices: approximately 16 to 20 cents per pound to fishermen; retail prices for smoked chub from $0.89 to $1.10 per pound in Chicago

(3) Market Characteristics

(a) general: principal market for smoking; considered a delicatessen-type specialty product; mainstay of the Great Lakes smoked fish industry; occasionally used for animal food

(b) market area: Chicago, Detroit, Great Lakes Region, New York, and other eastern cities

(c) product forms: smoked (drawn)

(4) Consumption

(a) general: no specific information on chubs available. In cross-sectional studies, purchases of smoked fish in general are higher in upper-income families. Widespread publicity given to botulism and pesticide problems in chubs has probably adversely affected demand.

(b) substitute species: none within price range of chubs or with similar smoking characteristics

(c) expected trends: nationwide decline of per capita consumption of smoked fish. Smoked fish appears to have relatively narrow regional and ethnic markets and only small increases in demand are expected, attributable mainly to population growth.

(5) Future Outlook

The status of the resource base is uncertain over the next few years. With maintenance of current MSY (10 to 11 million pounds), some modest price increases could be expected. Concern about pesticide levels in chubs may have dampening effect on demand.

2.5.1.5 Lake Herring

(1) Supply

(a) 1945 to 1970: generally downward trend in landings and abundance from 1955 on; believed by some to be attributable to competition with alewife and possibly smelt; current landings between 5 and 6 million, the estimated MSY

(b) 1970 to 1980: no increase in abundance expected and further declines likely

(c) post 1980: future status uncertain; may depend on trends in alewife stocks. Continued presence of alewife in large numbers in Lake Michigan and Lake Huron is likely to hold lake herring abundance down at or below current levels.

(d) other supply sources: none for lake herring

(2) Prices

(a) 1945 to 1970: generally steady through 1963; sharply upward trend thereafter

(b) current prices: approximately 10 to 15 cents to fisherman; retail at 79 to 89 cents

(3) Market Characteristics

(a) general: traditionally low-value, high-volume species considered a pan fish substitute; formerly largely salted

(b) market areas: Great Lakes Region, adjoining areas of Midwest, and Appalachian region. Lake herring were formerly shipped in large quantities to New York.

(c) market forms: dressed with head on; pickled; smoked; salted

(4) Consumption

(a) general: demand for herring believed to decline with rising incomes. Demand apparently drops off beyond relatively low retail prices. Historically no price increase occurred until total supply dropped by 60 percent.

(b) substitute species: river herring or alewife substitute in some markets

(c) expected trends: will continue to occupy current market niche. Demand for herring at current prices will increase slowly with population growth and with rising incomes. The rising prices will be offset by substitution of other fish.

(5) Future Outlook

The resource base is expected to remain at or below current levels. The current MSY is 5 to 6 million pounds. Slowing rising demand may have mild effect on prices with fixed supply, but prices should level off over next 10 years.

2.5.1.6 Lake Trout

(1) Supply

(a) 1945 to 1970: steadily downward trend in landings reflecting decline in abundance brought about by sea lamprey predation; current production (approximately 0.4 million pounds) associated with research assessment program of the Great Lakes Fishery Commission; current MSY somewhat more than current landings

(b) 1970 to 1980: continued increase in abundance expected as sea lamprey control is effected; rate of increase will depend upon status of forage stocks, especially chubs, lake herring, smelt, and alewife

(c) post 1980: 85 percent pre-lamprey abundance could be reached, possibly in early 1980s; potential MSY may be 13 to 15 million pounds annually, depending on availability of forage stocks

(d) other supply sources: only North American source is western and northern Canadian lakes where production has declined since early 1950s; inland Canadian lake trout valued at 25 to 50 percent less than Great Lakes trout on U.S. wholesale markets

(2) Prices

(a) 1945 to 1970: steady upward trend with decline in supply; a 50 percent increase in ex-vessel prices between 1950 and 1969

(b) current prices: approximately 65 cents per pound to fishermen; $1.29 to $1.49 retail (dressed) in Chicago

(3) Market Characteristics

(a) general: traditionally a preferred, choice, high-value species; sold to restaurants and on fresh market

(b) market area: formerly the Great Lakes Region and New York, currently Great Lakes supply usually consumed locally

(c) market forms: fresh, drawn preferred; some frozen fillets produced; occasionally smoked

(4) Consumption

(a) general: demand believed to increase with rising incomes. It is considered relatively price inelastic over a moderate range, and there is some ethnic preference in the New York market.

(b) substitute species: whitefish to some extent and possibly walleye.

(c) expected trends: demand expected to increase at current price levels with rising per capita incomes and population growth

(5) Future Outlook

The resource base should increase through early 1980s, possibly approaching 85 percent pre-lamprey abundance with potential MSY of 13 to 15 million pounds. Under current management policies, approximately 7 million pounds of the potential MSY may be allocated to the commercial fishery, but mostly in Canadian waters. With this quantity marketed, some moderate price declines will occur as local market areas are saturated, and fish are shipped to urban centers. Because of relatively poor freezing qualities, trout will generally be sold fresh and the ability of the fresh market to absorb such quantities without moderate price decline is questionable. It is expected that the total allowable commercial yield will not be sold at current price levels until the early 1980s.

2.5.1.7 Sheepshead

(1) Supply

(a) 1945 to 1970: no overall trend in landings; generally fluctuating between 2 and 6 million pounds annually; MSY estimated currently at more than 25 million pounds

(b) 1970 to 1980: production expected to hold around 2 million pounds, substantially less than MSY

(c) post 1980: resource base expected to increase particularly in Lake Erie

(d) other supply sources: Lake Winnebago, Wisconsin; upper Mississippi River; inland lakes of Wisconsin and Minnesota

(2) Prices

(a) 1945 to 1970: stable nominal prices; slightly downward trend in real terms

(b) current prices: approximately 3 cents for human food markets; 1.5 to 2 cents for animal feed; retail prices 25 to 40 cents per pound

(3) Market Characteristics

(a) general: low-value food fish in Midwest. Great Lakes sheepshead are considered hard-meated and inferior to river fish; considered a substitute for porgy in New York; some use as mink feed

(b) market areas: upper Great Lakes and Canada (mink feed); Chicago and New York

(c) market forms: fresh, whole preferred

(4) Consumption

(a) general: other species have substituted for sheepshead and will in the future. Demand should decline with rising per capita incomes. Sheepshead should be relatively sensitive to price changes in other fish species, particularly carp and buffalo fish.

(b) animal feed use: one of the preferred freshwater species used in mink feed because it is not thiaminase-active. Use of Great Lakes sheepshead in this market has essentially stopped because of suspicion of reproductive failure in mink from unknown cause relating to consumption of various species of Great Lakes fish.

(c) substitute species: carp and buffalo fish on the human food market

(d) expected trends: declining demand expected for both human food and animal feed

(5) Future Outlook

The MSY is estimated to be at least 25 million pounds and probably much higher, and the resource base should increase. Demand is expected to decline, but efforts at harvesting greater quantities for management purposes may lead to development of new markets in the future.

2.5.1.8 Smelt

(1) Supply

(a) 1945 to 1970: steadily upward trend in landings from 1945 through 1961; more or less steady since; increased landings resulted from development of Canadian smelt fishery in Lake Erie; current landings between 15 and 18 million pounds; MSY estimated at approximately 20 million pounds

(b) 1970 to 1980: decline in resource base in Lake Erie expected as the result of a parasitic infestation; abundance in other Lakes may increase; MSY could drop to 5 to 10 million pounds over period

(c) post 1980: uncertain; continued low levels of abundance possible

(d) other supply sources: none from freshwater areas

(2) Prices

(a) 1945 to 1970: generally steady after production peak reached in mid-1950s

(b) current prices: prices to fishermen between 2 and 4 cents per pound; fresh smelt retail at 9 to 15 cents in round; frozen, headed, and gutted, 39 to 59 cents

(3) Market Characteristics

(a) general: fresh smelt seasonal only; processing of frozen smelt has extended market appearance; some animal feed use

(b) market areas: Great Lakes Region

(c) market forms: fresh, whole; frozen, headed and gutted; frozen for animal feed

(4) Consumption

(a) general: relatively little is known of smelt consumption aside from its seasonal nature. It is a traditional, seasonally available species in the lower Great Lakes Region, and a panfish substitute in Midwest.

(b) substitute species: white bass and yellow perch are mild substitutes

(c) expected trends: no major shifts in demand expected. A relatively mild increase in demand is possible as a result of population growth, and greater use in animal feed is also a possibility.

(5) Future Outlook

The resource base is expected to drop below current levels to an estimated MSY of 5 to 10 million pounds by 1980. Prices should rise somewhat, but other species may be substituted as supply falls. Price increases should be moderate.

2.5.1.9 Suckers

(1) Supply

(a) 1945 to 1970: slightly downward trend in landings; believed to be the result of diminishing fishing effort rather than a decline in abundance; current landings 1 to 2 million pounds annually

(b) 1970 to 1980: previous trends in landings expected to continue; resource base to fluctuate; some decline in abundance in Lake Michigan possible; MSY estimated at minimum of 30 million pounds

(c) post 1980: fluctuations in resource base expected

(d) other supply sources: Mississippi River; certain inland lakes

(2) Prices

(a) 1945 to 1970: generally downward trend

(b) current prices: approximately 3 cents to fishermen; 25 to 39 cents retail

(3) Market Characteristics

(a) general: low-value species used mainly for preparation of gefilte fish

(b) market areas: Jewish communities of New York, Chicago, other eastern cities

(c) market forms: fresh (drawn)

(4) Consumption

(a) general: market generally weak, consumption apparently declining with rising incomes; principal market around Jewish holidays; less frequent home preparation of gefilte fish a factor in declining demand

(b) substitute species: carp, buffalo fish

(c) expected trends: demand expected to continue to decline

(5) Future Outlook

The resource base is expected to hold at present level or decline slightly, and MSY is estimated at a minimum of 30 million pounds. No increase in landings is expected although effort at increasing sucker production for management purposes could generate new markets.

2.5.1.10 Walleye

(1) Supply

(a) 1945 to 1970: sharply downward after 1956; overexploitation, poor environmental conditions in Lake Erie and possible sea lamprey predation have decreased abundance; current production between 2 and 3 million pounds annually, the estimated MSY

(b) 1970 to 1980: uncertain; poor reproduction in Lake Erie, apparently because of unfavorable conditions on spawning reefs; sea lamprey control in Lakes Michigan and Huron may result in some increase in abundance in those Lakes

(c) post 1980: uncertain; some modest increases in abundance possible, but future status in Lake Erie questionable. MSY could be in the range of 3 to 5 million pounds if lamprey controls result in greater abundance.

(d) other supply sources: western Canadian lakes, but supply has been dropping; Canadian walleye valued at 25 to 50 percent less than Great Lakes walleye; some foreign imports of walleye-like frozen fillets

(2) Prices

(a) 1945 to 1970: sharply increased with drop in supply; more than 100 percent gain in real prices between 1952 and 1968

(b) current prices: approximately 50 to 60 cents to fishermen; retail levels at $1.29 to $1.49 per pound

(3) Market Characteristics

(a) general: currently a preferred, choice, high-value species, considered equal to lake trout and whitefish in quality and widely sold in restaurants in the western Great Lakes States in addition to the fresh and frozen market

(b) market areas: Great Lakes Region; other midwestern areas; New York. It is somewhat more widely distributed than lake trout or whitefish.

(c) market forms: fresh (drawn); fresh and frozen fillets

(4) Consumption

(a) general: demand believed to increase with rising incomes with a wider market appeal than lake trout or whitefish. Decline in supply of blue pike, lake trout, and whitefish has apparently increased demand for walleye, which is considered relatively price inelastic over a moderate range.

(b) substitute species: considered generally distinct on the market although lake trout and whitefish are mild substitutes in some markets

(c) expected trends: demand to increase at current price levels with rising per capita incomes and population growth

(5) Future Outlook

Some modest increase in the resource base is possible with sea lamprey control, and MSY could be 3 to 5 million pounds annually. Sizeable increases in Lake Erie are not likely. Demand should remain strong. Potential increase in production is not sufficient to drop prices significantly. Post-1980 demand could absorb projected MSY at real prices slightly exceeding current levels.

2.5.1.11 White Bass

(1) Supply

(a) 1945 to 1970: no overall trend in landings but some increase during 1954 to 1956 and in 1961–62; followed by slight downward trend thereafter; current landings between 1 and 2 million pounds; current MSY estimated at 3 to 4 million pounds

(b) 1970 to 1980: no change expected

(c) post 1980: no change

(d) other supply sources: none

(2) Prices

(a) 1945 to 1970: widely fluctuating with changes in supply; generally upward since 1955

(b) current prices: 20 to 30 cents for fishermen; retail approximately 69 to 79 cents (head off, gutted)

(3) Market Characteristics
(a) general: relatively small market; considered a pan fish substitute of intermediate value in Midwest
(b) market area: lower Great Lakes Region
(c) market forms: fresh, head-off and gutted, or filleted (skin on)
(4) Consumption
(a) general: little information available. One of the most sensitive of the Great Lakes species in regard to wide price fluctuations with relatively small changes in supply. White bass are considered to have a narrow regional appeal confined to southern Michigan and northern Ohio and are seldom seen in Chicago
(b) substitute species: yellow perch
(c) expected trends: no significant shifts expected; considered a less preferred substitute for yellow perch. Demand could increase somewhat with major decline in yellow perch landings.
(5) Future Outlook
No increases are expected in the resource base. MSY is estimated at 3 to 4 million pounds. Future demand is probably related to yellow perch supply.

2.5.1.12 Whitefish

(1) Supply
(a) 1945 to 1970: steady downward trend as a result of sea lamprey predation and possible overexploitation; current production is 3.6 million pounds as compared with 11 to 12 million pounds prior to lamprey invasion; current MSY somewhat higher than current landings because of management restrictions on open fishing areas
(b) 1970 to 1980: resource base expected to increase but not to pre-lamprey levels because of the disappearance of whitefish in Lake Erie
(c) post 1980: pre-lamprey resource base expected to be reached; potential MSY estimated at 7 to 8 million pounds; no further increases expected
(d) other supply sources: the western Canadian provinces, where production has declined sharply since 1961, are the only other significant North American sources. Fish from these sources are valued at 25 to 50 percent lower than Great Lakes whitefish. Alaskan whitefish are a potential supply source.
(2) Prices
(a) 1945 to 1970: steady upward trend after 1950 amounting to a 70 percent increase in ex-vessel prices between 1952 and 1968
(b) current prices: approximately 60 cents per pound to fishermen; retail prices in Chicago $1.49 to $1.79 (drawn Lake Superior whitefish)
(3) Market Characteristics
(a) general: historically a preferred, choice, high-value species; popular in restaurants
(b) market areas: Great Lakes Region; New York
(c) market forms: fresh, drawn preferred; some market for frozen fillets; also used in gefilte fish; smoked
(4) Consumption
(a) general: demand believed to increase with rising incomes. Whitefish are considered relatively price inelastic over a moderate range with some aspects of ethnic preference in the New York market.
(b) substitute species: lake trout to some extent and possibly walleye are substitutes in certain markets
(c) expected trends: demand expected to increase at current price levels with rising per capita incomes and population growth
(5) Future Outlook
The resource base will increase through 1980 to potential MSY of 7 to 8 million pounds, but less than pre-lamprey abundance of 11 to 12 million pounds. Total MSY will be available to commercial fishery. Some moderate price declines expected with increase in supply. As landings reach MSY, prices should again rise as increase in real per capita incomes shifts demand upwards. Total potential MSY expected to be consumed at 1970 prices by 1980.

2.5.1.13 Yellow Perch

(1) Supply
(a) 1945 to 1970: sharp increase in landings up to late 1950s resulting from development of Canadian marketing and processing facilities on Lake Erie; somewhat fluctuating through 1969 but usually exceeding 20 million pounds; current MSY 40 to 50 million pounds
(b) 1970 to 1980: wide fluctuations expected because of erratic strength of year classes in Lake Erie; some improvement in Lake Michigan stocks may occur
(c) post 1980: relatively heavy sport fishery harvest of unknown quantity makes MSY estimation difficult; assuming environmental conditions in Lake Erie improve somewhat or at least do not worsen, MSY estimated at current level of 40 to 50 million pounds

(d) other supply sources: none of significance

(2) Prices

(a) 1945 to 1970: widely fluctuating with the changing supply; slight upward trend in real prices since the mid-1950s

(b) current prices: approximately 11 to 16 cents per pound to U.S. fishermen; retail at 89 to 99 cents in Chicago for fillets

(3) Market Characteristics

(a) general: considered a pan fish substitute of intermediate value in Midwest. Decline of high-value species in Lake Erie is believed to have increased demand for yellow perch.

(b) market areas: Great Lakes Region and nearby areas of Midwest

(c) market forms: whole (drawn) fresh; fresh; frozen and breaded fillets

(4) Consumption

(a) general: demand considered to be relatively price sensitive, and effect of rising income on consumption unknown. Appearance of frozen, packaged fillets apparently expanded market for perch. Appeal is widespread in lower Great Lakes Region, partly attributable to greater familiarity with the species because of large sport fishery on Lake Erie.

(b) substitute species: several frozen, filleted, saltwater species are believed to be close but less desirable substitutes; white bass to a lesser degree

(c) expected trends: some increase in demand expected with population growth; probably will be substituted for as per capita income rises but not enough to offset increased demand through population growth

(5) Future Outlook

The supply base and MSY are difficult to estimate because of possibility of collapse in Lake Erie as a result of worsening environmental conditions. With maintenance of current MSY at 40 to 50 million pounds (25 to 50 percent taken by the sport fishery), a moderate increase in real prices is expected to level off after 1980.

2.6 General Management Problems, Needs, and Solutions

Although a number of specific problems are associated with the fisheries of each Great Lake, some are common to all. This section will concentrate on Basinwide, Federal, or international programs dealing with fish resources and fishery problems. Individual Lake reports will concentrate on State and Federal programs for each Lake.

Coordinated management is complicated by jurisdictional and ecological differences in the Great Lakes area. The 61,000 square miles of United States waters are divided among eight States, each having full jurisdiction over its fisheries. This results in eight different fishery codes and a number of different, and at times, incompatible management policies and philosophies. Inter- and intralake ecological conditions vary widely. Only the deep waters of the three upper Great Lakes have any degree of uniformity and stability of habitat.

Solution to the fishery problems of the Great Lakes will demand close international and interstate coordination and cooperation. Although circumstances require agencies to confine their studies to waters within their jurisdictions, the agencies must think collectively because fish do not recognize international and interstate boundaries. The United States and Canada have established two commissions to foster this cooperation. The first, the Great Lakes Fishery Commission, was given a clear mandate to perform its activities in the form of a treaty. The commission has employed procedures that have brought about reductions in the sea lamprey populations. It has also induced productive relationships among Federal, State, and Provincial agencies in developing coordinated fishery rehabilitation programs and management practices.

The International Joint Commission (IJC), established with the ratification of the Boundary Waters Treaty of 1909, serves as the second coordinating body of the two countries. Although initially concerned with water levels and flows of boundary waters, the IJC has recently been encouraged to assume a major role in controlling pollution problems in the Lakes.

Another problem facing management agencies is the present instability of fish resources. Prior to 1940 a reasonably good balance between prey and predator species existed in the Great Lakes. The invasion of the sea lamprey and selective overexploitation of climax predators upset this predator-prey relationship in the upper Lakes. With the disappearance of the large predators in Lakes Michigan and Huron and their severe depletion in Lake Superior, smaller prey species such as bloater and smelt began to dominate. After the predators were decimated the imbalances and instabilities of the fish populations in Lakes Michigan and Huron were further complicated by the invasion and subsequent increase of alewife. Conditions are different and perhaps more serious in the shallower and warmer waters of Lake Erie. Discharge of domestic sewage, industrial wastes, and agricultural drainage have caused the nutrient content of the waters to increase at an abnormal and accelerated rate. Reactions to this accelerated enrichment include drastic changes in bottom fauna and in feeding habits of fish.

The instability of sport and commercial fisheries of the Great Lakes is caused by the interaction of several factors:

(1) long-term cyclic changes due to equally long-term changes in regional climates

(2) changes in the environment affecting certain life history stages of fish

(3) excessive exploitation of fish stocks

(4) effects of interbreeding among closely related fishes like the chub, blue pike, sauger, and walleye

Thus, the complex problems faced by fishery agencies require studies of fish populations, their interrelations, their environment, and the fisheries.

Two other factors that complicate management are the limited amount of information available and the generally low priority of fish programs in relation to other programs competing for limited public funds.

Before we can implement any program, we must determine its possible effect. At this time, because we cannot predict the reaction of species population to varying levels of exploitation and controlled predation, we lack the means to determine guidelines for the success or failure of any given program. Unless adequate research funds are made available, this lack of knowledge will severely hinder the implementation and success of any meaningful program.

In order to balance total fish resources at a socially optimal level, management would have to consider the differential characteristics of species and groups of species. In order to attain this kind of management ability, it would be useful to develop a theoretically applicable model that incorporates our present knowledge. Given our lack of knowledge, the model would necessarily be crude, but an attempt to incorporate the population dynamics of individual species should provide more than academic instruction. By learning more about reaction of fish resources to management programs, we might discover other approaches.

Management agencies have been unable to allocate fish resources because they lack the necessary economic information. To this time, no concerted effort has been made to develop these data. If economic data were made available, they could be incorporated into the utilization model. This would provide the conceptual information necessary for program development and implementation.

In spite of this lack of knowledge, management must carry on. However, projected increases in demand on the Great Lakes system will require sound management planning of the fish resources in the future. If adequate funds are still unavailable, this will be impossible. Thus, the Fish Work Group recommends that the following research and applied programs be instituted:

(1) Success of any attempt to reestablish a balance between predator and prey species will be almost totally dependent upon how the fish species react to changes in water quality, introduction of other species, sport and commercial exploitation, the implementation of various management techniques, and changes in food supply. Therefore, we must determine how the highly individualized biological characteristics of the various species affect their responses to these influences. In order to determine these reactions, the following measures are recommended:

(a) accelerated research in defining those biological characteristics most important in determining species response to management measures. Because of the tremendous complexity of the interactions involved, considerable investment of time, money, and effort would be required to develop a model to isolate these important biological characteristics.

(b) review and organization of all species literature necessary for the success of the model and collection of all this information in one place. This information should include longevity, time needed to attain sexual maturity, year class structure, growth rate, spawning requirements, behavioral characteristics, and vulnerability to changes in the environment.

(c) possible establishment of a Great Lakes data collection center, which could be funded and used by any interested agency

(2) Substantial research should be directed to the discovery of species capable of reestablishing a balance between predator and prey species. This type of research must not be confined to providing only predator species, but must make a concerted effort to discover those species that could strengthen the forage bases of the different Lakes. If lamprey control is effective, the success of any predator stocking program will depend upon the

amount and kind of forage fish available.

(3) The effect of species introduction on the ecosystems must be evaluated. The fact that such introductions have reached massive proportions in Lake Michigan and are to become more intensive in Lakes Huron, Superior, and Ontario indicates that these studies should be initiated as soon as possible. These studies should include at least the following:

(a) studies to determine the direct effects of species introduction

(aa) position of introduced species in food chain

(bb) consequent competition with other species for food

(cc) competition with other species for spawning areas, nursery grounds

(dd) effect on the forage base

(ee) other

(b) studies to isolate the indirect effects

(aa) changes in plankton populations because of predation of the introduced species on local planktivores. Some work in this area is being conducted in Lake Michigan by the Bureau of Sport Fisheries and Wildlife (BSF&W).

(bb) other

(c) investigation of the economics of the fisheries involved. Economic analysis of both sport and commercial fisheries is necessary to rationally allocate fish stocks for competing uses. Any benefit-cost analysis should include considerations of intangible or non-market as well as tangible benefits.

2.6.1 Applied Programs

As previously mentioned, free movement of fish across State and international boundaries contributes to the ineffectiveness of diverse regulations and compounds the problems associated with uncoordinated management efforts. Despite a long history of failures, compatible management philosophies must be developed for the Great Lakes Basin. To insure compatibility, guidelines based on the common consensus of good management must be created. However, this consensus has not as yet been reached.

The Great Lakes Fishery Commission has been successful in fostering unified moves to rehabilitate the fisheries of the Great Lakes. For example, since its inception in 1955 the commission has induced apathetic governmental agencies to fulfill their obligations to management of the Great Lakes. The commission fosters coordination of State and Provincial activities through a Research and Management Committee and recommends the following programs:

(1) continuation of present efforts to control the sea lamprey throughout the Great Lakes Basin

(2) continued assessment of the effects of successful lamprey control on fish stocks. Knowledge gained from such assessment efforts has been very valuable in the development of salmonid stocking programs.

(3) continued assessment of fish populations in order to determine

(a) strength of year classes

(b) age structure of populations

(c) general abundance and distribution

(d) management capability to isolate certain populations

(e) projected future availability to the fisheries

(f) other

(4) concerted efforts to use what is already known about the peculiar biological characteristics of individual species

(5) development of management philosophies that are consistent with the status of fish stocks and flexible enough to adjust to changing conditions in fish resources

(6) statement of long- and short-range objectives relating to fish resources in general and sport and commercial fisheries in particular

2.7 Economic Problems and Needs of the Commercial Fishery

Institutional regulations and the needs of the commercial fishery often conflict causing severe economic problems. If a solution is to be reached, the two must be coordinated. However, their separate aspects should be examined first.

2.7.1 Economic Problems

The basic economic problems of the U.S. commercial fishery in the Great Lakes are common to any small, fragmented, undercapitalized, and technologically stagnant enterprise relying on an undependable and fluctuating supply base and a sluggish market. If these problems are considered within the framework of a publicly-owned resource situation which is in strong competition with the sport fishery, they become almost insurmountable.

For purposes of analysis, the economic problems and needs can best be examined under the subcategories of harvesting, processing, and marketing:

(1) Harvesting aspects of the commercial fishery face a number of specific problems:

(a) The depressed populations of high-value species (lake trout, lake whitefish, walleye, lake herring) have already been discussed in relation to the historical background of the commercial fishing industry. However, recent assessment programs conducted in Lake Michigan have indicated that lake trout and lake whitefish are responding favorably to effective sea lamprey control measures. Given an adequate forage base, a similar response can be expected to occur in Lake Huron where first-round treatment of streams and rivers was completed in 1970. The problem thus becomes one of the feasibility of using some portion of these rejuvenated high-value stocks for commercial purposes. This will be covered in the section on institutional problems.

(b) The Great Lakes commercial fishery is in a state of technological stagnation. Except for the conversion to nylon gill-nets and the development of a trawl fishery in Lake Michigan, no significant changes have occurred in the harvesting industry of the U.S. Great Lakes commercial fishery over the last four decades. The reasons for this stagnation, including highly restrictive State regulations which will be discussed later, are numerous. We are immediately concerned with fisherman conservatism, vessel specialization, and economic difficulties.

(aa) Fisherman conservatism continues to play an important role in determining types of equipment used. For instance, many Great Lakes commercial fishermen believe that high-value species will return to their former levels of abundance. Such a hope fosters a reluctance to give up fishing equipment and methods formerly used to harvest high-value species.

(bb) Traditional freshwater fisheries use vessels with specialized equipment used only to catch specific species. This maintains the status quo because these specialized vessels are not used to their full capacity. This situation results in insufficient earnings to properly maintain the vessel or invest in improvements and replacement of the craft.

(cc) Technological improvement has been checked by the limited amount of capital available to the commercial fisherman. Because most of the fishing in the Great Lakes is carried out by one-, two-, or three-man operations, there is little money available to purchase equipment required by a trawl fishery. Furthermore, most of the equipment now in use has production costs much too high to efficiently harvest the low-value species which dominate the present day resource.

(2) Many problems associated with the processing aspect of the commercial fishery are directly related to those of resource supply harvesting. When this is the case, they are restated below in processing terms:

(a) With the possible exception of lake herring, high-value species have been favored with a brisk demand for a product with a minimum of processing. Even in the round, these species command good prices and it can be seriously questioned whether major innovations in processing are required in view of the lack of supply. Even if the stock is replenished, this lack of supply will still prevail because of the natural limits of the stocks and the legitimate demands of other users. Because of the present and the projected conditions of high-value stocks, the industry cannot place unlimited dependence on stocks where processing problems are relatively incidental.

Medium- to low-value species such as yellow perch, chub, sheepshead, and suckers require greater amounts of processing to compete successfully in current markets (medium-value species) or to retain a marginal slice well below what the supply could produce (low-value species). In both categories major processing advances would be necessary to transform them into usable and desirable product forms and to support significantly higher production levels at profitable prices. In the case of some species like carp and sheepshead, quantity production for the human food market may not be acceptable to the general consumer.

(b) Except in the case of very high-value items, there must be reasonable assurance of steady, adequate supply. Otherwise justification of the additional investment and cost of converting and improving processing facilities for food fish and particularly for industrial uses such as fish meal are impossible. This problem is aggravated by the fact that all but a few processors are small family units with limited available capital to make adjustments. Attraction of outside capital is a problem that will be discussed in the section on institutional problems.

The lack of steady supply is due to the inherent seasonal nature of fish production complicated by the limitations of traditional harvesting techniques. This problem could be partially remedied by establishing large storage and freezing units which could hold fish for later processing and marketing. However, funds to finance this program are not available.

(c) Traditional processing operations have been necessarily labor-intensive with mostly hand labor involved. Skilled laborers are hard to recruit into the industry, especially for work that may last only for a few weeks during the year. Overhead costs, which continue to be exacted whether or not equipment is being used, are significant because the amount and size of the equipment must be substantial in order to adequately handle large spring catches.

(d) If sufficient knowledge existed to process less-desired species into acceptable market forms, substantial investments in time and money would still be required to convert existing processing plant facilities. Unless sufficient sales can be guaranteed to enhance the value of such products on an open, competitive market, relative investments would be risky. Instability of the fish resource, especially the medium-value fish stocks, severely complicates the matter. Processing technology necessary to develop more attractive product forms at a competitive price for underutilized species like sheepshead and carp is not available. Thus, there is little financial capability for research and technological development within the industry. Such investment would probably come from some level of government.

(3) With the exception of high-value species for which market demand, both present and projected, is brisk even in existing product forms, the basic marketing problem is one of either fluctuating, undependable demand (e.g., yellow perch and lake herring) or virtually nonexistent demand (e.g., carp and sheepshead). Continued, long-range, sluggish market demand is not only a fundamental constraint on the commercial fisherman, but it discourages long-range investment in improvement. At the same time, it reduces the strength and flexibility of the commercial fishery to respond to changing management needs. Some of the reasons for this basic market demand situation have already been covered under the discussion of harvesting and processing. Additional dimensions of the problem include the following:

(a) The Ontario commercial fishing industry, with the encouragement of the Provincial government, employs efficient and large-scale harvesting, processing, and marketing techniques. Despite the fact that the total U.S. catch over the last 10-year period exceeded that of Canada by more than 30 percent, the latter's large-scale, highly mechanized operation combined with cheaper labor supply have allowed it to place its products on American markets at lower prices. Furthermore, Canada's processing techniques turn out a variety of relatively sophisticated products, all of which are inspected for quality and condition before shipment to the U.S. Because of the above situation, Canadian freshwater fishery products can be supplied to U.S. markets on a continuous, ample basis in already acceptable food fish forms at a reasonable price to the consumer (less than one dollar per pound). These are the requirements of large, U.S. market chains. There are no U.S. processors of Great Lakes fish who can meet these demands because the continued employment of traditional harvesting and processing techniques with the associated high labor costs does not allow for the economic handling of available species. While the Canadian commercial fishery faces the same basic marketing demand problems already described for the U.S. Great Lakes commercial fishery, it has been able to respond from an entirely different basis of economic and institutional arrangements. Tariff restrictions on the import of Canadian fish products were originally intended to safeguard U.S. commercial fishermen from being undercut by the Canadians. They have now ceased to be effective.

(b) Rough fish such as carp, sucker, and sheepshead have limited acceptability as food fish to the U.S. consumer. Thus, one of their outlets is the animal food and fish meal market, one of lower profit margin. The mink food market, which used to entail large volumes of freshwater fish, is currently depressed because it was suggested that pesticide concentrations in Great Lakes fish might be partially responsible for the failure of the mink to reproduce satisfactorily.

(c) The demand for Great Lakes fish has suffered additional blows due to the recent discovery of mercury in some species. This has resulted in closure of the commercial fishery in some areas, plus an increase of public apprehension regarding the wholesomeness of Great Lakes fish in general. The possibility of discovery of other contaminants above allowable levels cannot be discounted. The chub, a species available to the industry, heavily utilized, and suitable for already established processing techniques, illustrates past and current problems with contaminants. The smoked chub market has expanded as a natural function of population growth. However, outbreaks of botulism and contamination from pesticides as well as consumer conservatism prevent the further expansion of this industry.

2.7.2 Economic Needs

The following list covers certain specific economic needs of the U.S. Great Lakes commercial fishery. A more comprehensive overview will be pursued in Subsection 2.9, Institutional Needs.

(1) The commercial fishery needs vertical integration of harvesting, processing, and marketing operations and the consolidation of small harvesting and processing establishments into larger, more viable economic units. This new structure would necessitate the dissolution of the small, uneconomical fishing port and the consequent establishment of a few strategically located ports with the associated necessary landing, processing, freezing, storage, and shipping facilities.

(2) The employment of such high-volume, low-cost harvesting methods as the trawl, improved seining techniques, and other equipment is indicated. The trawl is currently being used on Lake Michigan where it has proved successful in capturing alewife. This particular fishery, which decreased in 1969 from 18 to 14 vessels, has made possible the construction and operation of two large fish meal processing plants in Wisconsin. Experimental trawling in Lakes Erie and Huron has indicated that many areas in these two Lakes are also suitable for trawling.

Furthermore, recently improved methods and equipment for operating hand seines in the Great Lakes have been developed. Conversion to these new techniques would involve the transformation of the many trap net boats throughout the Basin.

There are major advantages of this improved seining system over conventional haul seine operations:

(a) greatly reduced heavy manual labor requirements (three-man crew as compared to five- or six-man crews)

(b) considerably less time per set (2½ to 3 hours as compared to 4 to 6 hours)

(c) substantially increased mobility

Such a system should be highly effective in the harvest of carp, suckers, and sheepshead in areas such as Green and Saginaw Bays, as well as Lake Erie. The equipment would also be highly effective for taking large quantities of alewife during their spring inshore movements.

(3) If the harvest of large quantities of low-value species is to be possible, increased outlets for low-value products such as fish meal and animal food are necessary.

(4) If problems of sluggish or almost nonexistent demand are to be solved, investment in technological research to develop more efficient processing techniques and more attractive product forms is necessary. These problems must be solved if underutilized low-value stocks are to become viable market commodities. The bulk of this investment will have to come from outside the extremely undercapitalized fishing industry.

2.8 Proposed Solutions to Economic Problems and Needs

2.8.1 Increasing Demand for Commercial Fishery Products

For high-value species like lake trout, lake whitefish, and walleye, increasing demand is not a problem. This is not true for low-value species like carp and sheepshead. The lack of demand for these species tends to be nationwide and solutions are unlikely to come about solely within the scope of the Great Lakes fishery because this fishery contributes a relatively small proportion of the national supply. Demand and prices for these species will be heavily dependent upon decisions made by either government or industry to invest in research resulting in more attractive freshwater fish forms. Given the depressed state of the industry, the investment would have to come largely from government. This aspect is discussed under solutions for problems of institutional arrangements.

Expanding freezing facilities to avoid market gluts and refining marketing methods would decrease costs for medium-value species like yellow perch and smelt. These methods are discussed further under solutions for problems of institutional arrangements.

2.8.2 Stabilizing Supply

At present the problem of stabilizing supply pertains more to high- and medium-value species than to low-value species. There are a few proposed solutions to this problem:

(1) The total supply available to both the sport and commercial fishery should be increased by halting environmental deterioration and improving management techniques. Great Lakes biologists agree that improvement of environmental conditions in at least Lakes Erie and Ontario would eliminate factors which presently limit certain stocks and prevent their reestablishment or the introduction of other species. Such a program could certainly improve the plight of lake whitefish, lake herring, and sauger. Environmental improvement and pollution control would also reduce the problem of pesticide and mercury contamination of fish flesh, which is currently depressing market demand for certain fishery products.

(2) Research geared to developing a better understanding of fish population dynamics would allow for greater accuracy in predicting the direction and magnitude of future fluctuations of stocks and would enable the industry to anticipate changes and make adjustments for them.

(3) The reallocation of important commercial species 3 to 5 years prior to their harvest is a controversial solution which promises immediate benefits to the industry. The allocations would have to be based on the best available information on stock condition and prospects. The feasibility of this approach will increase as research data become more broadly based and reliable. Of course, care would be taken to insure that fish populations could tolerate such removal. Without the assurance of at least minimum advance allocations, the industry could hardly make the investments necessary to employ the innovations which would insure its continued existence.

2.8.3 Reorganizing the Commercial Fishery

In order to change the existing undercapitalized, fragmented, and depressed industry into a viable unit, it will be necessary to make some dramatic changes in the commercial fishery.

This is a complex question and is inextricably related to questions of industry and institutional arrangements to be discussed later. Developing more efficient harvesting equipment and methods is also influenced by State regulation and restrictions.

2.8.4 Subsidies and Import Restrictions

Detailed consideration of this approach is outside the scope of a framework study.

2.9 Institutional Problems and Needs

The economic problems of the Great Lakes commercial fishery discussed in the previous section, i.e., stagnant or unstable market demand, depressed prices, undercapitalization, and Canadian competition, are extremely serious and could lead to eventual elimination of the fishery. Nevertheless, institutional problems and needs are even more fundamental. Without solution of the institutional problems, it becomes almost impossible to consider workable solutions for the purely economic problems in an orderly manner. The general pattern that has prevailed in dealing with these problems has been one of confusion, characterized by the lack of an effective mechanism to develop rational solutions to current problems and realities based on equitable inputs from all concerned with the resources. In contrast to the working relationship existing between the Canadian fisheries and the governing institutional framework, the U.S. fishing industry and the resource management agencies are burdened by an institutional framework which lacks unity and is prejudicial, unrelated, and at times, restrictive. While development of an adequate institutional framework will not guarantee success to any solution of economic and management problems, lack of such a framework will guarantee its failure. The only example of a successful international institutional framework, the Great Lakes Fishery Commission, has been restricted to two limited problems, sea lamprey control and related research.

The following points should be considered in any examination of the problem of institutional arrangements:

(1) The international status of the Great Lakes (except Lake Michigan) and the division of the U.S. portion among eight States require that any ultimate institutional arrangements for fishery utilization and management be capable of dealing with this diversity of jurisdiction. This is not to imply that absolute uniformity of fishing regulations must prevail throughout the system. Certain fish stocks are relatively discrete and limited in location and many problems are local in nature. Nevertheless, the local exceptions and variations

should be recognized as part of a larger, interacting system.

(2) The question of institutional arrangements is not limited to the public management sector. The commercial fishery must have the organizational and institutional capacity to take the necessary steps to change and improve its structure and operations in order to meet its problems responsibly. The Canadian commercial fishery already possesses partial institutional capacity to make corporate decisions on changes in operations, marketing, and processing procedures. It can also respond to new biological knowledge and make pertinent investment decisions.

(3) Central to any discussion of institutional arrangements is the kind of restrictions placed on the commercial fishery, the manner in which they are determined and applied, and the provisions for equitable participation by all the legitimate interests involved.

(a) The fishery resource of the Great Lakes has been used almost exclusively by the commercial fishery. However, recent laws have banned some efficient harvesting techniques and prohibited commercial fishing where it would compete with sport fishing. Even now, no comprehensive management and regulatory goals exist. The biological data necessary for determining these goals are unavailable. These factors have restrained innovative research and discouraged investments necessary to retain or expand the commercial fishery as a viable entity.

(b) Recently there has been increased emphasis on the sport fishery, not only in the traditionally utilized inshore waters but on the open Lakes. Because of this, restrictive regulations have been imposed on the commercial fishery to favor growth and development of the open-Lake sport fishery. Lawmakers feel that restriction of the commercial fishery may facilitate the reestablishment of a balanced predator-prey fish resource. This is needed to support a viable, self-perpetuating sport fishery. While the legislators have certain misgivings about traditional commercial fishing equipment and methods, there is even more concern over the more efficient technique of trawling, which would supply the needs of a large-scale commercial fishery. They feel that commercial fishing will severely deplete prey species, for example the alewife, thereby jeopardizing the food supply available to the desired predator species. They also feel that the use of highly efficient trawling equipment and methods will result in a high incidental catch of such valuable predator species as lake trout or salmon.

In summary, an institutional framework that encourages the sport fishery by restricting the commercial fishery provides the latter with few options concerning fishing areas, methods and equipment, and species. In turn, these restrictions dampen incentive for investment and innovation in the commercial fishery, and so, the vicious circle is perpetuated.

(4) The fishery resources of the Great Lakes are renewable publicly-owned resources. Wise use requires an approach that will permit distribution of the resources to the sport and commercial fisheries in a manner that maximizes the overall benefit to society. This involves institutional arrangements that would advocate a balanced, mutually supportive sport-commercial fishery. The commercial fishery could become an effective management tool, which could manipulate fish stocks and achieve the desired balance.

(5) Maintenance of a Great Lakes commercial fishery flexible and efficient enough to contribute to the economy, supply an expanded demand, and respond to changing biological and management conditions requires certain institutional arrangements. Support must be generated for the commercial fishery to maintain and enhance its productivity and to insure its availability as a flexible management tool. Reasonable expectation of continuity, particularly concerning supply levels, is necessary to justify investment. Despite the natural supply variability and the limited capability for quantitative assessment and prediction, a firm program of stock reallocation over a sufficiently extended time period (e.g., five years) would justify investment in a more diversified, flexible, and responsive commercial fishery. In this event, the management component of the institutional framework would endure only a normal medium-range risk factor. In the event of unanticipated fluctuations of stocks, maintenance of the program could result in temporarily excessive removals as well as some adjustments of sport fishing harvest. These reallocation risks can be reduced as the level of biological knowledge permits more accurate prediction of stocks and if the institutional framework expands to encompass the whole Great Lakes ecosystem. Once arrangements were made to provide reasonable allocative continuity, the basic condition for the commercial fishery to solve its own economic problems in a responsible manner would be met.

2.10 Proposed Solutions to Institutional Problems and Needs

2.10.1 Interstate and International Cooperation and Coordination

The fish stocks of the Great Lakes represent an international as well as interstate resource. While certain stocks are discrete and should be managed on a localized basis, the most efficient system to handle problems of an economic, environmental, and managerial nature relating to fish stocks would have to be couched in an international framework. This need has been partially fulfilled by the creation of the Great Lakes Fishery Commission, an international, institutional mechanism established in 1956, which provides for clear-cut cooperation in decisions regarding the limited objective of effecting sea lamprey control throughout the Great Lakes Basin. The commission is additionally charged with improving the cooperative and productive relationships among Federal, State, and Provincial agencies, especially regarding research and rehabilitation programs. To realize this goal a number of advisory Lake committees have been established.

Expansion of the Great Lakes Fishery Commission apparatus to cover the international gamut of fishery problems, including uniform management and regulation policies, economic solutions, and a fully integrated approach to environmental problems, is not a realistic short-range goal at the present time. This problem of international cooperation is not unique to fishery matters, but hinders the entire Framework Study, allowing it only to touch upon international problems. However, the existence of the Great Lakes Fishery Commission puts the fishery resource in a relatively advanced position in comparison to resources that have no institutional entity.

2.10.2 Reorganization of the Industry

There is a need for a new set of internal institutional arrangements that would give at least the same degree of internal coherence, flexibility, and responsiveness enjoyed by the Canadian industry. The present organization and institutional arrangements within the industry tend to reflect the eight-part, autonomous jurisdictional framework that prevails on the U.S. side. This discourages cooperation for mutual benefit, consolidation of investment decisions, and joint, effective response to the need for change and innovation.

The prospects for short-range solutions are not bright. However, a partial step in this direction would be voluntary integration among existing commercial fishermen associations, trade groups, and wholesalers. To some extent the Midwest Federated Fisheries Council attempts to perform this function in the Great Lakes area. However, the arrangement is a loose one, complicated by differences between producers and processors and the Council's interest in marketing all commercial fish products, not just those from the Great Lakes. Nevertheless, the advantages to all concerned (including the State regulatory agencies) from the existence of a Basinwide industry organization capable of responsibly representing its components justifies continued efforts in this area. Since the fisheries in each State would be responsive to their respective State management approach, the achievement of this goal is dependent upon the success of achieving interstate coordination and cooperation of management agencies.

2.10.3 Reorganization of the Management Framework

Framework reorganization is not only necessary for the successful management of the commercial fishery, but also for the optimal management of the entire fishery resource. With some variations the same problems are being encountered in fisheries outside the Great Lakes. Identical theoretical solutions are being proposed, and in some cases, implementation and experimentation are being carried out.

2.10.3.1 Abolition of the Commercial Fishery

Sport fishermen and some fishery administrators have suggested this solution, which would solve the abrasive sport-commercial fishery relationship problem in a clear-cut, definitive manner. Strong support for this solution comes from people who feel that any economic or biological benefits accruing from the existence of a commercial fishery are not significant enough to justify the trouble and expense of administering it. Objectively, however, implementation of this alternative would have the following consequences:

(1) It would eliminate the modest, but not inconsequential contribution from the Great

Lakes commercial fishery which currently amounts to approximately 71 million pounds and $5,900,000 annually (average for 5-year period, 1966 to 1970). These figures do not take into consideration value added to the dockside catch through processing. They represent output under severe constraints and depressed conditions.

(2) It would eliminate the commercial fishery as a tool for manipulation and management of fish stocks. The validity of this potential can be questioned, but it is inseparable from the contention that overexploitation by the commercial fishery has occasionally adversely affected the status of certain stocks.

(3) It would remove the best indicators of shifting Great Lakes fish population dynamics (commercial fishery statistics). These figures, which are the basis for all the analyses to date of past history and current condition of stocks, would have been even more reliable had comparable data on sport fishing utilization been available.

2.10.3.2 Establishment of a Limited Entry Commercial Fishery

The classic concept of a limited entry commercial fishery envisions the reduction of fishermen to bring about a more efficient use of the resources in the industry. Specifically, its goal is to adjust fishing effort to the point where the maximum net economic return is realized. The assurance of an adequate fishery resource to allow for long-term investments promoting efficiency and availability of product, and the allowance for the participating fishermen to realize a fair return on their investment are essential to this concept.

Controversies associated with limited entry do not stem from the concept itself, but from the method selected to reduce the fishermen and from the administrative procedures developed to regulate the reduced fishery. Fishermen often agree in principle with limited entry, but strongly object to precipitous or arbitrary allocation of fishing rights. Reducing the number of fishermen presents obvious difficulties and a long-term approach is often taken. This approach may involve gradual reductions by retiring licenses upon the death or exit of fishermen from the industry until the desired number of fishermen or operating units is reached. Actual regulation of the fishery once the appropriate level of fishing effort is reached may take a number of forms such as competitive bidding for available licenses, contractual agreements between fishermen and the management agency, or administratively determined allocations based on various management criteria. In practice both the reduction of fishermen and administration of the fishery are closely related problems which often are resolved on social or political grounds and reflect the varied nature of individual fisheries.

2.10.3.3 Establishment of Species Quotas

In a limited way, a quota fishery already exists for lake trout in the Isle Royale and Caribou Islands areas of Lake Superior. There is no other similar fishery in the Great Lakes Basin.

From a management standpoint this alternative has much to recommend it, especially in terms of directness, simplicity, and flexibility. To operate efficiently, sufficient biological data must be available to assign species quotas that will simultaneously insure protection and conservation of stocks while providing the maximum contribution possible to the sport and commercial fisheries. Subquotas or allocations between sport and commercial fisheries will be based on good judgment and not on prior value.

There are a number of drawbacks to this alternative. Adequate biological data for management and allocation decisions do not exist. Also, quotas are essentially meaningless for low-value species with low demand. Quotas for high-value species can be economically deterimental to the commercial fishery. Fishermen may overinvest in harvesting equipment so that they can harvest the greatest amount as quickly as possible before the quota is filled. In this system speed is essential because of the expense of manpower and equipment.

Enforcement of quotas without limited entry is nearly impossible. Therefore, it is doubtful that the establishment of quotas can be viewed as an overall institutional solution. However, as an implementation tool in a larger institutional framework, it may be a partial solution to fishery problems.

2.10.3.4 Establishment of a Contract Fishery

A contract fishery is one in which the resources available to a selected number of fishermen are allocated on a contract basis, either through a process of competitive bidding or direct allocation by the concerned management agency. The total number of participating commercial fishermen and the harvest of particular species is strictly controlled by the management agency. Contract fishing is often implemented for the purpose of utilizing rough fish species, a goal which in most instances results in improving fish resources for the sport fishery. Contract fishing is also a method used by management to obtain greater control over commercial harvest and, at least theoretically, afford protection to selected species which are considered to be threatened by commercial overexploitation. If implemented for the purpose of increasing industry efficiency, contract fishing would be considered a tool of limited entry.

The contract fishery system works best in frameworks where the habitat naturally falls into discrete blocks and there are only one or two target species whose particular behavioral or biological characteristics facilitate their capture.

Such a fishery presently exists on some of the inland lakes of Minnesota and Wisconsin where carp and buffalo fish are the target species. The respective management agencies assign the exclusive fishing rights to individual fishermen on an individual lake or series-of-lakes basis. Although this assignment may be for one year only, it usually is good for a number of years. Since highest bidders do not necessarily equal best performers, contracts are not awarded on a competitive bidding basis. Rather, assignment is based primarily on location of the fishermen, their past performance, and the amount and kind of equipment they have available. In the case of inland lakes, equipment is simple and does not require a large amount of capital. If the fishermen require additional help, they recruit temporary labor on a day-to-day basis, usually from the local population. States set various conditions and stipulations for the fishermen. For example, if the economics of the situation permits, a small per-pound fee is assessed by the State.

By carefully balancing fishermen and lakes, the States are usually able to achieve continuity in the fishery and efficient deployment of available equipment. In those cases where the resources of available fishermen are not sufficient to achieve the required removals, State crews and equipment are employed to achieve the objectives.

Any attempt to implement this kind of fishery on the Great Lakes would face certain difficulties:

(1) A major difficulty would be the reduction of the present number of fishermen in an equitable manner. Of the alternatives available (i.e., buying out the fishermen, establishing grandfather clauses in current regulations, etc.), only those which took into account the loss of job opportunities and consequent loss of future income would be truly equitable.

(2) The magnitude of the investment necessary to maintain capability of stock manipulation large enough to be effective in the Great Lakes would require substantial subsidization by concerned management agencies, especially in the absence of a guaranteed supply created by highly unstable fish resources.

(3) Certain questions inherent in the above points would have to be answered. For example, what constitutes a proper wage for a contracting fisherman, and therefore, what constitutes reasonable subsidization? Response to such a question will require an understanding on the part of management of the economics of harvesting, processing, and marketing.

A bill recently introduced to the Michigan State Legislature and closely watched by other Great Lakes States management agencies provides the legal foundation for establishment of a contract fishery in the Michigan waters of Lakes Erie, Huron, Michigan, and Superior.

Because of the unbalanced nature of the fish resources throughout the Great Lakes Basin, the infrequency of large, high-value fish populations, and the poor markets currently available for low-value species, the need to limit fishing effort in the Lakes has become widely accepted. The fact that the commercial fishery has occasionally produced significant changes in certain fish populations underscores this necessity.

There are reasons for controlling the commercial harvest other than concern that uncontrolled fishing may result in overexploitation of fish stocks. Efforts to obtain better fishing control to avoid jeopardizing the predator rehabilitation program and to rationally allocate certain stocks to sport and commercial fishermen are also legitimate. Given the historically high demand for such species as lake trout, whitefish, and walleye, fishermen exploit these species which are at low levels of abundance and thereby jeopardize efforts to reestablish better balanced predator-prey populations in the Lakes. In these cases, controls are obviously necessary. Allocations based on quotas or similar measures are absolutely necessary for stocks affected by present or potential sport-commercial conflicts (lake trout, walleye, salmon, yellow perch, and alewife). The methodology involved in determining these quotas is another issue involving resource allocation similar to those addressed in the Great Lakes Fishery Commission cost-benefit study of the sea lamprey control program.

In addition to the usual justification for a limited entry type of commercial fishery, other factors that make this need more compelling are the high demand for certain Great Lakes species, the consequent economic incentive to exploit certain valuable species to low levels of abundance at a time when restoration of a more desirable fish population is being stressed, and the need to allocate portions of certain stocks to both sport and commercial fisheries.

Many methods geared to controlling the number of commercial fishermen have been tried in the Great Lakes, but none has taken the pure form of those traditional methods already discussed. In Michigan's case, the number of fishermen was reduced, but apparently not to the levels necessary to make the system operable in the classic mold. More importantly, objections by some commercial fishermen that the elimination process was carried out unfairly or capriciously have resulted in long drawn-out litigation, a fact which serves to indicate the possible complexities involved in implementing this type of approach. Because of this, State authorities have concluded that limited entry is not a workable option in terms of reorganization of the management framework for the Great Lakes commercial fishery and have turned to the establishment of a contract fishery as an alternative.

This should serve as adequate warning that any solution that will result in decreased numbers of commercial fishermen will face a major, initial problem in its implementation, that of reducing the number of fishermen in a fair, equitable, and realistic fashion. As already indicated in our discussion of the contract fishery, there are a number of ways to bring about such a reduction.

2.10.3.5 Mixed-Alternative Solution

An alternative approach might be found by establishing two different types of commercial fisheries in the Great Lakes: one geared to the harvest of large volumes of low-value species, and the other geared to the harvest of smaller numbers of medium- and high-value species. This arrangement might be achieved in the following fashion:

(1) A low-value fishery based on the capture of species such as the carp, sheepshead, and sucker would require the following to be profitable:

(a) suitable markets which could guarantee a return to the fishermen large enough to constitute a fair earning

(b) efficient harvesting equipment

(c) management guarantee that as long as the amount harvested is based on sound biological principles, industry would be guaranteed a sustained level of catch

The allowable catch would be based on the estimated maximum sustainable yield of the relevant species. In the case of carp, sheepshead, and suckers, the present annual harvest from all Great Lakes waters (12.5 million pounds) is only 13 percent of the estimated MSY (93 million pounds) for these species.

The number of operating units which the fishery could accommodate would be estimated on the basis of what constituted a fair rate of return to each. The precise number of fishermen involved probably could not be determined, although any attempt to do so must be a function of the technology employed.

If suitable markets could be developed for these rough fish, and if biological data indicated that these stocks could withstand severe pressure from the commercial fishery, it might not be necessary to impose quotas on this fishery.

(2) The high-value fishery would concentrate on the capture of species such as lake trout and whitefish. The number of fishermen involved would be strictly limited by management.

Because commercial fishermen restricted to low-value species might incidentally capture large or significant numbers of high-value fish, management should make some kind of arrangement where the high-value industry, because of its vested interest in the stocks, could regulate the low-value industry. In this manner, the commercial industry would be more adherent to sound management practices. This is not to imply that fishermen restricted to low-value species would be receiving less income than those restricted to high-value species. In the final analysis, the value of the catches might be identical. It is only an attempt to insure that stocks are protected for the benefit of all.

The entire system might be further refined by establishing a training program for prospective Great Lakes commercial fishermen. Those who wanted to participate in either fishery would be required to take part in the training program school. Each would receive a certificate upon successful completion of the program which would indicate his familiarity with such things as the biological determinants of management policy and the problems facing management agencies, and serve as a license to participate in the fishery. Since management agencies would be benefiting directly by having the industry available as a tool with which to manipulate stocks, remove rough fish, and assess population characteristics, they might finance or partially subsidize the training program.

The number of allowable fishermen would have to be determined by management, based on guaranteed allocation of stocks valuable enough to allow the fishermen involved a decent living.

In summary, it is possible that the problems currently facing management regarding the commercial fishing industry might be ameliorated by the establishment of two kinds of commercial fisheries: one using highly sophisticated equipment capable of harvesting large volumes of low-value fish without threatening the capture of high-value species, and the other being highly regulated by management and using selective equipment to harvest limited numbers of medium- and high-value fish. The fishermen of both would be required to take part in a training program geared to provide a solid background in biology, harvesting techniques, and boating safety.

2.11 Solutions to Some Noneconomic Institutional Problems of the Commercial Fishing Industry

Implicit in the preceding discussion is the existence of other, more specific problems. These are susceptible to particular, operation-oriented solutions.

2.11.1 Harvesting Solutions

In order to exploit large volumes of low-value species, continued research is necessary to develop efficient methods to capture these low-value, presently underutilized stocks. Because of the depressed economic conditions throughout the industry, research into the feasibility of converting conventional fishing equipment and boats into forms better geared to the efficient harvest of certain fish species is necessary. For example, the former Bureau of Commercial Fisheries' Exploratory Fishing Unit converted trap net boats into modified haul-seining vessels. The improved seining system is highly efficient in the capture of shallow water species like the carp and sucker and has a great advantage over traditional haul-seining equipment because it requires half the manpower and only one boat. With further refinement this method could be adopted as a suitable technique for the capture of low-value species throughout the Basin.

2.11.2 Processing Solutions

A factor which hinders the development of handling techniques for low-value species is their present unacceptability to the consumer as food. If these species are to be utilized, forms acceptable for human consumption must be developed. Because of the poor financial position of the industry, this research should be subsidized almost entirely from public funds. If this is possible, every effort must be made to develop simplified but effective processing techniques which require minimal skills. In this way, training of processing laborers will not constitute a significant expense.

At the same time, investigations should be made into the feasibility of consolidating the present small-scale, poorly equipped processing operations into a few large-scale, well equipped cooperative operations located at strategic points. These facilities should include landing, handling, processing, storage, and freezing components.

2.11.3 Marketing Solutions

Because of recent restrictions of certain fish products by the Food and Drug Administration and the closure of specific fisheries, fish products should be inspected to determine contaminant levels. The industry could then develop descriptive packaging announcing the findings of the inspection or some other kind of assurance that would allay consumer fears.

2.11.4 Other Solutions

The following solutions are compatible with each other and with those already discussed:

(1) research programs

(a) investigations into the feasibility of consolidating the presently numerous, small, widely-scattered, and generally poor landing facilities into a small number of large, strategically located fishing ports

(b) reevaluation of past and present regulations in order to determine their effectiveness and economic impact on the fishery

(2) applied programs

(a) development of a program or newsletter by management agencies to inform commercial fishermen of

(aa) changes in fish stocks

(bb) management efforts to restore a balanced predator-prey resource

(cc) management methodology in doing this

(dd) reasons for management philosophies

(ee) process of decision-making regarding management of fish resources

(b) development of a program by the National Marine Fisheries Service and other concerned agencies to keep commercial fishermen informed of changes in fishing methods and equipment, markets, and product forms

(c) development of a master plan for improving fish resources of the Great Lakes prepared under the auspices of the Great Lakes Fishery Commission. Management officials from each of the eight Great Lakes States as well as Ontario should play an integral role in the development of such a plan.

(d) creation of institutional arrangements by the fishing industry that encourage disciplined, intelligent self-regulation. This is compatible with management objectives, and, at the same time, encourages the economic well-being of the fishermen involved.

2.12 Contaminant Problems and Associated Needs

2.12.1 Mercury

Mercury pollution is currently a serious problem in many parts of the world. Humans have died or developed neurological disorders as a result of eating fish from mercury-contaminated coastal regions of Japan. High concentrations of mercury in fish and birds have been traced to industrial and agricultural discharges in Sweden. Seventeen States in the U.S. have either banned fishing in contaminated waters or warned people not to eat fish and shellfish from these waters. The sources and environmental pathways of mercury have been studied in Japan and Sweden. Investigation of mercury pollution in the United States is just beginning.

In late 1969, Canadian authorities discovered concentrations of mercury in several commercial catches of fish from inland lakes which ranged from 5 to 10 parts per million (ppm). The action level for mercury in fish tissues currently accepted by U.S. and Canadian authorities is 0.5 ppm.

Subsequently, mercury concentrations above the action level have been found in fish in Lake St. Clair, western Lake Erie, and the St. Clair, Clay, Wabigoon, and Detroit Rivers. Embargos on export of commercial fish, closure of certain fisheries (including temporary closure of the sport fishery in Lake St. Clair) followed these discoveries. The direct effect of closures and embargos and the indirect effect of public apprehension resulted in substantial losses to the commercial fishermen and processors. Restrictions on sport fishing in the Lake St. Clair area depressed the entire local recreation industry.

Mercury is presently in the environment both naturally and as the result of man's contamination. Certain industries such as paper processing and chemical plants have been particularly outstanding offenders, but the use of mercury is common in many industrial and agricultural practices. In the St. Clair area alone, up to 200 pounds of mercury wastes per day have been discharged by the chlor-alkali industry in Sarnia, Ontario. Mercury contamination in the mud sediments directly below the outfall of one of these plants was recorded as high as 1800 ppm.

Mercury is discharged in different chemical forms: metallic mercury, inorganic mercury, methylmercury and phenylmercury. Although all these forms are toxic to humans at some level, the organic forms are without a doubt more toxic than the inorganic. We know that mercury has a high affinity for the fetus, but we are ignorant about the effect of long-term, low-level exposure.

After discharge into the aquatic environment, mercury tends to be tightly bound to the sediment in an insoluble form. However, Swedish research indicates that under anaerobic conditions, methylation of inorganic mercury may occur because of actions of microorganisms present in the sediment, producing two end products: monomethylmercury, which is relatively fat soluble, and tends to stay in the water environment; and dimethylmercury, which is a highly volatile compound and may evaporate into the atmosphere. Although dimethylmercury is more fat soluble than monomethylmercury, it can be readily converted to monomethylmercury in the water environment before evaporation occurs.

Fish can incorporate mercury by either direct absorption from the water through the gills, or ingestion of mercury-contaminated foods. For example, suckers or sculpins consume benthic forms that have fed on microorganisms, and predators consume prey species (beginning with plankton and culminating in top predators). Much is still unknown about the detailed mechanics of the system.

Problems of mercury contamination and their possible solutions may be summarized as follows:

(1) All sources of mercury contamination must be identified and rigorously controlled by Federal, State, and Canadian authorities to shut off all inputs of mercury to Basin waters. This has already been initiated on an emergency basis, and no known mercury losses to Basin waters are being tolerated. Sale, use, and loss of mercury should be recorded. Inventories should be monitored and any possible losses to the environment should be reported.

(2) Monitoring of mercury occurrence in fish flesh, aquatic life, and the aquatic environment should be improved and expanded. This will establish the dimensions of the problem and determine the effects of item one. At present, sampling and monitoring of fish flesh are being carried out in the Great Lakes by Canadian agencies, the FDA, NMFS, and BSF&W in the U.S., and the States of Ohio and Michigan. The total effort is not adequate and is hampered by a lack of uniformity in analytical techniques and sampling methodologies, which creates difficulties in comparing results. In addition, techniques are needed to differentiate the various organic and inorganic mercury compounds, but this is essentially a technical problem and should be resolved quickly.

(3) Toxicological research on selected fish species at all stages of their life histories should be expanded to determine acute and sublethal effects of mercury. Such studies should include consideration of the mechanics of concentration through the food chain. Also, a profile of various mercury compounds in selected species would facilitate a better understanding of changes detected by environmental monitoring.

(4) Research on the true magnitude of the human health hazard from ingestion (by food intake or other means) of substances with a low level of mercury contamination should be expanded. A lack of knowledge of background levels that may have been operable for generations without harm necessitates establishment of an extremely low action level for mercury, 0.5 ppm. This arbitrary level causes economic hardship to sport and commercial fisheries, but until a safe, realistic level is determined, the present action level must be deemed necessary.

(5) Expanded investigation of the detailed cycling of mercury in the environment is necessary to estimate the time frames involved in reduction of existing mercury contamination in the aquatic environment to acceptable levels. Of course, this assumes rapid control of new inputs. This investigation will also aid the development of safe and realistic removal methods for existing mercury contamination. Four approaches to removal and neutralization of existing mercury contamination are under consideration:

(a) Dredging would require that spoils be deposited in a suitable location to permanently avoid reentry. Disturbance of the contaminated sediments and possible reentry of presently inert mercury is an obvious problem.

(b) Sealing would involve covering the mercury-rich sediments with inert clay or absorbing material.

(c) Permanent fixation involves chemical complexing of mercury to prevent its methylation.

(d) Dissipation involves raising the pH to facilitate dimethylmercury formation which may eventually escape to the water and then to the atmosphere. These would decrease the concentration, but spread the pollution over a larger area. However, the dimethylmercury may be converted to monomethylmercury and enter the food chain.

Preferably, these and other approaches should be tested on a scale large enough to be realistic but small enough to permit adequate monitoring and analysis of the complex biological and environmental interactions. Decisions can then be made on major implementation. Such testing would be expensive and time-consuming, but justified in contrast to hasty, possibly dangerous tampering, the effects of which could not be measured.

2.12.2 Pesticides

Monitoring of pesticide levels in Great Lakes fish was initiated in 1965 by the Great Lakes Fishery Laboratory in Ann Arbor, Michigan. Since that time, only two pesticides, DDT (including DDT, DDE, DDD) and dieldrin have been recorded in all Great Lakes fish.

Ranked on the basis of concentration levels of these substances, the Lakes follow this descending order: Lake Michigan (where the fish have two to seven times as much of these two pesticides as those from the other Lakes); Lakes Ontario, Huron, Erie, and Superior.

As is true of mercury, the degree of pesticide concentration is heavily dependent upon the species characteristics, and concentration varies markedly between species from different Lakes and within different areas of individual Lakes.

The two organochlorine groups to which DDT and dieldrin belong increase excitability of the nervous system and have a damaging effect on the liver. Amounts found in food sources in the environment have not proved fatal to man. However, both DDT and dieldrin are among those chlorinated hydrocarbons which are causing serious damage to certain species of birds and fish. For example, low concentrations of these pesticides have had deleterious effects on the reproduction of fish species such as lake trout and brook trout, and relatively low concentrations of DDT in birds result in unusually thin egg shells. Furthermore, the concentration of other toxicants has been shown to be the causative factor in a number of fish and gull fatalities.

Halogenated pesticides may have another effect just as profound as the death of fish and birds or the loss of commercial or recreational fisheries. DDT and other chlorinated hydrocarbons reduce the photosynthetic activity of some species of marine phytoplankton, especially when cell concentrations are low. If this phenomenon is widespread in the Great Lakes, large segments of the food chain could be destroyed. At least one scientist has suggested that selective destruction of the food chain may partially explain the emergence of normally uncommon phytoplankton species and the accompanying nuisance algal blooms of eutrophic lakes.

Concentration of pesticides in Great Lakes fish is cause for concern. In April of 1969, the Food and Drug Administration ordered the seizure of approximately 28,000 pounds of coho salmon because of DDT levels which exceeded the established action level of 5 ppm.

Unlike terrestrial animals which are exposed to insecticides primarily through their food, fish are in constant contact with these materials in the water. Because fish gills are extremely efficient in removing insecticides from the water, fish can build up concentrations of DDT and dieldrin at the parts per million (ppm) level from the parts per trillion (ppt) level found in water. A contributory factor is that chlorinated hydrocarbon insecticides such as DDT have very high partition coefficients; that is, they are more soluble in oil than in water. Therefore, the higher the fat content of the fish, an increase which naturally occurs as a fish grows in size, the more insecticide it can accumulate.

Let us summarize a few pertinent facts:

(1) Fish are highly efficient concentrators of chlorinated hydrocarbons.

(2) Large amounts of DDT and other chlorinated hydrocarbons are used in the Great Lakes Basin annually; 127,000 pounds of DDT were used in the Wisconsin-Lake Michigan watershed in 1962 and 134,000 pounds of chlorinated hydrocarbons (including DDT) were used in the Green Bay watershed during the same year.

(3) DDT is extremely stable in the environment.

(4) Flushing times of the Great Lakes range from 3 years for Lake Erie to approximately 200 years for Lake Superior.

(5) Success of reestablishing lake trout as well as stocking of other high-value species might well depend on the reproductive success of those species.

(6) A safe level of contamination has not been determined for humans.

(7) While there is no evidence to indicate that pesticides presently in use are carcinogenic or teratogenic in man (that they increase the incidence of cancer or that they have a damaging effect on reproduction, including malformation of the fetus or newborn infant), some pesticides cause these effects in experimental mammals.

All these facts dictate prudence in the use and consumption of Great Lakes fish. Although fish occurs less frequently than meat in the American diet, some groups consume four or five times more fish than the average, and therefore, their chances of eating contaminated fish are greatly increased. Several steps are recommended:

(1) Current FDA tolerance levels for pesticides in fish shipped across State lines (.3 ppm dieldrin and 5 ppm DDT) should be subjected to immediate review because of differences in consumption habits exhibited by people of different races, regions, income groups, religions, occupations, and education.

(2) Concurrent efforts should be made to apply processing methods capable of reducing pesticide content in fish. For example, a reduction of approximately 97 percent occurs when yellow perch are filleted.

(3) Above all else, we must insure that contamination of the aquatic and general environments by these pesticides is reduced to a minimum.

To this end, many pesticides have been restricted by both Federal and State governments. In 1971, EPA conducted registration cancellation proceedings against DDT, Mirex, 2, 4, 5-T, aldrin, and dieldrin. In June, 1972, EPA banned nearly all use of DDT. Major provisions of the 1972 amendment to the Federal Insecticide, Fungicide and Rodenticide Act of 1947 included: classification of pesticides into general use or restricted categories; strengthening of enforcement policies; establishment of pesticide packaging standards; certification of pesticide applicators by the State; and establishment of disposal regulations for excess pesticides and pesticide containers. EPA has also instituted measures to minimize pesticide impact on public waters, public health, and the environment.

One possible solution to the pesticide problem is to replace these chlorinated hydrocarbons with others which are less persistent. However, caution must be exercised in substitution because many substitutes are organo-phosphates which are very toxic to mammals. Furthermore, these materials are biodegradable and must be applied repeatedly, increasing the risk of toxication and introduction of phosphates into the aquatic system.

Integrated pest management is probably the best alternative. This approach calls for maximum use of natural pest populations such as predators, parasites, pest-specific diseases, etc., for control of unwanted species.

2.12.3 Other Contaminants

Although it is not yet known whether or not other contaminants such as cadmium, arsenic, and copper are dangerous to humans at present levels, studies on the concentrations of these elements are in progress. To date, these studies have concluded that the concentration of trace elements varies with species and Lakes. For example, uranium and thorium vary among species but not among individuals of the same species from different Lakes. On the other hand, the levels of copper, cobalt, zinc, and bromine vary little between species and Lakes. Finally, the concentration of cadmium, arsenic, and chromium vary among species and among fish of the same species from different Lakes.

This would indicate that the rate at which some of these trace elements are concentrated is heavily dependent upon biological responses to environmental parameters. In view of the current mercury and pesticide problems, investigation of these materials and their effects on aquatic plant and animal life throughout the Basin must continue.

Although PCBs (polychlorinated biphenyls) were used in various industrial applications before the turn of the century, they are less well known than chlorinated hydrocarbon insecticides and have only recently begun to gain public attention. This attention is due, principally, to two factors: the recent disclosure that these compounds occur worldwide, having already been found in such diverse places as Antarctica and Central America, and the fact that the most deleterious effects of PCBs appear to be long-range and sublethal.

If the rate of PCB buildup in the environment exceeds rate of breakdown over a long enough period, certain organisms will begin to manifest chronic effects due to the toxicity of PCBs. In man the most apparent effects are skin lesions and liver damage. PCBs, like DDT and dieldrin, affect the calcium metabolism of wildfowl and as a result the birds lay thin-shelled eggs. Some ornithologists believe that PCBs have an important effect on bird populations by delaying the breeding cycle. As for effects on marine life, laboratory experiments have shown that PCBs have detrimental effects on growth of oysters and shellfish, and can, at relatively low concentrations, cause heavy mortality in juvenile shrimp. Swedish experiments have shown that high mortality of salmon eggs corresponded to high concentrations of PCB residues.

Because of the effects of PCBs on aquatic organisms, the recent discovery of relatively high concentrations of these compounds in a Lake Ontario white perch and in Lake Michigan coho salmon, lake trout, and sediments should encourage further investigation and caution. When, in the fall of 1971, a sample of 10 coho salmon from Lake Michigan contained an average of approximately 10 ppm PCBs, the State of Michigan exercised caution by discontinuing its practice of giving away weir-caught coho salmon. In addition, the Monsanto Company, the sole producer of PCBs in the United States, has stopped all sales of PCBs except for those used in closed systems.

In comparing PCBs with DDT compounds, one is immediately aware of certain basic similarities:

(1) Both are relatively insoluble in water.

(2) Both are quite soluble in fatty tissues, and can be accumulated in the ppm range from an environment in which they occur in the ppt range.

(3) Both are accumulated in living organisms in much the same way.

(4) Both exhibit relative inertness due to their resistance to oxidation and other chemical and biological degradation. This explains their stability and consequent persistence in the environment.

Despite their similarities, significant differences between PCBs and chlorinated hydrocarbon insecticides exist. For example, PCBs are more resistant to biological and chemical breakdown than DDT. This fact means that their eradication from the environment will be more difficult, and that they can accumulate in higher concentrations because of their longer half-life. PCB concentrations as high as 14,000 ppm were found in certain tissues of a Swedish white eagle, a fish-eating bird.

The most important difference between these two classes of compounds is that PCBs are not introduced into the environment deliberately. Their presence is purely accidental. Because we do not know how all PCB compounds are introduced into the environment, and because a complete index of their uses is not available, the escape of PCBs into the environment is extremely difficult to control.

It has been postulated that some PCB contamination of the environment is a result of incineration of products which contain PCBs. Some examples are carbonless reproducing paper, plastics, specialized lubricants, gasket sealers, and machine cutting oils. These products find their way to city dumps where they are burned, vaporized, carried into the atmosphere, collected on particulate matter, and subsequently returned to earth by rain. Their entrance into the natural system may also occur directly from land runoff from industrial waste and dump areas. The predominant occurrence of PCBs in industrial and urbanized areas lends credence to both of the above hypotheses.

However, answers to the following questions have not been determined:

(1) extent of the chronic effects of PCBs

(2) level of concentration (accumulation) that begins to exhibit toxic effects

(3) which of the many PCB compounds in commercially available mixtures are responsible for their toxicity

(4) fate of PCBs in natural waters

The consequences of the recent discovery of PCBs in the Great Lakes ecosystem are as yet unknown. They could be similar to those which followed the discovery of high concentrations of DDT in Great Lakes fish, i.e., seizure of some commercial catches. The closure of entire fisheries, as occurred shortly after the discovery of high mercury concentrations in certain Great Lakes fish, is unlikely but possible. The only certain result is that as the public becomes increasingly aware of the PCB problem, the image of the Great Lakes as a producer of attractive fishery products will be further tarnished.

2.13 Thermal Pollution and Associated Needs

The demands for electrical energy, which are expected to double in the next 10 years, will cause an increase in the demand for cooling waters. In 30 years the total industrial and thermal power input into the Great Lakes waters is projected to increase more than 11-fold from the present 9.98×10^{10} Btu per hour to 114×10^{10} Btu per hour. In Lake Huron alone the waste heat load is expected to increase by more than 35 times the present load. Much concern has been expressed over the real and possible effects of these discharges on the ecosystem. Consequently, these effects are under intensive study, and some preliminary results are now being published.

Factors determining the growth, survival, distribution, and abundance of fish and other cold-blooded aquatic organisms are complex and incompletely known, but the major role of temperature is firmly established. Each organism has specific thermal tolerances or limits that reflect the thermal requirements for each of the important metabolic functions in the individual. These functions and thermal tolerances vary from life stage to life stage. When the limits are exceeded, the organism functions at reduced efficiency and may ultimately die. The rate at which individuals, populations, or species are lost depends on the degree to which the thermal limits are exceeded, the duration of exposure to thermal stress, and the indirect effects of these thermal conditions. The fact that many Great Lakes species are stenothermal will necessitate close supervision of thermal pollution.

Rapidly lethal temperatures have well defined limits for many species. Temperature limits are not well determined for successful survival in situations where unfavorable temperatures reduce the ability of the organisms to move about, escape predation, compete with other species for food, and otherwise successfully complete all of the life stages vital processes, including reproduction.

The addition of heat to the aquatic environment produces basic changes other than those just described. For example, in laboratory experiments temperature rises reduce the percent of oxygen in solution. However, this is not always the case in the field, for only when the concentration of dissolved oxygen is greater than the resultant saturation level will heat drive off some of the oxygen. Increased water temperature also causes an increase in the rate of chemical reaction resulting in accelerated eutrophication and bacterial decomposition and a decreased waste assimilation capacity which reduces the suitability of the water for municipal, industrial, and recreational uses.

Site location of proposed plants must be taken into account. At present, the majority of plants are located on or near lakeshores. As a result, their cooling waters are usually taken from and returned to the lakes. With flow-through cooling the water returned to the lake would average approximately 15°F above ambient water temperature. If the heated water is returned to the productive inshore or beach water zone where a majority of the fish spawning and nursery areas are located and a great variety of shallow-water invertebrates are found, adverse consequences may result because these forms are the least mobile and thus least able to avoid unfavorable thermal conditions. The movement of adult, anadromous fish into rivers and streams may also be serverely affected as would be the return of their young to the open lake.

Several other consequences of using lake waters for cooling also merit serious consideration. For example, certain organisms have become accustomed to thermal shock (associated with being pulled into a power plant) or reverse thermal shock (associated with the dissipation of heated waters as the result of plant shutdown). However, available information on the effect of the former on larval fish indicates that the expected temperature rise experienced by these fish would be very injurious or immediately lethal. Similar undesirable effects are anticipated for other important aquatic organisms including the phytoplankton that serve as food for Great Lakes fish. Organisms (adult fish, fish fry, and plankton) are subjected to physical jarring and smashing when they are brought up against the fish screens and internal piping of the intake structures. Assuming a use rate of 91,000 cfs by the year 2000 in Lake Michigan, approximately 1.1 percent of the total volume of the water inside the 30-foot depth contour (where the eggs, larvae and juveniles of many important Lake Michigan fishes are abundant) will be passed through the cooling systems of power plants daily, and in one year a water volume equal to several times the entire water mass inside the 30-foot contour would pass through these cooling systems. Although studies conducted at these thermal plume sites have been inadequate to thoroughly assess possible effects, no significant damage has occurred to this time. In addition to the preceding facts, in January of 1971 the Technical Committee on Lake Michigan Enforcement Conference concluded that the use of Lake Michigan waters for the dissipation of waste heat may be damaging to the ecology of the Lake, and that such adverse effects might be avoided by the reduction of the use of Lake waters for waste heat dissipation.

Although the above conclusion was derived specifically for Lake Michigan, it should be emphasized that the effects of heated effluent discharges on aquatic plant and animal life in any of the Great Lakes are likely to be similar. Adding heat to a warm lake may cause tolerances for warmwater species to be exceeded just as adding heat to a cold lake may cause tolerances of coldwater species to be exceeded.

Therefore, despite the fact that obvious physical, chemical, and biological differences exist between the Lakes, we are justified in concluding that the general recommendations of the Lake Michigan Committee are applicable to the entire Great Lakes system:

(1) All thermal electric power plants using or planning to use Great Lakes water for the dissipation of waste heat should be required to have closed cycle cooling systems. Other techniques should be approved by one of the agencies mentioned in paragraph (2).

(2) Intensive field and laboratory studies should be conducted to determine the effects

on the ecology. These studies should be carried out under the guidance of a technically competent steering committee to be appointed by the Lake Michigan Enforcement Conference and should be closely coordinated with that of similarly established technical committees for each of the other Lakes. The IJC should be used as a vehicle for international coordination of the technical steering committees.

(3) These studies should determine the physical and biological effects of heated discharges from thermal electric power plants and the effects on organisms in the cooling water passing through these facilities.

(4) Geographic areas affected by thermal plumes from waste heat discharges should not overlap or intersect.

(5) Because of the possible detrimental effect on various aquatic organisms resulting from the use of chlorine or other elements in cooling waters, all new power facilities using Great Lakes waters should be required to incorporate mechanical rather than chemical cleaning procedures into plant design.

(6) Because of the distinct possibility of physical damage to phytoplankton, zooplankton, and fish at intake structures and during passage through the cooling system, future intake structures should be designed and located to minimize entrainment and thus avoid possible destruction of these organisms.

(7) All thermal plants should be required to record intake and discharge flows and temperatures continuously and to make these records available to the established regulatory agency upon request.

The Technical Committee proposed the following interim guidelines for Lake Michigan facilities with once-through cooling so that ecological damage might be reduced or avoided:

(1) discharging far enough offshore to prevent the thermal plumes from reaching the shoreline

(2) designing the discharge structure to prevent the thermal plume from reaching the Lake bottom

(3) designing plant piping and pumping systems to minimize physical damage to entrained aquatic organisms

These interim guidelines may apply in some degree to the other Lakes.

2.14 Problems of Oil Spills and Associated Needs

Although there has never been an oil spill of the magnitude of that which occurred in the Santa Barbara Channel in 1969 in any of the Great Lakes, the danger of such a spill is steadily increasing with the amount of oil shipped through the Great Lakes-St. Lawrence Seaway system. Since the opening of the St. Lawrence Seaway in 1959, shipping on the Great Lakes has increased steadily. Each ship now plying the Great Lakes carries on the average more than 1,000 tons of bunker oil. This is equivalent to 252,000 gallons, an amount greater than that lost during the drilling rig rupture in the Santa Barbara Channel. This amount of oil could create a slick approximately four to five square miles in size.

However, significant spills have occurred. For example, during the Great Lakes shipping season, several severe cases of local pollution occur per month. These result from mishaps associated with normal vessel operation. Included in this classification would be fueling or transferring petroleum products, discharging oil-saturated ballast from vessels, cleaning of oil tanks, and negligent discharge of bilge waters with their associated oil residues. These incidents have had deleterious and often serious effects on water quality in harbors, marinas, and along bathing beaches.

Incidents of this nature, along with industrial spills similar to that which occurred in the Trenton Channel of the Detroit River in April, 1969, where 96,000 gallons of cutting oil entered the western basin of Lake Erie, increased 30 percent during the first nine months of 1969 with 43 percent of the Great Lakes total occurring on Lakes Huron and St. Clair and the Detroit-St. Clair River complex. Throughout 1969, more than 42,000 gallons per day (gpd) of oils and greases were discharged into the Detroit River alone.

Other posed threats include sunken vessels (30 in Lakes Ontario and Erie alone), waste oil from gasoline filling stations (approximately 350,000,000 gallons per year throughout the United States), and leaks or pipeline breaks. Forty percent of all petroleum pollution enforcement cases involving the U.S. Army Corps of Engineers result from causes other than shipping.

Additional oil pollution could result from gas and oil drilling operations in the Lakes. Although exploration of some Pennsylvanian offshore sites was scheduled for 1970, gas and oil drilling in the United States is restricted to Lake Erie where there are, at present, no active wells. Canada, on the other hand, had 221 producing wells in operation at the end of 1968, all restricted to natural gas production. Although Canadian interests have been drilling in Lake Erie since 1913 without any significant pollution incidents (only two small spills have occurred), there is always the threat of blowout, indiscriminant dumping of oil-based drilling muds and cuttings, and losses of oil or gas in production, storage, and transportation.

Although the likelihood of a major spill is small, the risk is increasing as industrialization through the Great Lakes Basin increases. This situation, combined with existing problems already discussed, necessitates the development of an international program which recognizes prevention, surveillance, notification, and clean-up responsibilities. To meet this need, the U.S., through its Environmental Protection Agency (formerly through the Federal Water Pollution Control Administration), has developed contingency plans which are procedural arrangements for the notification and clean-up of spilled pollutants. Canadian contingency plans are still in the embryo stage.

Existing legislation should be reviewed with the purpose of insuring that authority exists for undertaking adequate measures to abate pollution. A significant step in this direction was taken with the enactment of the Water Quality Improvement Act of 1970 which contained an amendment to the Federal Water Pollution Control Act prohibiting the discharge of oil of any kind or form into or upon the navigable waters of the contiguous zone. In addition, the Province of Ontario and the States of Michigan, New York, Wisconsin, and Ohio have developed increasingly strict watercraft laws relating to the discharge of wastes and oil productions.

2.15 Problems and Needs Associated with the Effects of Lake Level Control

Plans and studies for artificially regulating the levels of the Great Lakes were initiated in the early 1900s. These resulted in the construction of regulatory works in Lake Superior in 1921. After further planning and studies, control works were constructed on Lake Ontario in 1960.

In 1964 the International Joint Commission (IJC) was asked to determine whether it was feasible and in the public interest to further regulate the levels of all or any of the Great Lakes and their interconnecting waters. The results of this study were published in a report entitled *Regulation of Great Lakes Water Levels*, published in 1973 by the International Great Lakes Levels Board of the IJC. While the intent of original plans and studies was to improve navigation by stablizing water levels, current research is concerned with this aspect as well as the possible benefits accruing to power, industry, and recreation. This research also addresses the problem of shoreline property protection and the effect of water level control on the fisheries (sport and commercial) and the fish stocks. This appendix is concerned with the last two categories.

2.15.1 Effects on the Fisheries

Extreme water levels pose a number of serious problems to fisheries. For example, the high waters which occurred in 1952 caused extensive damage to the dockside facilities of the commercial fishing industry as well as public and private access sites and shoreside docks, slips, and hoists. On the other hand, the low water levels experienced during 1964 posed a different type of problem. As the water level receded, depths in ports, harbors, and marinas decreased correspondingly, making it increasingly difficult, and often impossible, for commercial fishing vessels to either leave or enter fishing ports. If water levels drop low enough, fishing may be suspended altogether or fishermen may be forced to move operations to a new and deeper port location. Similarly, low levels hinder and often prohibit the launching of small boats from both public and private facilities.

2.15.2 Effects on the Fish Stocks

The effects of fluctuating water levels on fish stocks are more subtle than those on fisheries. Addition or subtraction of one or two feet of water in the open lake is probably negligible. However, effects on the littoral zone (less than 30 feet) and the interconnecting waters are far more significant.

Within the littoral zone biological production is at its peak, and fluctuations have their greatest effects. Based on the analysis of all present biological data, fisheries favor high stable levels in order to increase the littoral productive area and thereby enhance the total fishery resource.

The interconnecting waters, which are generally less than 30 feet deep and can be considered littoral, are the logical sites for regulatory structures. Structures composed of movable tainter gates would regulate the flow of these connecting waters according to the requirements of the plan. However, in the actual construction of the works, problems occur during dredging, dyking, and filling. Due to the rapid flow through these areas, the increased turbidity and siltation caused during construction would be carried downstream destroying valuable spawning and benthos-producing areas. After construction is completed, the structures could cause changes in the flows and current patterns leading to changed flushing time for the bays and channels in the system. The changes in flushing times of these restricted areas could create an oxygen shortage reducing the overall biological productivity of the area. Extreme caution should be used in evaluating any future regulatory plans because of the possibility of increased pollution related to the lower flows, damage to fish migratory routes because of the actual structures, and the problems already mentioned.

Section 3

LAKE SUPERIOR BASIN, PLAN AREA 1.0

The comments on Plan Area 1.0 (Figure 8–12) are divided into two major parts. The first is limited to Lake Superior, and the second treats the individual planning subareas of the Lake Superior basin.

3.1 Resources, Uses, and Management

3.1.1 Habitat Base

In addition to the information included in the introductory section of the appendix, the following statements will serve to characterize Lake Superior more specifically:

(1) Lake Superior is the largest freshwater lake in the world in area.

(2) The Lake has an 80,000 square-mile drainage area with an exit rate at Sault Ste. Marie of approximately 73,000 cubic feet per second.

(3) Lake Superior stretches 350 miles across North America. It is 160 miles wide and occupies 3,820 square miles.

(4) The Lake's principal island groups are Isle Royale and the surrounding islands, Michipicoten and the surrounding islands, and the Apostle group.

(5) The only important stretches of shallow water lie in the Apostle Islands area, Whitefish Bay, and the north shore bay region.

(6) Lake Superior is the deepest of the Great Lakes, with a maximum depth of 1,333 feet. The mean depth is approximately 487 feet. Only 17.5 percent of the lake is shallower than 100 feet, while 51 percent is deeper than 420 feet.

(7) Although thermal discontinuity is common throughout sections of the Lake during the summer period, Lake Superior exhibits thermal stratification by mid-July.

(8) Lake Superior is the only Great Lake in which chemical conditions have remained unchanged over the period of record (1886 to present). Concentration levels are constant throughout the Lake (Figures 8–13 and 8–14).

3.1.2 Fish Resources—A Summary of Major Changes

The Lake Superior fishery has always been dominated by coldwater species. Lake trout, whitefish, herring, and chubs have dominated both in total pounds and value.

Although the changes in fish populations occurred somewhat later in Lake Superior, the declines in lake trout and herring followed the pattern of the other Great Lakes. Under the combined effects of sea lamprey predation and commercial fishing, the lake trout population collapsed. Subsequent shifts of fishing effort to lake herring and chubs have produced changes in these stocks as well.

Although alewife has become established in Lake Superior, it is not as abudant there as in Lakes Huron and Michigan. Smelt is the most abundant inshore forage species found in Lake Superior today.

Whitefish was the most valuable commercial species in Lake Superior until the late 1890s. Under heavy exploitation, the whitefish production peaked at 4.5 million pounds in 1885. Stocks of whitefish have generally declined ever since. Although occasional strong year classes and favorable market conditions have pushed annual whitefish production to more than one million pounds, the average production from Lake Superior is now between 300,000 and 400,000 pounds a year.

Recent introductions of coho and chinook salmon, and restockings of both lake trout and steelhead have added tremendously to the sport fishery of Lake Superior. Maintenance or supplemental stocking of these species is still required to maintain their abundance.

3.1.2.1 Value of the Individual Species to the Ecosystem

Subsection 2.3.1 discusses in detail the major relationships between species common throughout the Great Lakes. This section will deal with those relationships in Lake Superior.

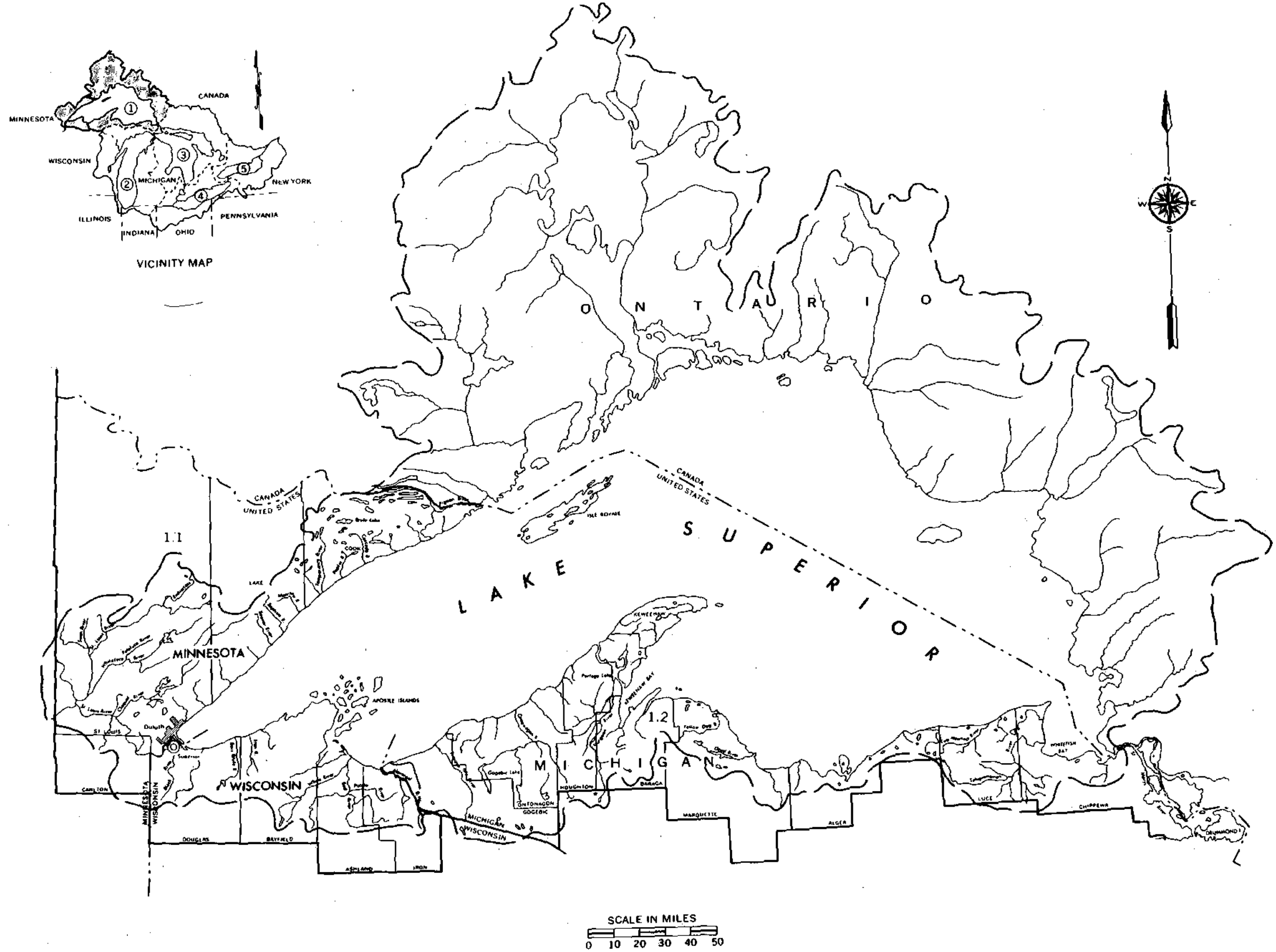


FIGURE 8-12 Plan Area 1.0

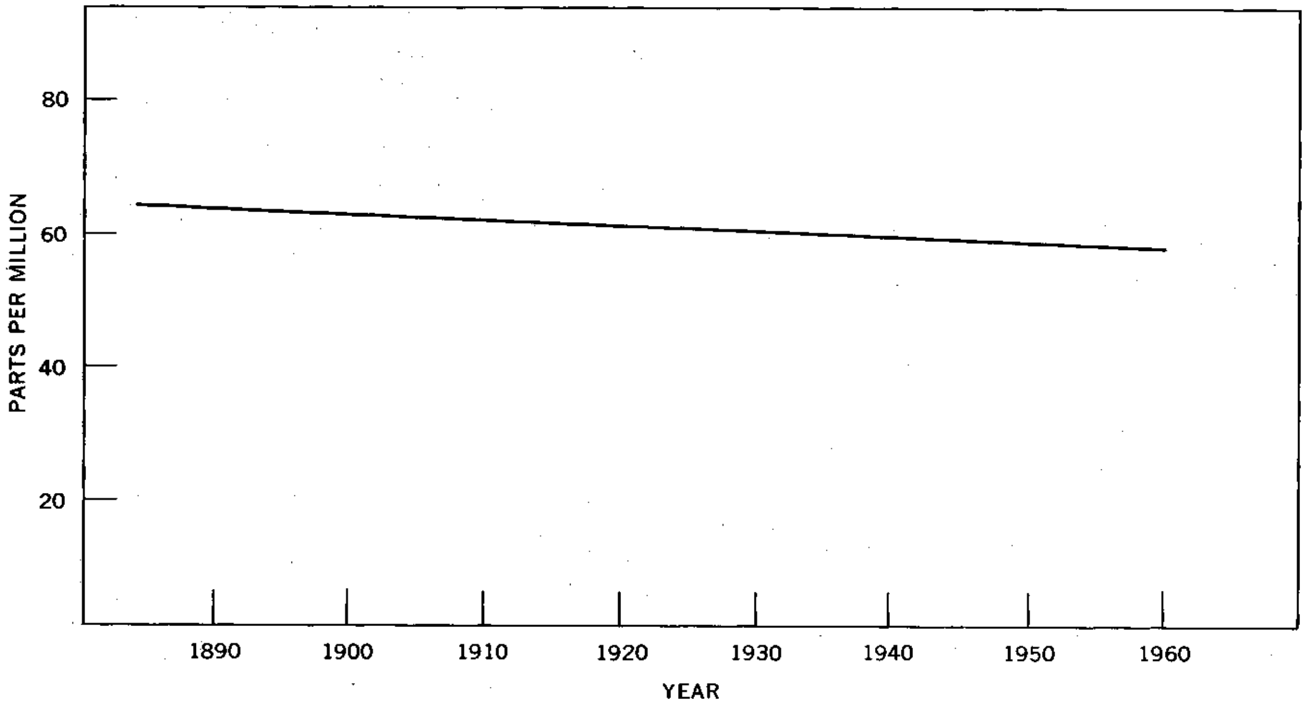


FIGURE 8–13 Lake Superior and Tributaries, Total Dissolved Solids

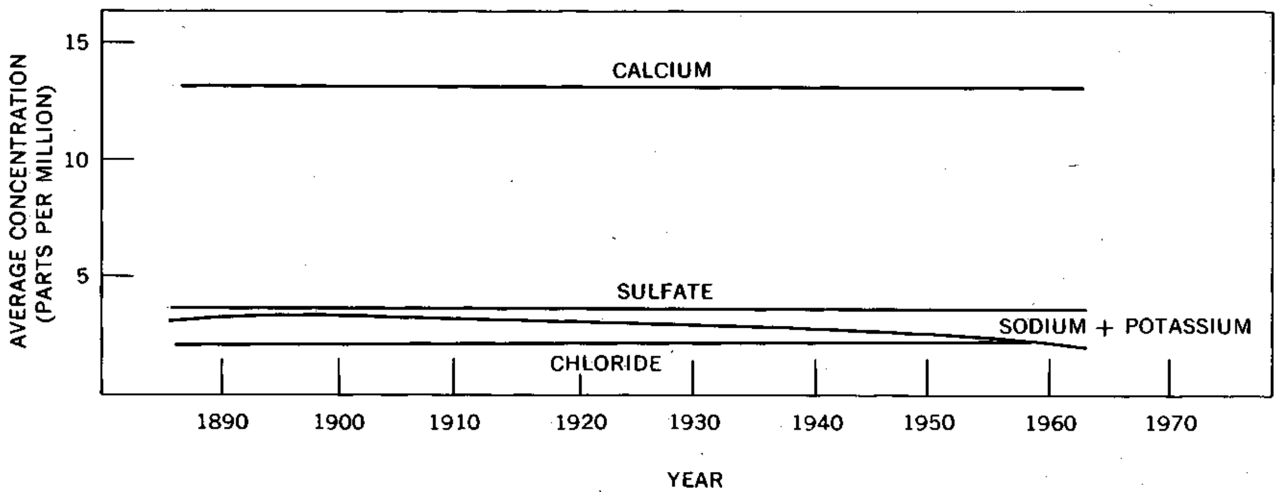


FIGURE 8–14 Lake Superior and Tributaries, Chemical Changes

Lake Superior is oligotrophic, with a relatively simple complex of fish species. In such a simple system the abundance of one species can have an immediate and dramatic effect on the survival, growth, and abundance of another. Because growth is slow, exploitation rates are a major factor in the abundance of a species. Similarly, the introduction of nonindigenous species may have a pronounced effect on the species composition.

Sea lamprey continues to limit numbers of large salmonids, particularly lake trout. Despite more than ten years of a sea lamprey chemical control program, these predators remain a significant factor in preventing the establishment of a self-reproducing lake trout population.

Lack of forage species such as herring, chubs, and smelt will limit both the growth and abundance of lake trout, steelhead, brown trout, coho, and chinook. Conversely, whitefish compete directly with the forage species for the basic plankton productivity of the Lake.

Because of their abundance and the lack of other forage food, small suckers may provide forage for predators during certain times of the year. However, the effect of suckers on other fish species in Lake Superior is not clearly understood. Since suckers are omnivores, they may compete with more valuable species for the limited basic productivity of the Lake.

While carp, alewife, yellow perch, walleye, smallmouth bass, and northern pike are present in Lake Superior, they are ecologically important only in limited areas of the Lake.

3.1.2.2 Contribution of Individual Species to the Commercial Fishery

The contribution of each species to the commercial catch was reviewed in detail in the *Great Lakes-Illinois River Basin Report, Fish and Wildlife as Related to Water Quality of the Lake Superior Basin* by the Fish and Wildlife Service in 1969. Figures 8–15 and 8–16 and Tables 8–3 and 8–4 summarize the contribution of each species since 1935.

There is continuing concern for the precipitous reduction in herring catch since the early 1960s. Herring is the most important species to the Lake Superior commercial fishery. Herring and chubs combine to provide more than 70 percent of the pounds and more than half the value of the commercial take from the Lake. Whitefish catches have been relatively constant over the past decade. They rank second to herring in total dollar value of fish landed each year. Inshore lake trout catches are now limited to assessment fishing to determine the results of sea lamprey control and lake trout stocking programs. Some offshore stocks (Isle Royale and Caribous) are self-sustaining and conservative quotas have been established to provide a commercial catch. However, lake trout will continue to play a minor role in the Lake Superior commercial fishery until self-sustaining stocks are reestablished.

3.1.2.3 Contribution of Individual Species to the Sport Fishery

A 1970 creel census in Michigan waters of Lake Superior and major anadromous streams indicated that the angler take of warmwater species totaled over two million fish. The following numbers of fish were taken: smelt, 1,625,890; perch, 254,240; suckers, 118,520; centrarchid panfish, 39,420; northern pike, 37,240; walleye, 13,020; bass, 13,020. Similar data are not available on the catch of warmwater species from Minnesota and Wisconsin waters, but, catch from these two States would probably increase the above totals by approximately one-third.

The Lake Superior salmonid fishery is dominated by lake trout. Wisconsin reported that in 1970 sport fishermen took 16,988 lake trout, 2,545 coho, 1,562 rainbow, 2,324 brown trout, and 1,964 brook trout. Michigan reports indicate that 172,380 lake trout, 18,590 rainbow trout, 3,061 coho, and 2,020 chinook were taken by anglers in Michigan waters during 1970. In addition, the sport catch for salmonids in Michigan's anadromous streams tributary to Lake Superior totaled 10,420 coho, 69,070 steelhead, and 2,860 chinook during 1970. Minnesota reported a sport catch of less than 1,000 trout and salmon in Lake Superior during 1969. Although the fishery was reportedly growing, the catch was probably similar in 1970.

3.1.3 The Fisheries

3.1.3.1 Historical Background of the Lake Superior Commercial Fishery

Traditionally, Lake Superior has furnished approximately 16 percent of the total Great Lakes fishery production. Most of the commercial fishing is done in U.S. waters. Lake trout, whitefish, and lake herring have been the three dominant species in the commercial catch since the mid-1800s.

As the commercial fishing industry developed in Lake Superior during the latter part of the 19th century, lake trout increased in importance. By 1897 lake trout was the leading producer in pounds taken and it maintained this position until being eclipsed by lake herring in 1903. However, lake trout continued to be the top producer in value, accounting for 50 to 60 percent or more of the total value of the Lake Superior commercial catch through 1949. The largest harvest of lake trout in U.S. waters occurred in 1903, when 5.6 million pounds were taken. After 1903 production leveled off to between two and three million pounds annually and remained at that level for the next five decades. During this time, there was a westward shift in the major trout production centers, reflecting increased production from the less exploited western stocks.

Although the catch of lake trout remained farily constant until 1954, there was evidence by 1949 that the stocks were declining. In 1949 trout production was up six percent above the 1929 to 1943 mean, but commercial fishing

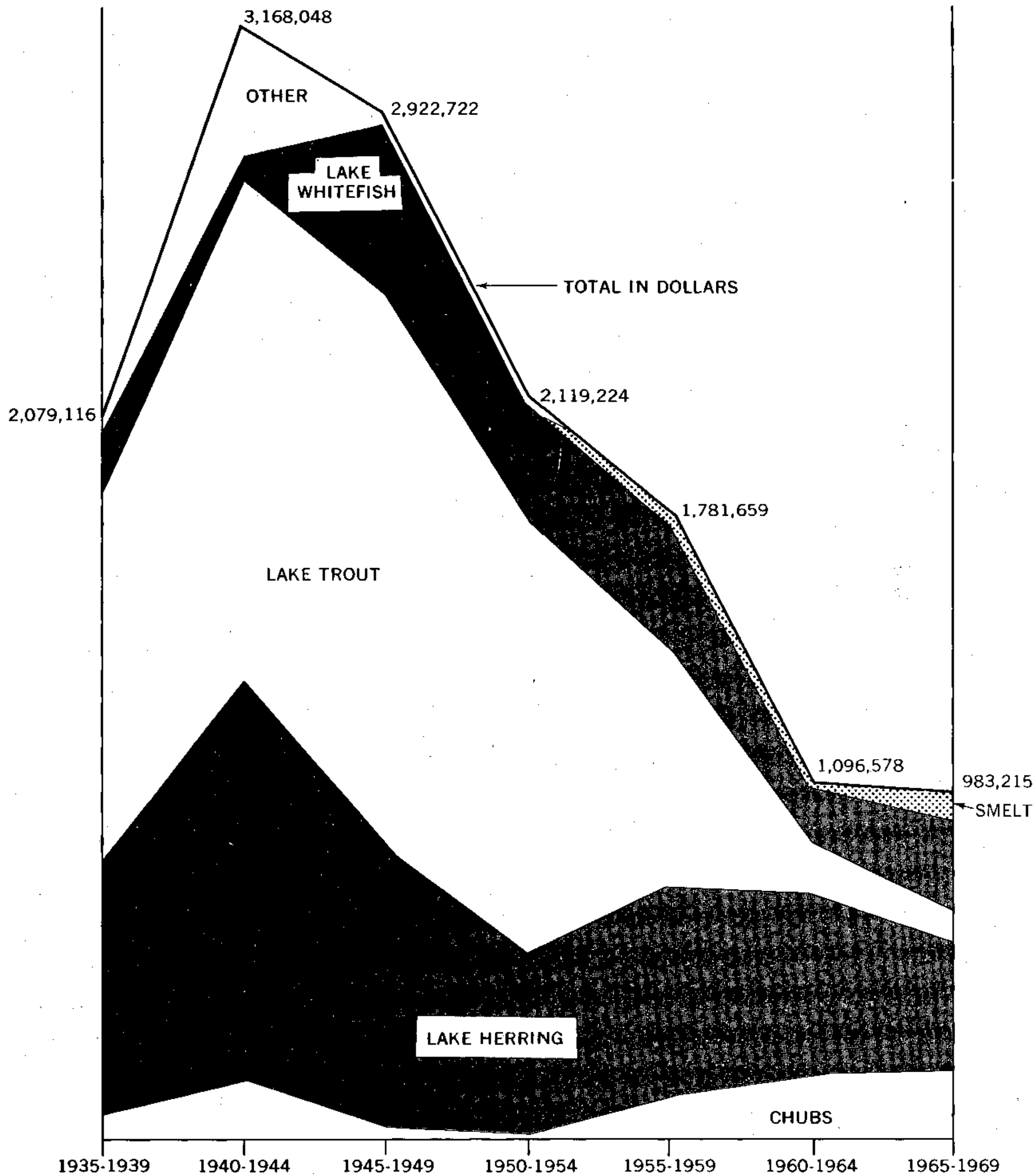


FIGURE 8-15 Average Annual Production (Dollars) of Major Species by the U.S. Lake Superior Commercial Fishery for 5-Year Periods, 1935-1969

pressure was up 62 percent. During the late 1940s and early 1950s, the combination of the efficient nylon gill net and increased fishing pressure maintained the commercial catch at a fairly stable level even though the stocks of lake trout were declining.

However, by 1955 the combined effects of fishing pressures and lamprey predation produced a sharp decline in the lake trout population. This decline was reflected in the commercial catch, which dropped from 3.1 million pounds in 1951 to 2.1 million in 1955, and only 380,00 pounds in 1960.

Since the decline of the lake trout, the primary commercial species have been lake herring, whitefish, and chubs. Strong individual year classes of whitefish in the late 1940s and early 1950s and increased fishing pressure pushed whitefish production over one million pounds during 1948, 1954, and 1955. Heavy fishing pressure has continued on whitefish, but annual production has leveled off to between 300,000 and 400,000 pounds.

The lake herring production ranged between 10 and 12 million pounds annually between 1951 and 1961, but during this time the average size was increasing and the abundance decreasing. Between 1954 and 1964, the average weight of the commercial lake herring doubled. Since 1961, the lake herring production has steadily declined as has catch per unit of effort.

Chubs and smelt have become increasingly important to the commercial fishery in Lake Superior. When the abundance of small lake trout and herring decreased, lake conditions became more favorable for the survival and growth of these two species.

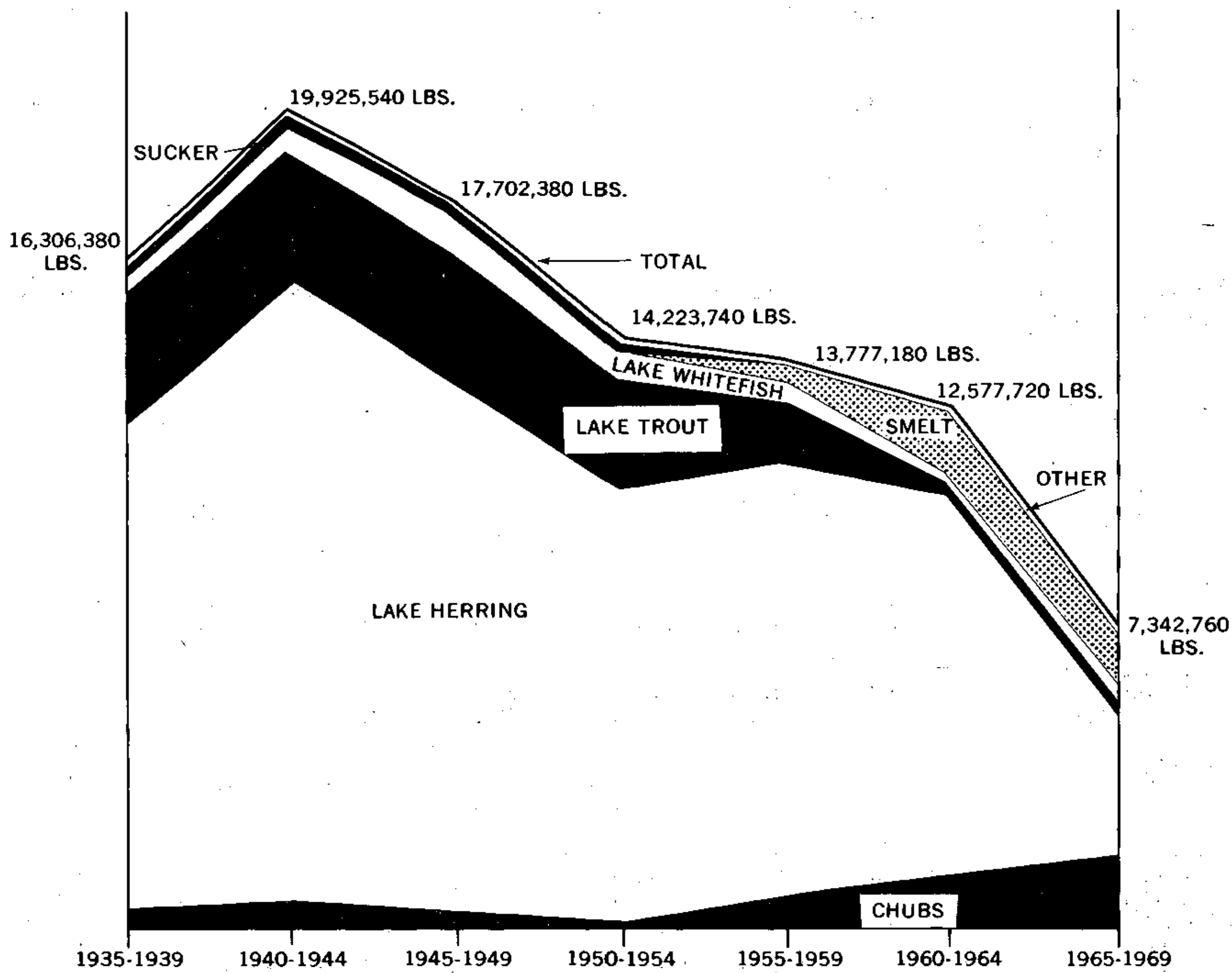


FIGURE 8–16 Average Annual Production (Pounds) of Major Species by the U.S. Lake Superior Commercial Fishery for 5-Year Periods, 1935–1969

TABLE 8–3 Average Pound and Percent Contribution of Six Major Species in the U.S. Waters of Lake Superior

Species	1935–1939	1940–1944	1945–1949	1950–1954	1955–1959	1960–1964	1965–1969
Chub							
lbs.	320,160	487,240	166,640	89,120	616,100	1,167,020	1,555,880
% of Volume	2.0	2.4	.9	.6	4.5	9.3	21.2
Lake Herring							
lbs.	12,063,120	15,457,120	13,180,820	10,572,860	10,739,000	9,354,840	3,773,520
% of Volume	74.0	77.6	74.5	74.3	77.9	74.4	51.4
Lake Trout							
lbs.	3,141,020	3,056,580	3,139,240	2,724,720	1,406,440	232,400	172,320
% of Volume	19.3	15.3	17.7	19.2	10.2	1.8	2.3
Lake Whitefish							
lbs.	440,480	713,140	1,013,460	688,680	627,580	379,320	477,680
% of Volume	2.7	3.6	5.7	4.8	4.6	3.0	6.5
Smelt							
lbs.	900	180	540	18,500	292,420	1,350,860	1,273,420
% of Volume	---[1]	---[1]	---[1]	.1	2.1	10.7	17.3
Suckers							
lbs.	261,520	162,620	144,300	84,600	44,780	51,780	45,560
% of Volume	1.6	.8	.8	.6	.3	.4	.6
Average Total Volume	16,306,380	19,925,540	17,702,380	14,223,740	13,777,180	12,577,720	7,342,760

[1]Less than .1%

TABLE 8–4 Average Value and Percent Contribution of Six Major Species in the U.S. Waters of Lake Superior

Species	1935–1939	1940–1944	1945–1949	1950–1954	1955–1959	1960–1964	1965–1969
Chubs							
Dollars	83,027	165,217	39,194	13,864	116,506	186,373	187,588
% of Value	4.0	5.2	1.3	.6	6.5	17.0	19.1
Lake Herring							
Dollars	703,635	1,148,225	790,556	517,245	605,026	518,521	371,434
% of Value	33.8	36.2	27.0	24.4	34.0	47.3	37.8
Lake Trout							
Dollars	1,062,075	1,444,374	1,596,743	1,248,754	691,614	139,772	101,478
% of Value	51.1	45.6	54.6	58.9	38.8	12.7	10.3
Lake Whitefish							
Dollars	197,211	38,054	468,940	322,408	346,485	199,187	262,770
% of Value	9.4	1.2	16.0	15.2	19.4	18.2	26.7
Smelt							
Dollars	---[1]	---[1]	---[1]	975	10,381	43,567	50,805
% of Value	---[1]	---[1]	---[1]	---[1]	.6	4.0	5.2
Suckers							
Dollars	17,782	15,572	11,505	5,781	3,382	2,255	2,353
% of Value	.9	.5	.4	.3	.2	.2	.2
Average Total Value	2,079,116	3,168,048	2,922,722	2,119,224	1,781,659	1,096,578	983,215

[1]Less than $100 or .1%

3.1.3.2 Historical Background of the Lake Superior Sport Fishery

The sport fishery, like the commercial fishery, relied heavily on lake trout. While the sport fishery took only approximately 10 percent of the total lake trout harvest in the early 1940s, it was a growing fishing attraction before the lake trout began declining drastically in number in the 1950s.

Steelhead has attracted fishermen to Lake Superior and its major tributaries since early in this century. The waterfalls which occur within a few miles of the mouths of many Lake Superior tributaries on the U.S. side have probably limited the abundance of this species. Sea lamprey control and recent stocking programs have renewed fishing interest in steelhead.

Although many trophy-size specimens have been taken in recent years, brown trout has never been abundant in Lake Superior. The largest sport-caught brown trout on record in the entire North American continent was recently taken in Wisconsin waters of Lake Superior where a specialized fishery for brown trout has developed.

Coho and chinook fishing began less than a year after the first plant was made in 1966. In 1971 Michigan planted 252,000 chinook, 403,000 coho, and 54,000 steelhead. Minnesota planted 130,000 coho in 1971. United States waters of Lake Superior were stocked with approximately 1,465,000 lake trout in 1971.

Ontario stocked approximately 25,000 coho in Lake Superior and cooperated in the planting of approximately 475,000 lake trout in Canadian waters during 1971.

3.1.3.3 Economics

The wholesale value of the United States commercial catch from Lake Superior has averaged approximately one million dollars annually during the last decade. Most of the fish taken from Lake Superior are marketed through Chicago wholesale markets. The net worth of the commercial fishery to the Lake Superior area has not been calculated, but it is relatively small. While commercial fishing contributes significantly to the economy of a few small Lake Superior communities, its most important contribution is the indirect benefit it provides to the tourist trade by supplying fresh fish to local restaurants. Table 8–5 lists commercial operating units and productivity in the U.S. waters of Lake Superior.

Michigan has conducted a series of economic studies on its steelhead and salmon fisheries in the Great Lakes. Projects based on these studies indicate that the net economic worth of the sport fishery of Michigan's Lake Superior lake trout, salmon, and steelhead fishery is 3.8 million dollars annually. This estimate is conservative because it neither includes the value of the fisherman's time, nor reflects secondary benefits such as net impact of the sport fishery on the local community in terms of added income and new jobs.

We therefore assume that the net economic worth of the total Lake Superior sport fishery exceeds 4.0 million dollars and is still expanding.

3.1.4 Effects of Non-Fishery Uses on the Fish Resources

Lake Superior has many uses other than fishing: navigation, water supply, recreation, and waste disposal. These uses can cause chemical, physical, and biological changes that indirectly or indirectly affect the fishery resource.

3.1.4.1 Effects of Chemical Changes

Lake Superior is the only Great Lake in which the chemical parameters measured since 1886 have remained unchanged. Figure 8–14 summarizes the chemical characteristics of Lake Superior water. These are relatively homogeneous in respect to both area and depth of the Lake.

The region of Lake Superior near Duluth has a higher concentration of ions such as sulfate. However, the effects of these higher ion concentrations on the fishery is unknown.

Trace elements such as manganese, copper, lead, and zinc are found in surface waters of Lake Superior indicating active sediment-water exchange of these materials. The significance of trace elements, particularly the heavy metals, is just now receiving attention because of the recent discovery that fish concentrate mercury to dangerous levels. Mercury from industrial discharges on the Canadian side of Lake Superior has made some fish unsafe for human consumption in localized areas.

Pesticides, particularly DDT and its

TABLE 8–5 Commercial Operating Units and Productivity in the U.S. Waters of Lake Superior

Year	Number of Fishermen[1]	Pounds Landed per Fisherman	Value of Catch per Fisherman[2]	Number of Vessels	Number of Boats
1930	1,278	11,497	$1,153	40	560
1931	1,200	9,400	1,310	40	479
1932	1,067	9,534	1,004	44	285
1934	1,202	14,526	1,466	41	295
1936	1,140	14,042	1,842	51	288
1937	1,227	13,049	1,586	61	468
1938	1,360	10,924	1,496	63	512
1939	1,491	17,256	1,465	62	567
1940	1,000	20,672	2,103	107	386
1950	1,029	12,230	2,214	173	361
1954	938	16,401	2,430	175	315
1955	857	15,847	2,358	166	319
1956	834	16,296	2,418	154	279
1957	823	16,482	2,032	146	295
1958	777	16,980	1,955	144	277
1959	877	17,053	1,942	136	265
1960	780	17,654	1,655	125	238
1961	742	19,877	1,697	114	221
1962	632	19,940	1,707	98	266
1963	608	19,942	1,657	97	278
1964	540	17,856	1,552	89	250
1965	542	16,140	1,913	85	249
1966	475	17,385	2,176	82	216
1967	451	17,506	2,368	80	213
1968	381	17,253	2,425	72	139
1969	316	16,580	2,729	57	125

[1]Refers to all fishermen engaged in harvesting.

[2]Value deflated by wholesale price index (1957-1959=100).

metabolites, are a problem in Lake Superior. Some long-lived species, such as lake trout, show signs of concentrating DDT above the maximum level of 5 ppm allowed for interstate commerce. The effect of the chlorinated hydrocarbons on the reproduction of lake trout in Lake Superior is not known.

There is considerable evidence that relatively small quantities of either heavy metal or persistent pesticide pollutants can cause severe problems in oligotrophic lakes. These pollutants are apparently more available for concentration in fish in oligotrophic lakes than in mesotrophic or eutrophic lakes. Therefore, the water quality of Lake Superior may need greater protection from these types of pollutants.

In addition, it is evident that the high quality of water now existing in Lake Superior helps maintain higher quality water in Lake Huron and perhaps in the lower Lakes. Thus, protection afforded the Lake Superior watershed benefits a large area of the Great Lakes.

3.1.4.2 Effects of Physical Changes

Major physical changes in Lake Superior have occurred near mining or ore processing facilities around the shoreline. At these locations, tons of waste material have been deposited into the Lake. Once a problem at several locations, the disposal of ore processing waste now constitutes a major threat in only one northshore location in Minnesota. This mining operation is now under orders from the Federal government to stop further disposal of waste into Lake Superior. However, a large area has already been affected by this operation.

Filling, dredging, and lake level manipulation for navigation does not pose a serious problem for the fish populations of Lake Superior. However, spoiling areas need to be carefully chosen to prevent destruction of valuable spawning areas. Obviously polluted waste from harbor facilities should not be dumped in the open waters of Lake Superior.

3.1.4.3 Effects of Biological Changes

Like Lakes Huron and Michigan, Lake Superior has been affected by the invasion of the sea lamprey, which gained entrance into the upper Great Lakes through the Welland Canal. In Lake Superior, alewife has never reached the abundance levels existing in Lakes Huron and Michigan. The introduction of smelt remains an important factor in the present composition of fish in Lake Superior.

Sea lamprey continues to have a depressing effect on the rehabilitation of the valuable fisheries of Lake Superior. The role of smelt is not clearly understood. The introductions of coho, chinook and pink salmon, brown trout, and steelhead have had both positive and negative effects on the Lake Superior fishery.

Commercial fishing has affected fluctuations of fish populations in Lake Superior. Since commercial exploitation has been directed at short-term gains, the net effect on the fishery has been negative.

3.1.5 Fisheries Management

3.1.5.1 Past and Present Management

Commercial fish production in Lake Superior remained relatively stable for whitefish and lake trout until the turn of the century and little effort was made to manage the fishery by any State. As virgin fish populations became more difficult to find and take, the whitefish catch dropped significantly. In the early 1900s, the States began programs to control the take of immature whitefish and in cooperation with the United States Fish Commission, whitefish and lake trout fry plantings were made in Lake Superior.

Despite little evidence that they were successful, the fry planting program continued through the early 1900s. The States concentrated their fish management efforts on their inland waters during the first half of this century. During this same period, a patchwork of regulations was imposed on commercial fishing dealing with seasons, size limits, and gear restrictions. The net result of these regulations was to make commercial fishing inefficient without providing adequate protection for the stocks.

During the late 1940s and early 1950s, the management agencies became concerned over declining stocks of herring and lake trout and potential effects of the sea lamprey invasion in Lake Superior. In the late 1950s, under the auspices of the Great Lakes Fishery Commission, Lake Superior was chosen as the first Great Lake to receive sea lamprey control and lake trout restocking under the new international compact. In 1958 chemical sea lamprey control began on Lake Superior tributaries and lake trout fingerling stocking began.

The States initiated further restrictions on commercial fishing for lake trout to protect the planted fish. By 1970, Michigan and Wisconsin had initiated forms of limited entry to reduce the number of commercial fishermen and had instituted closed fishing areas to protect expanding lake trout stocks.

By 1970 both Michigan and Wisconsin had licensed sport fishermen on Lake Superior for the first time and all three States had instituted creel censuses to estimate the sport catch of salmonids from Lake Superior. In Michigan and Wisconsin size and daily catch limits on sport-caught trout and salmon were made more restrictive.

The broad goal of the State fishery programs on Lake Superior is to restore an optimum balance between prey and high-value predator species, and to manage these populations for the maximum benefit of society. Management policies place high priorities on developing the recreational fishery to its maximum economic level and enhancing the commercial fishery by limited entry control.

In order to achieve management objectives, the States are currently involved in numerous management programs, in cooperation with the Federal governments of the United States and Canada and the Provincial government of Ontario. These include sea lamprey control, stocking of salmonids, habitat improvement and maintenance on anadromous streams, biological research, and regulation of the fishery.

Each Federal, State, and Provincial agency participates in phases of eight current studies evaluating the lake trout rehabilitation program. These lake trout studies include:

(1) success and movements of different hatchery plantings

(2) incidence of lamprey wounding

(3) relative abundance of trout at various ages

(4) growth

(5) relative abundance, age composition, and distribution of spawning stocks

(6) success of natural reproduction

(7) availability rates for sport fishery

(8) mortality rates at various ages

In specific projects, Michigan is evaluating the distribution, growth, sport catch, and survival of hatchery plantings of coho and chinook salmon, and brook and rainbow trout through creel census and biological surveys. Michigan is also continuing to evaluate the distribution, growth, age composition, and mortality rates of lake herring in an effort to determine the causes for recent decreases in catch. Wisconsin is conducting a creel census to determine the quantity and species contributing to the sport fishery. Wisconsin is also studying walleye to determine abundance, distribution, discreteness, and catch rates, and planted brown and rainbow trout to determine their contribution to the sport fishery. Minnesota is studying herring and associated species to determine the causes for recent declines and testing smelt fishing trawl gear for seasonal effectiveness.

The Department of Interior's Bureau of Sport Fisheries and Wildlife carries out research programs in addition to their sea lamprey control responsibilities. In addition to those on lake trout, studies now under way include monitoring changes in forage and noncommercial species, changes in invertebrate organisms, and pollutants.

3.1.5.2 Cost of Fish Management and Development Programs

Many States do not segregate fish management and enforcement costs on the Great Lakes from those on the adjacent inland waters. The known fish management costs are included in Table 8–6. Some of the activities of the former Bureau of Commercial Fisheries (now National Marine Fisheries Service) have been taken over by the Bureau of Sport Fisheries and Wildlife and the estimated costs of these programs are included in Table 8–6.

(1) State Costs for Regulating the Commercial Fishery

The State management agencies are responsible for enforcement of both sport and commercial fishing laws in the United States portion of Lake Superior.

As might be expected, Michigan, with its large geographic area, great number of commercial fishermen, and large sport fishery, has high enforcement costs. Michigan's annual enforcement cost exceeds $75,000 in Lake Superior. Wisconsin estimates its enforcement cost at $100,000 annually in Lake Superior, mostly in control of the commercial fishery.

(2) Fish Stocking Costs

All three States and the Bureau of Sport Fisheries and Wildlife stock fish annually in Lake Superior. For the past several years, the planting rate for lake trout has been approximately 3,000,000 in the United States waters of Lake Superior. This costs the Bureau of Sport Fisheries and Wildlife approximately $240,000 annually. Based on the 1970 planting rates, Wisconsin has the second highest fish planting costs at $75,000. Michigan ranks third at $33,453. Although no exact figures are avilable, Minnesota probably spends less than $20,000 annually.

(3) Fish Management and Research Costs

The Bureau of Sport Fisheries and Wildlife operates a fishery research station on Lake Superior at an annual cost of $84,300. This station carries out basic research detailed in earlier sections. Wisconsin spends approximately $115,000 each year on fish management and research in Lake Superior. Michigan's expenditures in Lake Superior amount to approximately $50,000 a year. Minnesota spends less than $30,000 a year in fish management and research on Lake Superior.

3.1.6 Projected Demands

Projected demands for Lake Superior commercial fish species are identical to those discussed in the general demand section of Section 2 and need not be repeated here.

TABLE 8-6 Approximate 1972 Expenditures by the Bureau of Sport Fisheries and Wildlife on Lake Superior and Lake Michigan

Program	Superior	Michigan	Unassignable Gen. Great Lakes
Fish Management			
Stocking	116.0	160.0	-----
Habitat Improvement	-----	-----	-----
Lamprey Control[1]	331.4	230.8	-----
Fishery Management	-----	-----	-----
Research			
Habitat Base	32.1	-----	-----
Heavy Metals	-----	-----	115.4
Fish	52.2	77.9	233.0
Sea Lamprey	-----	-----	203.2[1]
Fishery			
Commercial Fishery	-----	-----	-----
Statistics	-----	-----	84.5
Creel Census	-----	-----	-----
Total	531.7	468.7	636.1

[1]1971

Recreational fishing demand is detailed in the following planning subarea discussions. Future sport fishing demand for Lake Superior is not necessarily tied to the population of the Lake Superior basin. Much of the current fishing demand on Lake Superior comes from people living outside the basin. Future demand will depend on maintenance and improvement of the quality of the Lake Superior sport fishery.

3.1.7 Problems and Needs

3.1.7.1 Natural Resource Base

The protection of water quality in Lake Superior is of utmost importance not only to the fishery resources of Lake Superior, but to those of the lower Lakes as well. Fish are one of the first organisms to respond to degradation of water quality. High water quality is essential for feeding, growth, reproduction, and survival of trout, salmon, and whitefish found in Lake Superior.

There are few Lakewide water quality problems in Lake Superior. However, recent research has indicated that the fish of oligotrophic lakes are more likely to concentrate contaminants such as mercury and DDT than those of more eutrophic lakes. This fact may justify more stringent effluent standards on such contaminants in Lake Superior than in the other Great Lakes.

Rigid enforcement of the Water Quality Standards adopted by the States under the 1965 Water Quality Act and the cooperation of Canada through the IJC are necessary to perpetuate the high quality of water now present in Lake Superior.

Two major activities currently threaten the natural resource base in Lake Superior. These are the dumping of tailing waste and the open water disposal of harbor dredge material. Both practices should be controlled. A more specific discussion of these two problems occurs in the next section.

3.1.7.2 Problems and Needs of the Total Fishery

The reader should refer to Section 2 for detailed discussion of problems and needs of the Lake Superior fishery common to all the Great Lakes. There are five major problems hampering the development and effective use of the fishery resource in Lake Superior:

(1) An optimum balance between the prey and predator species must be restored in the Lake. Sea lamprey stocks must be reduced and maintained at levels low enough to allow the recovery of self-propagating stocks of lake trout and other salmonid species. During the recovery period of these high-value predator species, intensive biological and environmental studies are required to provide fundamental information on the factors which influence changes in the survival and abundance of fish. These factors must be fully understood in order to establish and maintain a well-balanced multispecies complex in the Lake.

(2) Coordinated management programs must be developed to assure that fish populations are utilized on an optimum sustained basis for maximum economic and social benefit. The solution of this problem requires:

(a) intensive biological and economic studies to provide the information needed to properly balance the fishing intensities of the sport and commercial fisheries

(b) development and public acceptance of limited entry control to improve the economic efficiency of the commercial fishery which is currently hampered by excessive operators using nonselective fishing gear

(c) full cooperation of agencies in developing well-coordinated and compatible management policies, philosophies, and programs

(3) Pollution abatement procedures must be developed to assure the maintenance of water quality standards required by salmonid fishes.

(4) Necessary funds must be obtained to sustain long-range fishery management and research programs.

(5) In order to maximize the sport fishery, adequate harbors of refuge and public access areas to the Lake must be provided.

3.1.8 Probable Nature of Solutions

3.1.8.1 Natural Resource Base

Many potential solutions to Lake Superior fisheries resource problems have already been discussed in Section 2. However, a few solutions need emphasis here because of their importance to the future of the Lake Superior fishery.

Lake trout is the preferred prey species of sea lamprey in the Great Lakes. Lake trout is probably more important to the Lake Superior fishery than to the future of any other Lake. Lake trout grows and matures more slowly in Lake Superior than in Lakes Michigan or Huron and is most vulnerable to sea lamprey predation in Lake Superior. Therefore, improved sea lamprey control methods are perhaps more important to the Lake Superior fishery than to the fisheries of the other Great Lakes. The integrated sea lamprey control program recently proposed by the Great Lakes Fishery Commission offers the best hope for more effective sea lamprey control. This integrated program calls for several methods including chemical and biological controls and physical barriers to migration. Research has begun on potential biological controls, and a task force has been formed to recommend potential migration barrier sites. The Fish Work Group strongly recommends that these two control methods be adequately funded both at the research and implementation levels.

The spoiling of mining waste into Lake Superior has already created serious losses in fisheries habitat. The United States Environmental Protection Agency has taken steps to stop the spoiling of mining waste and the Fish Work Group supports this action.

3.2 Planning Subarea 1.1

3.2.1 Species Composition, Relative Importance, and Status

Planning Subarea 1.1, located in Minnesota and Wisconsin along the western portion of Lake Superior (Figure 8–17), has fairly well-drained topography. As a result, the area is covered by streams, many of which support trout or other coldwater species. Lake trout is found in the northern section in the deeper

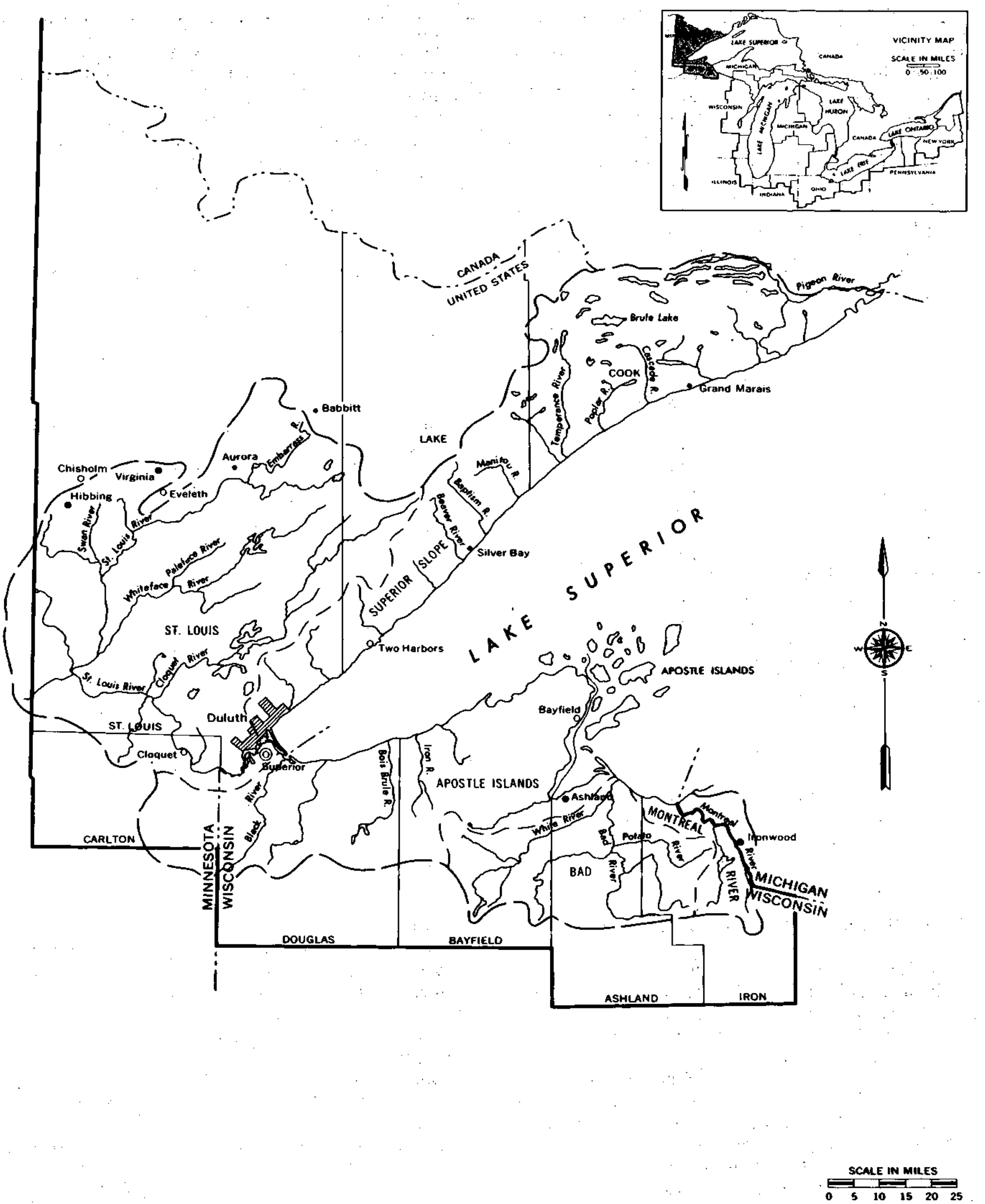


FIGURE 8–17 Planning Subarea 1.1

rock-bound lakes. Walleye, northern pike, and smallmouth bass make up the predominant remainder of sport catch in the inland waters of this area. Salmonids, including the steelhead or rainbow trout, brown trout, and coho salmon, are caught at the mouths of the tributaries to Lake Superior. Because of the nature of the lakes and streams and their low productivity, few panfish species are found. Due to their general inaccessibility, most inland lakes have provided good angling opportunities for the prevalent species. Increased fishing pressure has reduced fishing success in the lake trout lakes.

The stream fishery is characterized by lake-run rainbow, steelhead, or brown trout at the lower end and a coldwater portion at the headwaters where brook, brown, or sometimes rainbow trout exist. Because there are more mature trees and shade on the upper portions of the streams, water temperatures have been declining and providing more extensive trout habitat than was the case following the logging era.

A the present time factors limiting population are shallowness of the streams, lack of pools, and heavy winter ice cover when there is a lack of ground water. Because of the rocky terrain, the streams are not able to cut deep pools needed by trout for winter cover. To improve this habitat, pools need to be deepened for wintering trout.

Because coho salmon and steelhead make runs to spawning grounds, certain spawning areas in the lower ends of some streams must be improved. Fishways must be provided in some streams to circumvent the falls that block passage of fish near the lower end of these streams.

3.2.2 Habitat Distribution and Quantity

In Minnesota, the natural inland lakes provide approximately 562,500 acres of surface water within a land area of 10,281 square miles. In this portion of the State, the area of lakes per capita amounts to 2.08 acres. Figure 8–18 shows acres of ponded water in PSA 1.1. Approximately 84 percent of the Minnesota population in this basin dwells in St. Louis County, the major portion in the City of Duluth. Resident license sales, which total 94,163 for the Minnesota portion, and the rate per capita is generally the same in all counties except Cook. In Cook County, a sparsely populated area, resident fishing licenses sold exceed the number of people living in the county because outsiders buy licenses at the point of destination for their fishing trips. This is probably true to a lesser extent for the other counties.

In this planning subarea with its well-drained topography, a combination of warmwater and coldwater streams will be found. The largest stream is the St. Louis River which has hundreds of miles of main stream and tributaries. This stream contains channel catfish, northern pike, walleye, and smallmouth bass. It has many miles of fishable water in a remote wilderness surrounding and is considerably underfished. One of its major tributaries, the Cloquet River, has been designated a wild river, and the St. Louis River is partly designated as a State canoe river.

Watershed site investigations have been completed for both the St. Louis and north shore watersheds and management programs have been implemented in these streams.

3.2.3 Habitat Problems Affecting Production and Distribution of Important Fish Species

The low productivity of inland waters affects the production of sport fish in this northeastern section of Minnesota. However, this low productivity is associated with a good distribution of oligotrophic lakes which have high water quality and support lake troup fisheries. Introduction of bass and walleye has affected the production of lake trout in many lakes.

In many of the streams which support stream trout, poor wintering habitat, including lack of pools, escape cover, and a scarcity of good spawning gravel, limits population. Streams flowing over the outcroppings of the Laurentian Upland do not have the opportunity to create pools and banks undercuttings necessary for trout cover. Extreme winters and two or more feet of ice cover severely diminished the winter habitat and supporting capacity of the streams.

Lakeshore development has not created any problems except for a few lakes near the City of Duluth in St. Louis County. Water skiing and boating on these lakes reduce the amount of fishing on weekend days. Competition for the limited supply of fish food occurs in many of the northern inland lakes. Removal of suckers and other competing species will provide an increased production of desirable sport fish.

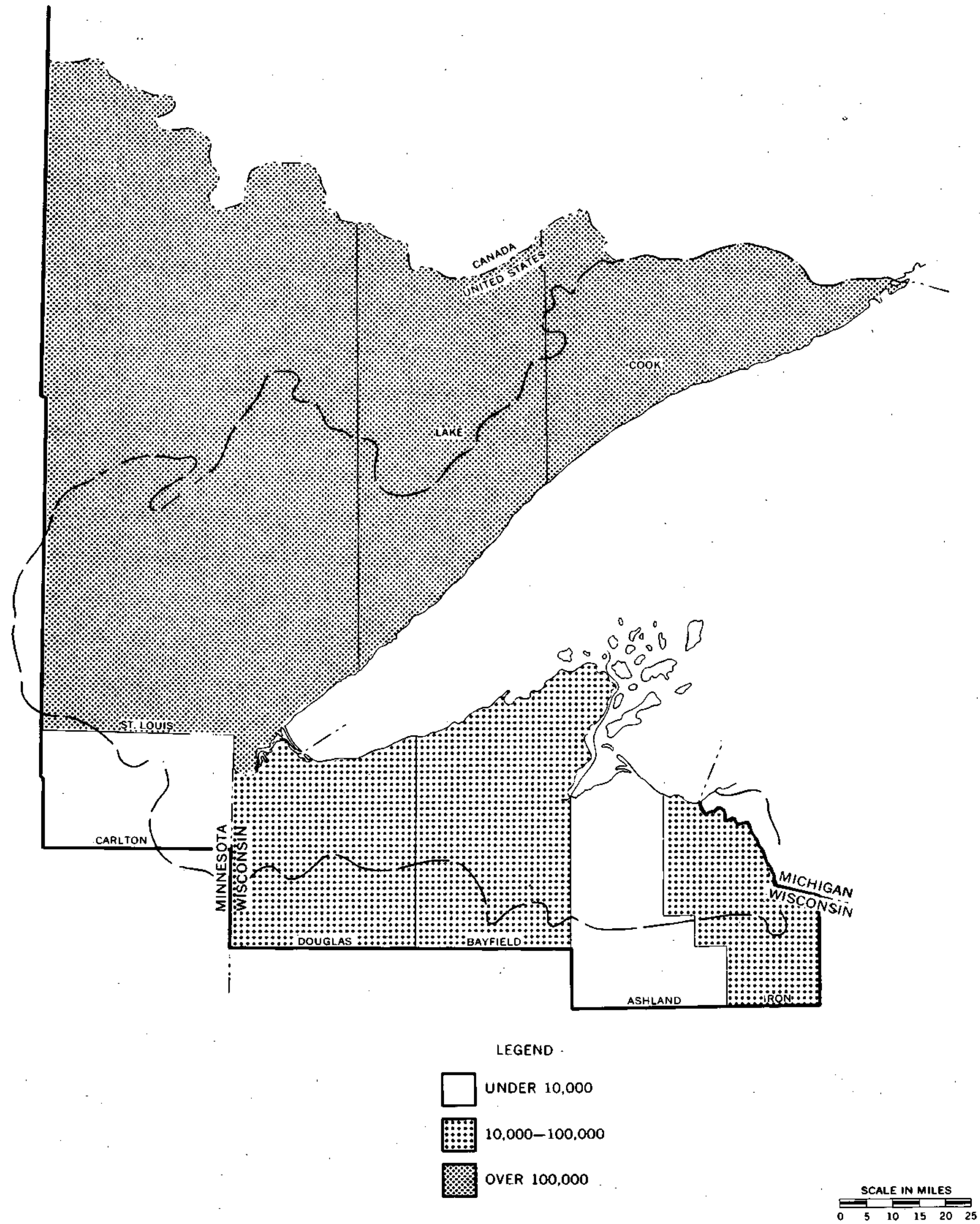


FIGURE 8–18 Acres of Ponded Water, Planning Subarea 1.1

Most rivers and streams in the Minnesota portion have not suffered much physical abuse or pollution. The short stretch of the lower portion of the St. Louis River has poorer water quality because of paper mill wastes and other sources of pollution in the vicinity of Cloquet. Several hydroelectric or storage reservoirs on the St. Louis River cause fluctuations that create fish production problems.

3.2.4 History of Sport Fishery

The sport fishery in the Minnesota portion of this basin started with emphasis on coldwater species. Lake and brook trout fishing in the tributaries to Lake Superior was the most popular sport fishing in the area. As fishing for lake trout declined in the 1930s and 1940s, emphasis shifted to warmwater fish which in turn brought demand for stocking such species as walleye and smallmouth bass. This stocking brought about a population boom in inland lakes with very little competition. As a result, many of the coldwater species suffered. The establishment of lake-run trout and salmonid species in the tributaries of Lake Superior has created a new interest in this sport fishery. This new sport fishery seems to offer the most promise for growth to meet future fishing demand in the area. Regulations on the harvest of lake trout and control of competing species may bring lake trout population back to acceptable standards for a limited number of sport fishermen.

3.2.5 Existing Sport Fishing Demand and Current Needs

According to a 1967 survey, Lake, Cook, St. Louis, and Carleton Counties and Koochiching and Ipasca Counties to the west sustained approximately 532,000 fishing trips for coldwater species and 1,534,000 for warmwater species. A comparison of lake and stream water area to coldwater fishing demand in terms of fishing trips shows that there was a deficiency of approximately 6,000 acres of lakes and 820 miles of streams to meet the resident demand within the State. By 1985 this demand is anticipated to increase nearly five times.

The number of lakes capable of supporting trout is now limited, and may be decreasing as certain lakes undergo natural aging and lose their trout production capacity. Future demand should be met in one or more of the following ways:

(1) additional intensive management of reclaimed trout lakes

(2) fishing for other species in other lakes

(3) successful introduction of new salmonid species into Lake Superior and tributaries

Programs necessary to raise production in trout waters are limited to small lakes and will not provide any large relief. Warmwater fishing is not a true substitute for trout fishing and will not be acceptable to ardent trout fishermen. New developments in coho salmon and rainbow trout introduction into Lake Superior and its tributaries hold the most promise in meeting new demand.

The lakes of the Minnesota border country should be maintained in their present oligotrophic state. Preservation of these high quality waters is important because the area is fragile.

Using population trends, a calculation based on multiple regression analysis was made and these figures show a 1970 total demand of 2.691 million angler days. By 1980 this will have reached approximately 2.840 million; by 2000, an estimated 3.228 million; and by 2020, a total of 2.679 million angler days. The Minnesota portion of the demand amounts to 1.906 million angler days in 1970 (approximately 70 percent of total demand for the planning subarea).

In-migration from other areas represents a large percentage of the total number of angler days. The number of residents who go to other areas of the State to fish and buy their licenses outside of Planning Subarea 1.1 is insignificant in the computation of demand (Table 8–7).

3.2.6 Ongoing Programs

The current fishery programs involve proper protection and improvement of the natural resources which serve as a basis for fish production and the direct manipulation of fish population in poor lakes and streams. Intensive warmwater management includes acquisition of a spawning area, chemical rehabilitation of small stream trout lakes, removal of warmwater competing species in certain soft-water walleye or oligotrophic lake trout lakes, and intensive fish stocking in trout streams, reclaimed trout lakes, and in some of the larger walleye lakes. Some lake trout stocking is done in the lake trout lakes.

TABLE 8–7 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 1.1

States and Counties	Land Area (sq.mi.)	Population (1000s)	Population per sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
Minnesota								
Carlton	860	29.4	34.2	6,910	.2350	693	9,897	.3366
Cook	1,335	3.2	2.4	101,152	31.6100	5,200	3,437	1.0741
Lake	2,050	12.9	6.3	118,038	9.1502	5,020	6,011	.4660
St. Louis	6,036	225.0	37.3	336,426	1.4952	27,938	74,818	.3325
Total	10,281	270.5	26.3	562,526	2.0796	38,851	94,163	.3481
Wisconsin								
Ashland	1,026	16.2	15.8	4,382	.2705	1,328	2,881	.1778
Bayfield	1,450	12.3	8.5	20,792	1.6904	5,358	4,072	.3311
Douglas	1,305	42.7	32.7	11,833	.2771	4,622	7,526	.1763
Iron	741	5.9	8.0	32,689	5.5405	4,967	2,710	.4593
Total	4,522	77.1	17.0	69,696	.9040	16,275	17,189	.2229

States and Years	Land Area (sq.mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand: Resident[1]	Projected Angler Day Demand: Total[2]
Minnesota					
1980	10,281	288.2	28.0	2,280,000	3,787,171
2000	10,281	334.3	32.5	2,623,000	4,392,961
2020	10,281	386.0	37.5	3,010,000	5,072,339
Wisconsin					
1980	4,522	78.4	17.3	510,000	1,247,000
2000	4,522	83.0	18.4	535,000	1,395,000
2020	4,522	88.9	19.7	569,000	1,569,000
Total PSA 1.1	14,803	347.6	23.5		
1980	14,803	366.6	24.8	2,790,000	5,034,171
2000	14,803	417.3	28.2	3,158,000	5,787,961
2020	14,803	474.9	32.1	3,579,000	6,641,339

[1]Demand generated within planning subarea.

[2]Total demand including in- and out-migration.

Regular rotational stocking of the walleye lakes and lake trout lakes generally follows the fishery management plans instituted for such waters. Annual stocking of stream trout usually follows a management plan.

Figure 8–19 shows the current extension of the stream trout fishery as well as the general area of the lake trout fishery. However, even the most vigorous programs to increase fishing potential in the area will not meet the demand because of the low productivity of waters and the increasing demand for trout fishing. Therefore, increases in fishing demand should be met by new developments such as coho salmon and rainbow trout introductions into Lake Superior and its tributaries rather than attempting to increase the productivity of the oligotrophic lakes in the border country. Anadromous fish passages are important to salmonid fishery development in both large and small river systems.

Plans for fishery development beyond 1980 have not been formulated at this time. However, it will probably include intensive management of reclaimed trout lakes, introduction of salmon and steelhead trout into Lake Superior and its tributaries along with necessary spawning run development, and perhaps

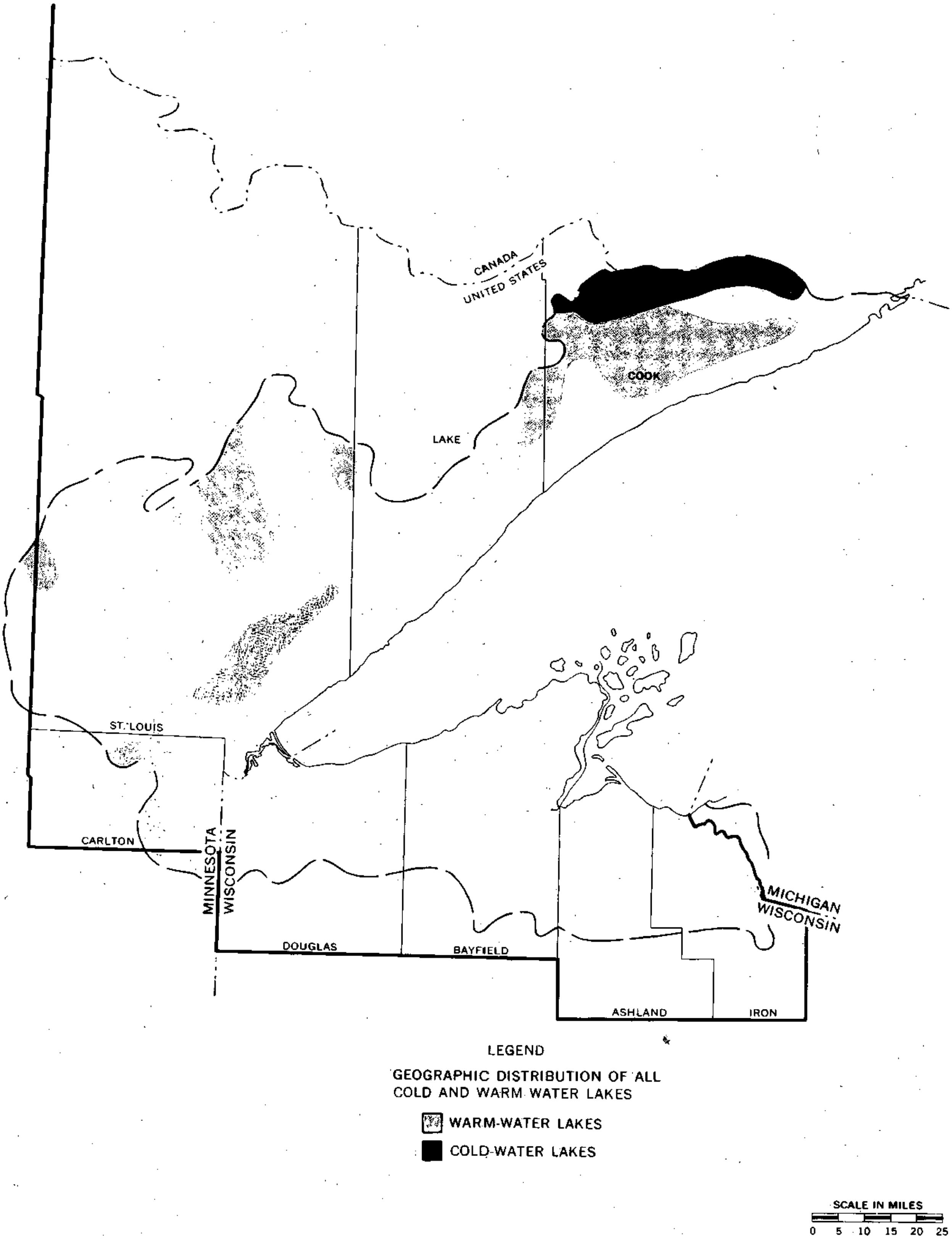


FIGURE 8–19 Current Fish Stocking Program, Planning Subarea 1.1

an expansion of warmwater species management via removal of competing species and development of artificial spawning areas.

3.3 Planning Subarea 1.2

3.3.1 Species Composition, Relative Importance, and Status

Planning Subarea 1.2 (Figure 8–20) covers the northern portion of Michigan's Upper Peninsula, with a number of short streams draining to Lake Superior. The topography is generally rolling to rugged.

Brook trout was indigenous to tributaries of Lake Superior, and most river systems still support its populations. Brown trout is less common in this area than in Michigan's Lower Peninsula. Steelhead runs most of the streams during the spring, but its penetration upstream is often only a short distance because waterfalls are common within a few miles of the mouths of Lake Superior tributaries.

Largemouth bass and bluegill were probably not indigenous to this area and their present distribution resulted from introductions early in this century. Neither of these warmwater species does well in the cold, generally oligotrophic lakes of this planning subarea, but they are common in impounded backwater areas. Smallmouth bass, yellow perch, northern pike, and rock bass are the most abundant and popular sport fish in the warmwater lakes of the area. Natural populations of walleye and muskellunge add to the recreational fishery in some warmwater lakes.

Lake trout is native to some of the inland lakes and annual stocking of rainbow trout, brook trout, and splake provides over 10,000 acres of trout fishing opportunities.

The same species found in the lakes are common in most river systems. Trout is most important in cold rivers and headwater areas, and warmwater species dominate the large, relatively warm mainstream areas.

3.2.2 Habitat Distribution and Quantity

The impoundments and inland lakes of Planning Subarea 1.2 total over 145,535 acres of fishable water. The distribution of water within the planning subarea is relatively uniform with only two counties having less than 9,000 acres of ponded water (Figure 8–21). The number of resident license sales per capita reflects this uniform distribution of water. Alger County has the highest number of resident license sales per capita at .2984, and Chippewa County has the lowest at .1212. Amount of ponded water per capita varies from .3038 acres in Chippewa County to 2.5871 acres in Keweenaw County (Table 8–8).

The river systems are relatively small and movement of fish is restricted by numerous waterfalls along an escarpment running generally east and west across the entire planning subarea.

3.3.3 Habitat Problems Affecting Production and Distribution of Important Fish Species

Only a few rivers around urban and industrial complexes have poor water quality and efforts are under way to improve waste treatment in these areas. Generally, water quality is excellent in Planning Subarea 1.2 in both lakes and streams.

The distribution of fish is primarily determined by natural conditions. Most larger lakes are oligotrophic and many of the smaller lakes border on being acid bogs. Low annual mean temperatures depress the growth of many species better adapted to temperate warmwater environments.

3.3.4 History of Sport Fishery

Resident fishing license sales reached an all-time high in 1969. Over 43,000 resident licenses were sold in 1969 compared to 26,000 in 1950. Part of the increase is due to the recovery of lake trout in Lake Superior and the introduction of salmon. The construction of the Mackinac Bridge and the recent reduction of tolls have made the fishery resources more available to anglers of southern Michigan. Access site development, new road construction, and better fish management practices have also provided new sport fishing opportunities in the last 20 years.

3.3.5 Existing Sport Fishing Demand and Current Needs

The total angler-day demand within the inland waters exceeds 1,400,000. Because demand is determined through license sales, there is no quantitative way to calculate need. However, the need to preserve and maintain

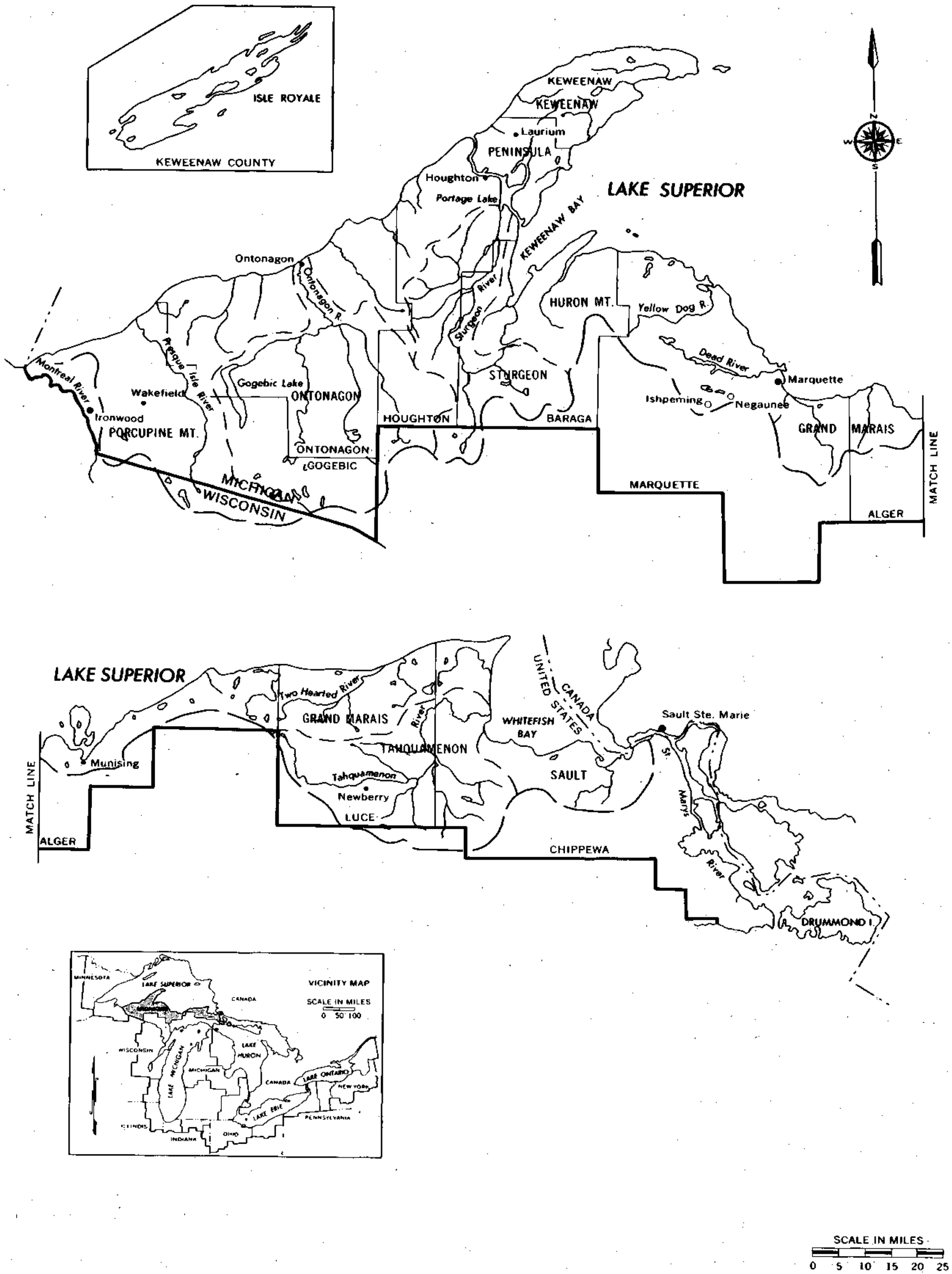


FIGURE 8–20 Planning Subarea 1.2

TABLE 8–8 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 1.2

State and Counties	Land Area (sq.mi.)	Population (1000s)	Population per sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
Michigan								
Alger	896	8.3	9.3	12,260	1.4771	1,951	2,477	.2984
Baraga	899	7.8	8.7	8,198	1.0510	883	1,696	.2174
Chippewa	1,586	36.8	23.2	11,181	.3038	4,420	4,459	.1212
Gogebic	1,104	20.7	18.8	37,634	1.8181	5,022	4,076	.1969
Houghton	1,013	34.3	33.9	22,899	.6676	1,844	5,656	.1649
Keweenaw	534	2.1	3.9	5,433	2.5871	329	509	.2424
Luce	901	6.8	7.5	10,311	1.5163	1,005	1,969	.2896
Marquette	1,818	67.8	37.3	27,510	.4058	2,472	10,879	.1605
Ontonagon	1,314	10.6	8.1	10,109	.9537	1,127	2,286	.2157
Total	10,065	195.2	19.4	145,535	.7456	19,053	34,007	.1742

State and Year	Land Area (sq.mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand: Resident[1]	Total[2]
Michigan					
1980	10,065	171.3	17.0	1,214,626	2,315,000
2000	10,065	177.4	17.6	1,257,879	2,589,000
2020	10,065	193.8	19.3	1,574,165	3,185,000

[1] Demand generated within planning subarea.

[2] Total demand including in- and out-migration.

the present fishery resource base is obvious.

Nearly all the demand expressed by local anglers is supplied within the planning subarea. In addition, many people who live and buy their licenses in other planning subareas come to PSA 1.2 to fish. In Alger, Chippewa, and Gogebic Counties, out-of-State fishermen buy as many licenses as Michigan residents. Fishermen who buy their licenses elsewhere probably add at least 1,000,000 angler days to the current demand.

Latent demand for fishing opportunities is low for people living in Planning Subarea 1.2, but the latent demand of southern Michigan and Wisconsin will be important in considering the future management plans for this planning subarea. The majority of fishing demand currently expressed comes from people living outside the planning subarea.

3.3.6 Ongoing Programs

Fish management activities involve maintenance plantings and introduction of game species. Habitat protection activities do not consume as much time as they do in the populous areas of southern Michigan.

The United States Forest Service has extensive areas under management, and many cooperative programs for developing the fishery resources are carried out by the State of Michigan and the Forest Service in National Forests. These include chemical rehabilitation, fish stocking, and access development.

Figure 8–22 and Table 8–9 summarize current intensive fish management programs. Most of the trout streams have sufficient natural reproduction and annual plantings are not required. In 1969, more than 800,000 trout were stocked primarily in inland lakes. Almost 3,000,000 warmwater fish were planted in inland lakes in 1969 including northern pike, bass, walleye, and muskellunge. The number of fish planted is somewhat deceiving because many of the warmwater fish planted were fry. Actually, trout plantings totaled more than 40,000 pounds in 1969 and warmwater fish plants totaled only 523 pounds.

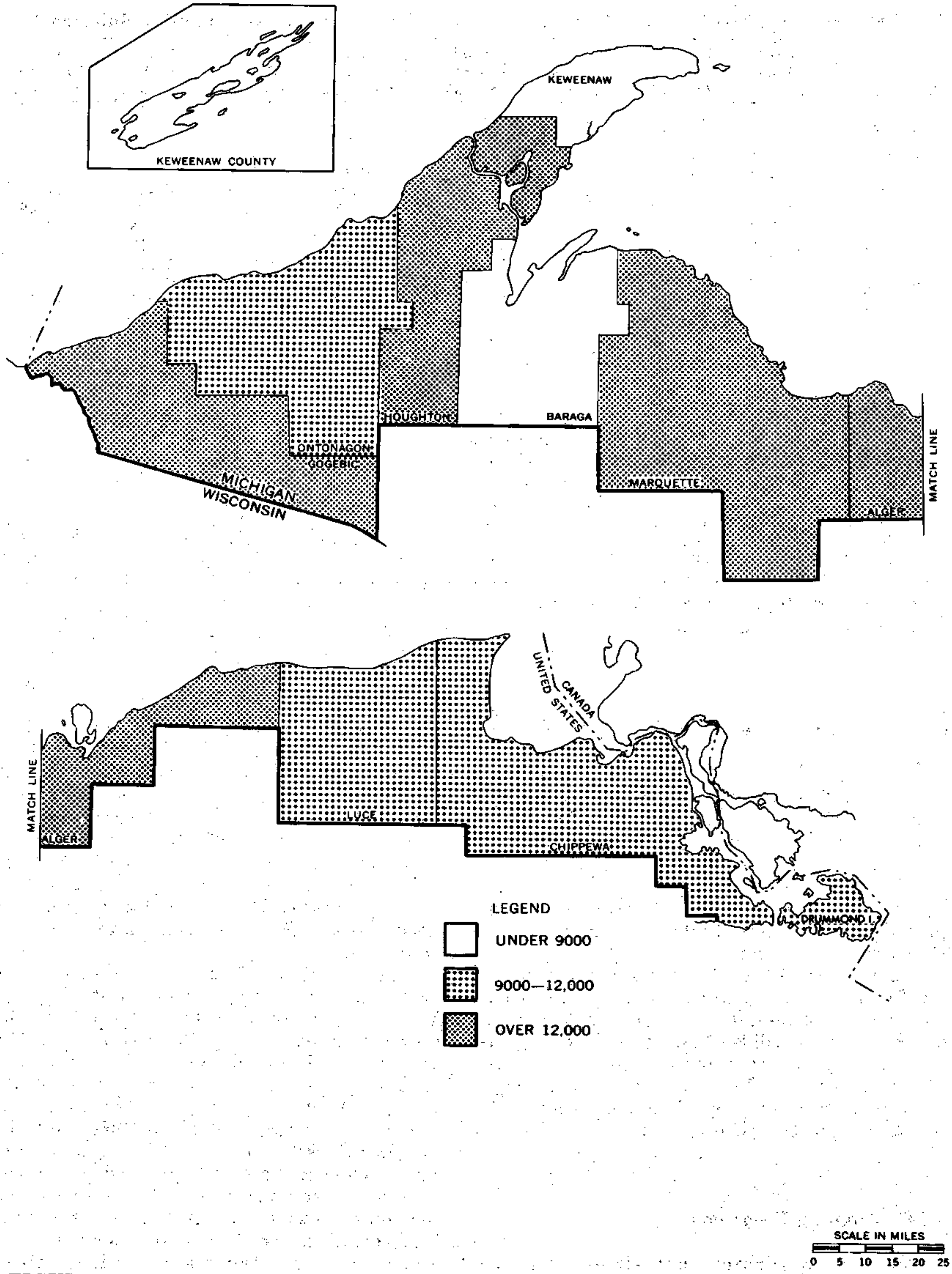


FIGURE 8-21 Acres of Ponded Water, Planning Subarea 1.2

TABLE 8–9 Summary of Base Year Fish Habitat and Management Efforts, Planning Subarea 1.2

County	Total Area (sq.mi.)	Acres Ponded Waters	Number Ponded Waters	Number Intensively Managed	Acres Intensive Warmwater	Acres Intensive Trout	Miles Total Streams	Miles Trout Streams	Miles Anadromous Streams
Michigan									
Alger	934	12,260	277	19	66.1	921.8	709	603.4	33.0
Baraga	925	8,198	157	9	-------	137	696	447.5	68.5
Chippewa	1,651	11,181	153	9	1,576.8	119.4	800	387.3	78.0
Gogebic	1,146	37,634	276	30	653.5	1,838	1,204	519.3	6.5
Houghton	1,047	22,899	139	10	-------	373	923	538.7	133.5
Keweenaw	587	5,433	46	6	-------	1,025	271	98.6	45.7
Luce	929	10,311	228	38	2,191.5	722.5	658	420.3	35.4
Marquette	1,878	27,510	419	38	32	4,970.5	1,906	1,363.5	23.5
Ontonagon	1,331	10,109	78	7	-------	152	1,282	555.0	114.0
Total	10,428	145,535	1,773	166	4,519.9	10,259.2	8,449	4,933.6	538.1

Table 8–10 summarizes the salmon plants made during 1970. Salmon plants provide some stream fishery and an open water Lake Superior fishery. Salmon plants were initiated in 1966 in the Big Huron River in Baraga County.

3.3.7 Future Trends in Habitat and Participation

Future demand was calculated on expected population trends. Since population is expected to decrease in the next 10 years, fishing demand figures decrease. However, from current trends, it is evident that fishing demand is increasing steadily primarily because of the inflow of fishermen living outside the planning subarea. It is reasonable to expect an increase of fishing demand to 2,000,000 angler days by 1980. If new fishing opportunities are added and promoted, latent demand from southern Michigan could add an additional 250,000 angler days by 1980. Similarly, the projections for the years 2000 and 2020 are one-half of the possible number (Table 8–8).

TABLE 8–10 1970 Salmon Stocking, PSA 1.2

Location	Coho	Chinook
Anna River	150,000	-------
Dead River	75,000	50,006
Falls River at Dault's Creek	81,616	-------
Presque Isle River	50,000	-------
Sturgeon River	100,000	100,000
Sucker River	50,000	-------
Total	506,616	150,006

The fishing quality and natural beauty of Michigan's Upper Peninsula must be maintained in order to attract fishermen from the more populous areas. State and Federal lands should be purchased and developed to preserve and enhance the unique qualities of the fishery resources. Fishery resources in this planning subarea cannot withstand heavy exploitation, but they can and should provide considerable recreation. Unique and fragile natural resources can be used and enjoyed without being destroyed or significantly altered. The current restricted catch fishery on the Sylvania Lakes of the Ottawa National Forest is a good example of this.

3.3.8 Fishery Development Plans

Most of the increased demand expected by 1980, approximately 1,000,000 angler days, will be supplied by Lake Superior where lake trout, salmon, and steelhead are providing a larger sport fishery each year.

Many of the inland lakes and streams could provide more fishing opportunities without large management expenditures. The lack of promotion and information about this fishery resource, and the relatively high cost in both money and time necessary to take advantage of them currently limits angler use.

New fish management expenditures will be directed toward developing and promoting unique high quality fisheries that can attract anglers from long distances. Land acquisition for access, habitat protection, and fish passage is essential to the development of the fishery. The priority land acquisition sites and

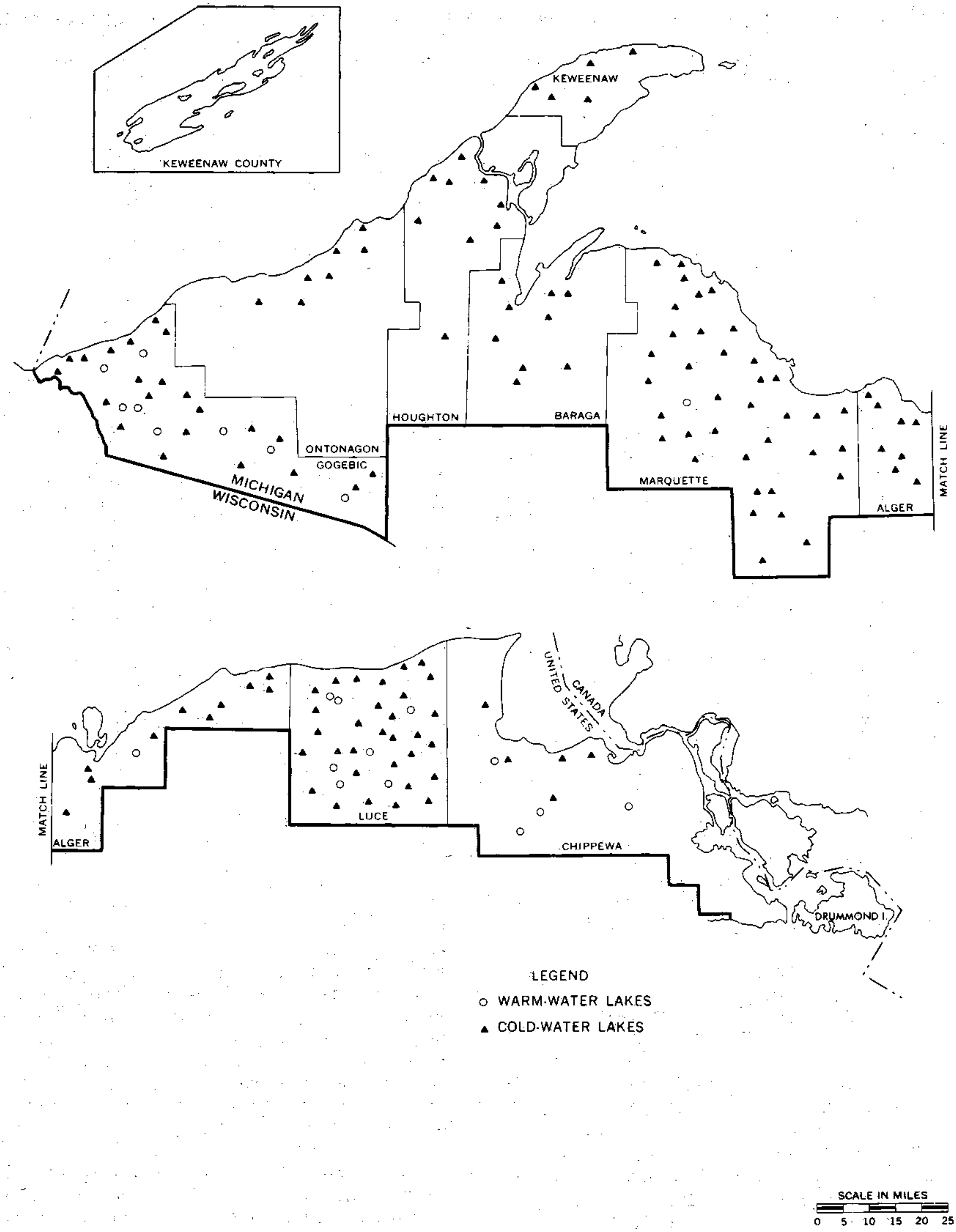


FIGURE 8-22 Current Fish Stocking Program, Planning Subarea 1.2

estimated costs are detailed in Figure 8–23 and Table 8–11. Fish passages over existing barriers are planned on at least one major stream before 1980 at a cost of between $100,000 and $200,000.

The planned trout hatchery will provide better quality and more trout for stocking lakes. Approximately $800,000 of the capital cost of the new trout hatchery will be charged to Planning Subarea 1.2. Operating costs for this new hatchery and the costs of treating lakes and planting the trout will add $75,000 to the annual operating expenditures. The benefits in terms of angler days attributable to this new hatchery have not yet been determined. Increases in fishing quality and cost efficiencies in providing trout for the creel are the primary justification.

The development of the new warmwater hatchery in southern Michigan will directly affect fish management. The lack of suitable replacement stock like walleye and smallmouth bass has always deterred warmwater rehabilitation projects. With this new source of eggs and fry, existing rearing facilities can be put to full use in the production of warmwater fish. Some new rearing facilities may be built to take full advantage of this new hatchery capability. The costs and benefits of this program have not yet been detailed.

TABLE 8–11 Priority Land Acquisition Areas, Planning Subarea 1.2

County	River	Acres	Cost
Baraga	Huron	220	$ 50,000
Baraga	Falls	40	40,000
Houghton	Pilgrim	900	60,000
Houghton & Baraga	Otter	700	40,000
Ontonagon	Ontonagon	2,560	130,000
Ontonagon	Big Iron	1,280	60,000
Total		5,700	$380,000

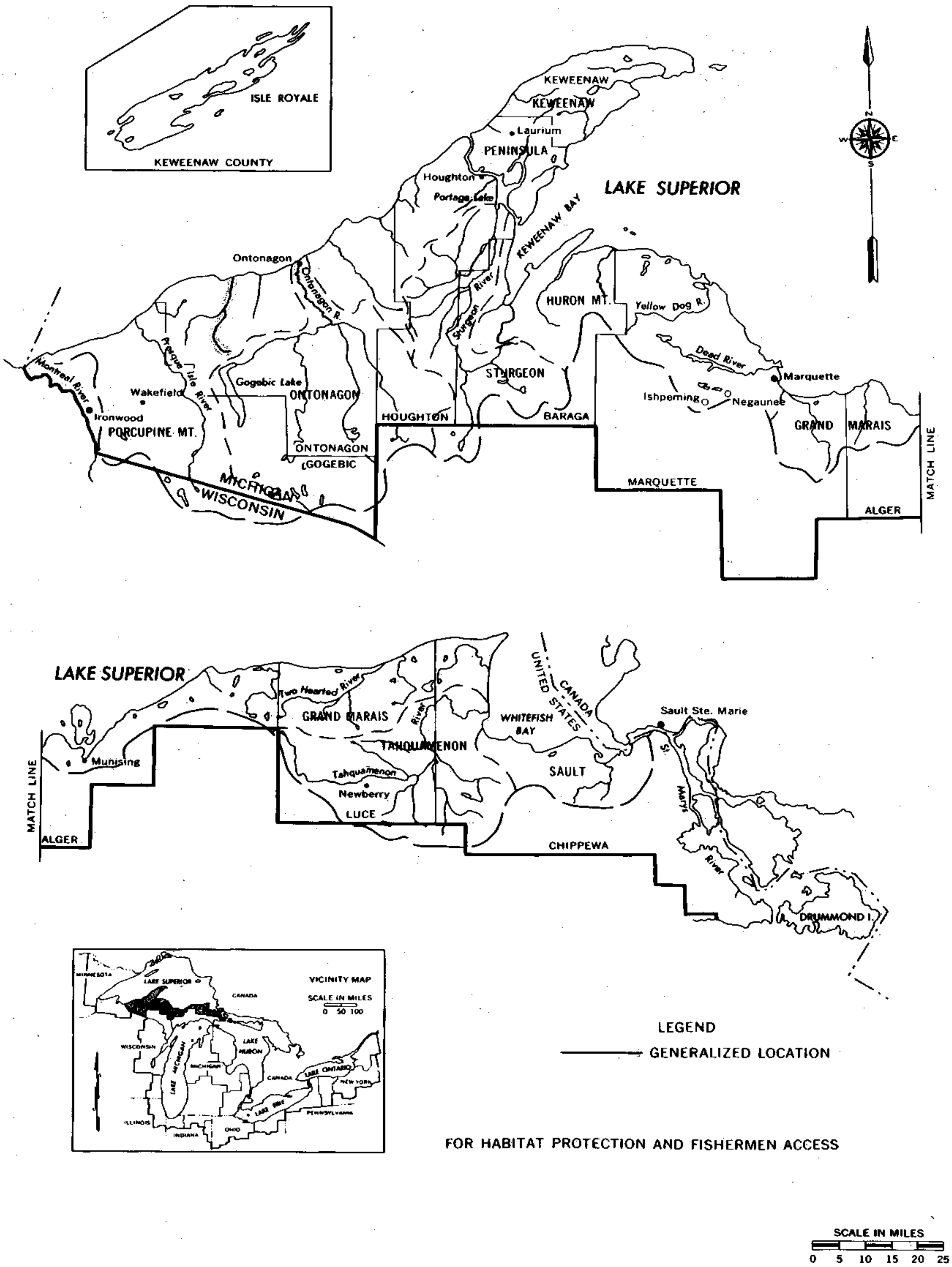


FIGURE 8–23 Priority Land Acquisition, Planning Subarea 1.2

Section 4

LAKE MICHIGAN BASIN, PLAN AREA 2.0

The comments on Plan Area 2.0 (Figure 8–24) are divided into two major parts. The first is limited to Lake Michigan and the second treats the individual planning subareas of the Lake Michigan basin.

4.1 Resources, Uses, and Management

4.1.1 Habitat Base

In addition to the information included in the introductory section of the appendix, the following statements characterize Lake Michigan more specifically:

(1) Lake Michigan is the second largest Great Lake (22,400 square miles).

(2) The Lake has a 67,860-mile drainage area and except for the man-made Chicago Diversion Canal, its only outlet is to Lake Huron through the Straits of Mackinac.

(3) Lake Michigan is the only Great Lake entirely within the continental limits of the United States.

(4) Maximum depth of Lake Michigan is approximately 924 feet and its maximum length and width are 315 and 75 miles respectively.

(5) Three large bays in Lake Michigan break up an otherwise regular shoreline: Green Bay (including the Bays de Noc), Little Traverse Bay, and Grand Traverse Bay.

(6) The major island areas are located near the eastern side of Green Bay and near Grand Traverse Bay in the northeast section of Lake Michigan.

4.1.2 Fish Resources—A Summary of Major Changes

Lake Michigan fish populations have undergone dramatic changes during the last 40 years. Coldwater species including lake trout, whitefish, herring, and chubs have dominated the catch of the commercial fishery.

Although changes occurred in the abundance of certain prized food species after the establishment of the first major commercial fishery in the mid-1800s, dramatic fluctuations in the numbers and kinds of fish began in the early 1940s. Since 1940 several major factors have affected Lake Michigan fish populations: overexploitation and selective exploitation by the commercial fishery of high- and medium-value species, the invasion of the sea lamprey, the population explosion of alewife, partial sea lamprey control programs, and large scale hatchery plantings of salmonids.

Commercial species such as herring and walleye are now nearly extinct. Yellow perch and lake trout have not yet recovered to former Lakewide abundance levels. Chubs, whitefish, and alewife now dominate the commercial catch in both dollars and poundage. The increasing sport catch of trout and salmon since 1966 reflects their increase in abundance.

The alewife forage base and the generally good water quality (Figure 8–25) have made Lake Michigan the top producer of trout and salmon. There are positive signs that natural reproduction of lake trout occurred throughout the northern half of the Lake for the first time in the fall of 1971. Although natural reproduction of lake trout may someday support the lake trout fishery, maintenance stocking of trout and salmon will be required in the future.

4.1.2.1 Value of the Individual Species to the Ecosystem

Subsection 2.3.1 discusses in detail the major relationships between species common throughout the Great Lakes. This subsection will deal with those relationships in Lake Michigan.

Considered as a whole, Lake Michigan could be defined as an oligotrophic lake with a simple complex of species. However, the shallow, productive areas of the southern portion of the Lake and the Green Bay area sustain fish populations similar to those found in Lake

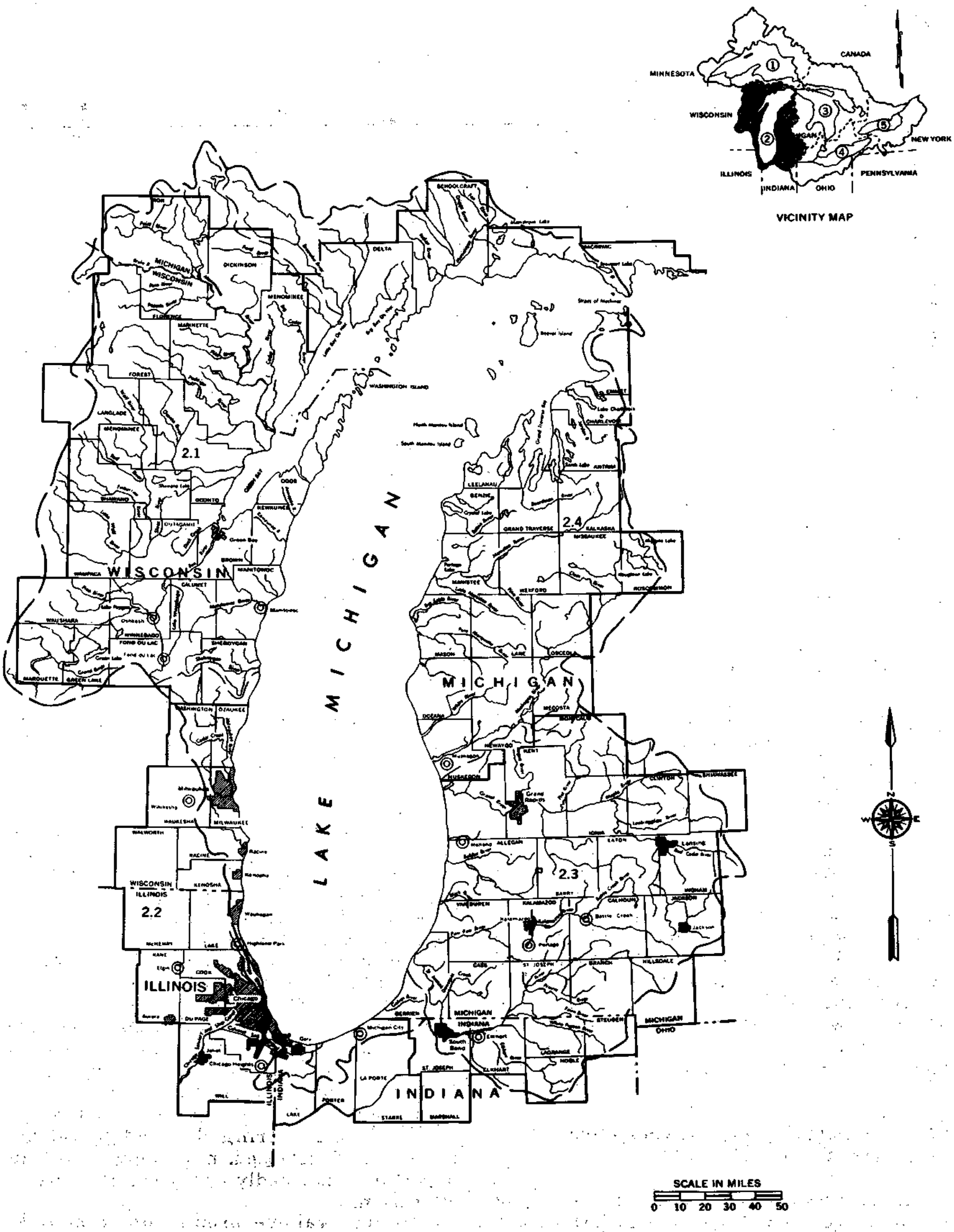


FIGURE 8–24 Plan Area 2.0

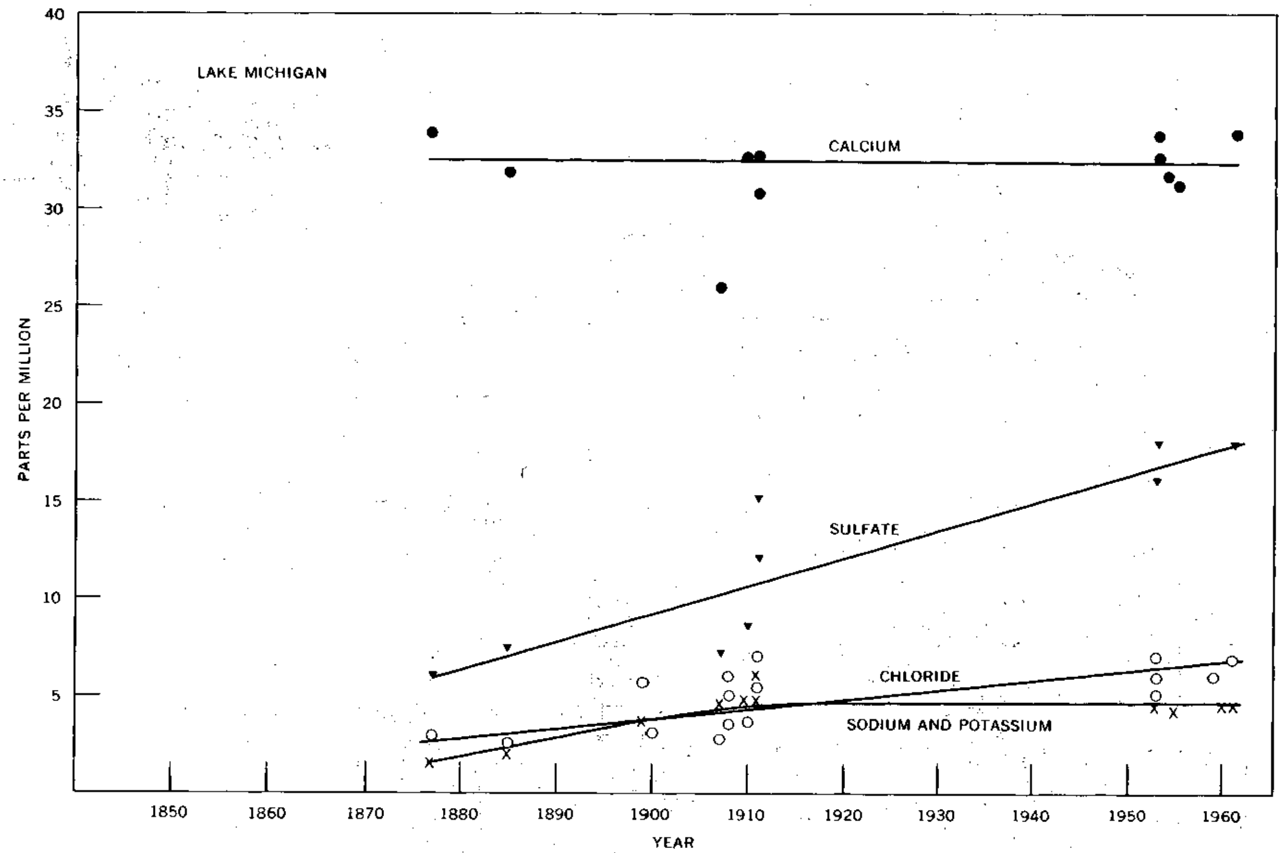


FIGURE 8–25 Lake Michigan, Major Chemical Cations

Erie. Alewife inhabits and dominates nearly all areas of the Lake at various times of the year and is the single most important species from a biological standpoint. Alewife directly or indirectly affects the growth, survival, and abundance of most major species in Lake Michigan. The sea lamprey, now at perhaps 15 percent of its peak abundance, still plays a major role in determining the abundance of larger species, particularly lake trout.

Hatchery planting programs will continue to affect the abundance of large salmonid predators, which feed largely on alewife. The level of trout and salmon plantings has helped to hold down the abundance of alewife and relieve population pressures on the other species such as yellow perch, smelt, and chubs.

4.1.2.2 Contribution of Individual Species to the Commercial Fishery

The contribution of each species to the commercial catch was reviewed in detail in the *Great Lakes-Illinois River Basin Report, Fish and Wildlife as Related to Water Quality of the Lake Michigan Basin* by the Fish and Wildlife Service in 1966. Figures 8–26 and 8–27 and Tables 8–12 and 8–13 summarize the contribution of each species since 1935.

The contribution of individual species to the commercial fishery has varied considerably depending upon intensity of the fishery and availability of high-value species. Peak years of production for many species were often followed by severe declines strongly suggesting that overexploitation had taken place.

Lake trout was the primary money species in the Lake Michigan commercial fishery until the late 1940s when the fishing effort shifted to more abundant low-value species. Lake herring production varied between two and five million pounds in the period 1920 to 1947. In 1948 the catch began to increase and hit a high of 9,691,000 pounds in 1952. By 1960 the catch of lake herring dropped to 233,000 pounds. Lake herring is now commercially unimportant and rapidly approaching biological extinction.

Similary, walleye production from Lake Michigan varied between 50,000 and 200,000 pounds annually from the turn of the century

TABLE 8–12 Average Pound and Percent Contribution of 12 Major Species in Lake Michigan

Species	1935–1939	1940–1944	1945–1949	1950–1954	1955–1959	1960–1964	1965–1969
Alewife							
Lbs.	---[1]	---[1]	---[1]	---[1]	568,340	5,490,020	28,269,600
% of Volume	---[1]	---[1]	---[1]	---[1]	2.1	22.8	63.7
Burbot							
Lbs.	37,700	44,140	66,420	15,200	17,520	5,200	34,720
% of Volume	.2	.2	.3	.1	.1	---[2]	.1
Carp							
Lbs.	1,605,440	1,701,840	1,318,600	1,169,680	1,785,520	1,412,020	2,348,800
% of Volume	6.4	7.8	5.4	4.0	6.5	5.9	5.3
Chub							
Lbs.	5,295,400	1,970,760	5,436,520	10,481,600	9,946,640	9,707,920	8,620,080
% of Volume	21.2	9.1	22.3	35.9	36.4	40.3	19.4
Lake Herring							
Lbs.	4,621,400	1,829,880	6,044,120	8,000,140	3,639,100	120,160	47,180
% of Volume	18.5	8.4	24.8	27.4	13.3	.5	.1
Lake Trout							
Lbs.	5,037,580	6,578,640	2,675,060	13,740	---[1]	5,440	31,320
% of Volume	20.2	30.3	11.0	---[2]	---[1]	---[2]	.1
Sheepshead							
Lbs.	9,420	85,780	86,200	17,840	3,400	2,020	---[2]
% of Volume	---[2]	.4	.4	.1	---[2]	---[2]	---[2]
Smelt							
Lbs.	1,452,040	2,911,460	765,140	4,384,040	6,982,580	1,827,540	1,506,520
% of Volume	5.8	13.4	3.1	15.0	25.6	7.6	3.4
Sucker							
Lbs.	2,265,820	2,125,120	1,900,940	881,940	652,180	407,580	443,260
% of Volume	9.1	9.8	7.8	3.0	2.4	1.7	1.0
Lake Whitefish							
Lbs.	1,200,940	1,349,160	3,775,880	1,436,000	107,340	369,400	1,114,700
% of Volume	4.8	6.2	15.4	4.9	.4	1.5	2.5
Yellow Perch							
Lbs.	2,406,160	2,728,940	1,446,320	1,962,220	3,055,180	4,600,200	930,500
% of Volume	9.6	12.6	5.9	6.7	11.2	19.1	2.1
Yellow Pike							
Lbs.	77,440	49,020	506,200	605,120	488,400	75,660	18,220
% of Volume	.3	.2	2.1	2.1	1.8	.3	---[2]
Average Total Volume	24,935,280	21,712,440	24,406,980	29,181,400	27,326,760	24,113,520	44,401,760

[1]Absent from the commercial catch

[2]Less than 100 pounds or .1%

to the late 1940s. In 1950 walleye production reached an all-time high of 1,349,000 pounds but it quickly dropped off to less than 200,000 pounds by 1960. Now walleye contributes less than 5,000 pounds annually to the commercial catch.

Commercial chub production varied between 1.5 and 6.0 million pounds between 1900 and 1948. In 1950 it surpassed 10 million pounds for the first time and has remained near the 10-million-pound mark since then. Formerly several chub species made up the catch, now only bloaters are left. These formerly common species of chubs now maintain only remnant populations. The largest of these is in Grand Traverse Bay which has remained closed to commercial fishing for several years.

TABLE 8-13 Average Value and Percent Contribution of 12 Major Species in Lake Michigan

Species	1935-1939	1940-1944	1945-1949	1950-1954	1955-1959	1960-1964	1965-1969
Alewife							
Dollars	---[1]	---[1]	---[1]	---[1]	15,248	94,348	325,782
% of Value	---[1]	---[1]	---[1]	---[1]	.5	4.2	12.2
Burbot							
Dollars	1,338	2,729	2,483	456	847	244	1,786
% of Value	---[2]	---[2]	---[2]	---[2]	---[2]	---[2]	.2
Carp							
Dollars	113,417	140,457	86,222	52,363	87,055	43,333	67,556
% of Value	2.2	2.2	1.5	1.4	2.8	1.9	2.5
Chub							
Dollars	1,509,202	737,112	1,235,884	1,736,749	1,944,015	1,143,829	1,348,268
% of Value	28.9	11.5	21.4	45.7	61.8	50.8	50.5
Lake Herring							
Dollars	321,020	211,986	470,757	495,662	232,358	13,228	7,400
% of Value	6.2	3.3	8.1	13.0	7.4	.6	.3
Lake Trout							
Dollars	1,930,982	3,330,860	1,524,185	5,410	---[2]	2,767	15,183
% of Value	37.0	51.9	26.4	.1	---[2]	.1	.6
Sheepshead							
Dollars	501	8,851	8,963	1,720	206	---[2]	---[2]
% of Value	---[2]	.1	.2	---[2]	---[2]	---[2]	---[2]
Smelt							
Dollars	119,807	268,419	134,301	248,043	227,116	61,020	42,974
% of Value	2.3	4.2	2.3	6.5	7.2	2.7	1.6
Sucker							
Dollars	160,490	216,746	148,076	56,891	36,222	16,825	12,744
% of Value	3.1	3.4	2.6	1.5	1.2	.7	.5
Lake Whitefish							
Dollars	534,660	776,752	1,585,329	674,766	58,654	219,308	568,847
% of Value	10.3	12.1	27.4	17.7	1.9	9.7	21.3
Yellow Perch							
Dollars	421,134	631,178	319,703	306,373	361,694	612,921	155,978
% of Value	8.1	9.8	5.5	8.1	11.5	27.2	5.8
Yellow Pike							
Dollars	23,311	17,419	186,320	191,338	164,608	30,459	7,938
% of Value	.4	.3	3.2	5.0	5.2	1.4	.3
Average Total Value	5,215,621	6,421,397	5,783,023	3,803,117	3,141,234	2,251,908	2,671,528

[1]Absent from the commercial catch

[2]Less than $100 or .1%

Yellow perch consistently provided a catch of between 1.0 and 3.4 million pounds in the period from 1900 to 1960. In 1961 the catch more than doubled to 4,959,000 pounds and reached a peak of 5,835,000 pounds in 1964. In 1968 the catch dropped to 632,000 pounds, nearly a 10-fold decrease in four years. Michigan has since closed its commercial fishery for yellow perch and there are indications that the yellow perch populations in Michigan waters of Lake Michigan are beginning to recover.

Whitefish is one of the few commercial species which appears to have recovered from the effects of heavy exploitation and sea lamprey predation. Whitefish, after reaching a peak production of 5,825,000 pounds in 1947, dropped off to 31,000 pounds in 1959. Sea lam-

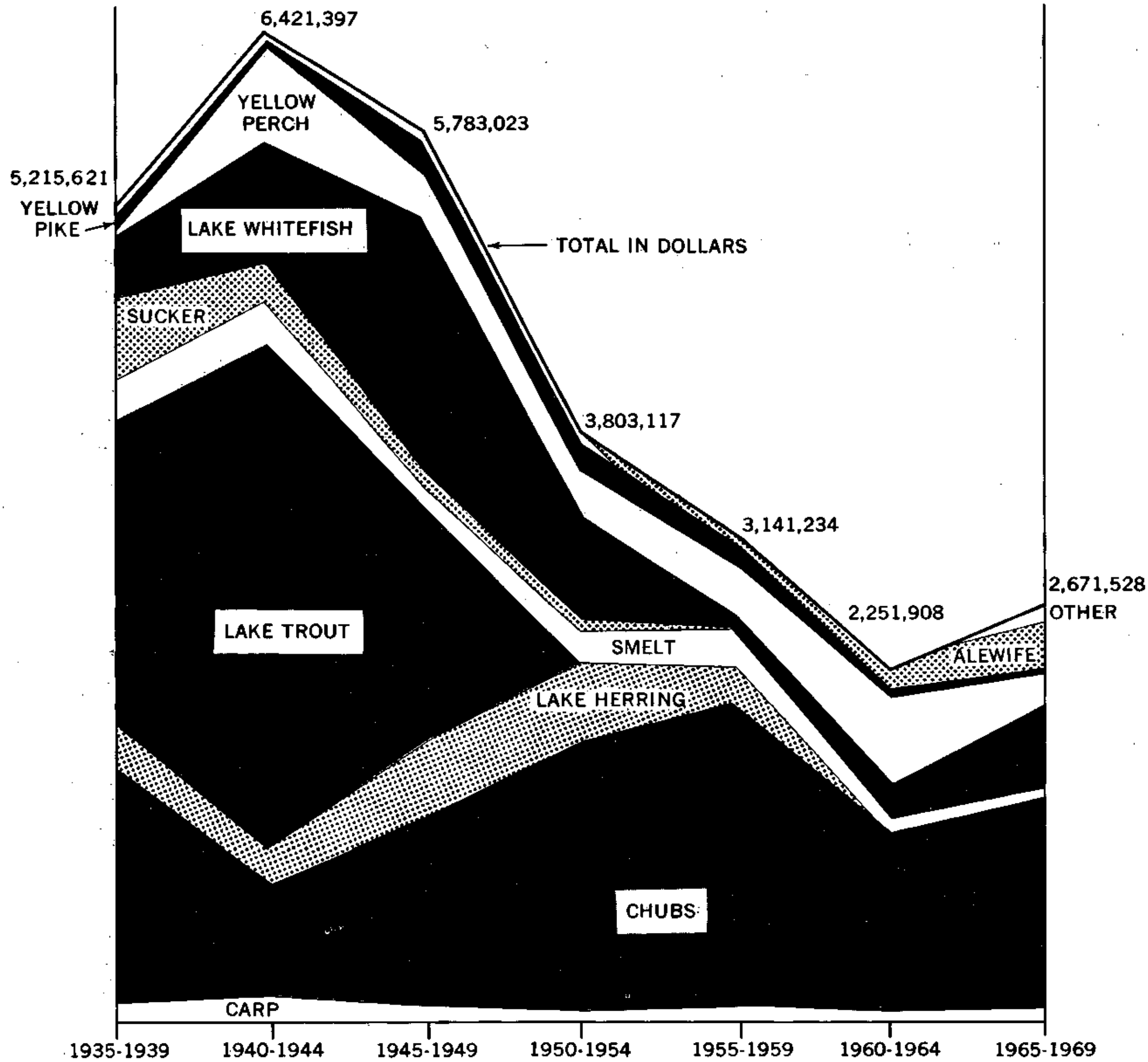


FIGURE 8–26 Average Annual Production (Dollars) of Major Species by the U.S. Lake Michigan Commercial Fishery for 5-Year Periods, 1935–1969

prey control began in the early 1960s and whitefish catches began increasing. The present catch is approximately one million pounds. Fishing effort has stabilized with the institution of limited entry and limitations on the net amount taken.

With the demise of high-value species, there has been an increase in effort for low-value alewife and smelt. Alewife hit a peak in abundance in 1967 prior to a major die-off. The commercial catch began with 220,000 pounds in 1957 and reached a peak of 41,895,000 pounds in 1967. Current alewife production has now stabilized at approximately 25,000,000 pounds annually. Smelt production reached a peak in 1958 at 9,102,000 pounds, but it has now leveled off at approximately 1,500,000 pounds annually.

4.1.2.3 Contribution of Individual Species to the Sport Fishery

The 1971 creel census in Michigan waters indicated that a total of 1,959,300 non-salmonids and 930,660 salmonids were taken by sport fishermen. The non-salmonids primarily consisted of yellow perch, smelt,

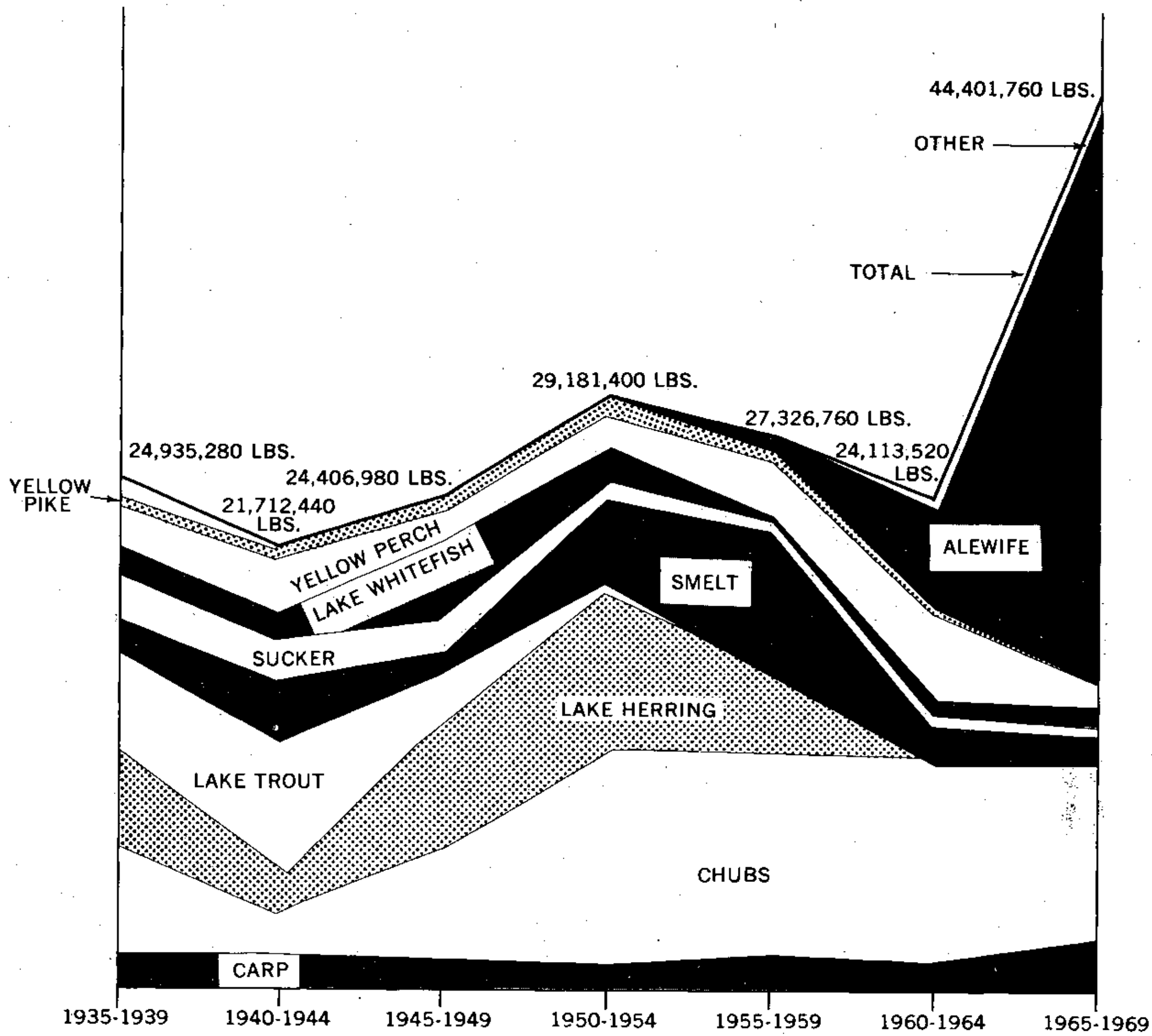


FIGURE 8–27 Average Annual Production (Pounds) of Major Species by the U.S. Lake Michigan Commercial Fishery for 5-Year Periods, 1935–1969

suckers, smallmouth bass, northern pike, walleye, and assorted centrarchid panfish. The openwater catch of salmonids consisted of 442,000 coho salmon, 48,000 chinook salmon, 76,000 rainbow trout, 311,000 lake trout, and some brown and brook trout.

In 1971 Michigan's anadromous sport catch in Lake Michigan tributaries included 218,000 coho, 202,000 chinook, 220,000 rainbows, and a few thousand brown trout.

Wisconsin reported an openwater catch of 900 brook trout, 11,300 brown trout, 14,300 rainbow trout, 28,000 coho salmon, 6,000 chinook salmon, and 43,100 lake trout from its Lake Michigan waters. In addition, Wisconsin reported an anadromous stream fishery of 380 brook trout, 800 brown trout, 4,600 steelhead, 4,800 coho, and 100 chinook in Lake Michigan tributaries.

The Lake Michigan total catch of salmonids by sportsmen is more than 1,700,000 annually, nearly equal to the total sport catch of salmon and steelhead in the five West Coast states of Washington, Oregon, California, Alaska, and Idaho. Sport catch of trout and salmon increased by 25 percent in 1971 in Michigan waters, and by nearly 50 percent in Wisconsin waters of Lake Michigan.

4.1.3 The Fisheries

4.1.3.1 Historical Background of the Lake Michigan Commercial Fishery

In general, the commercial fishery of the Lake Michigan basin has paralleled the origin and development outlined for the Great Lakes. Little is known of the earliest operations, but haul seines were probably the first gear used. As more people moved into the Lake Michigan area, the demand for fishery products increased and various gear that are still in use were evolved. Gill nets appeared in approximately 1835, pound nets in 1860, trap nets in 1885, set hooks in 1870, and trawls in 1957. At the present time, most fishermen operate in the gill-net fishery.

Table 8–14 summarizes data on commercial fishing units (fishermen, boats, and vessels) operating on Lake Michigan since 1930. The averages for each decade present a representative picture, showing a steady decline in fishermen and craft. This has been accompanied by an increase in production per unit, although there has been a leveling off in recent years.

Records for harvests prior to 1930 are based on figures for the years 1879, 1885, 1889 to 1890, 1892 to 1897, 1899, 1903, and 1908. While average total production has not varied greatly, there have been major shifts among the various components making up this production. These changes reflect the drastic influence of over-exploitation, sea lamprey invasion, introduction of new species, and other factors discussed in this report. In general, fishermen are now catching larger quantities of low-value fish to offset declines in landings of high-value varieties, such as lake trout and whitefish. For example, lake trout catches from 1911 to 1948 averaged more than six million pounds annually while landings from 1949 to 1963 were insignificant.

Over the period of record, Lake Michigan has occupied an intermediate position in rankings of commercial fishery production in the five Great Lakes. Its production of 1.81 pounds per acre ranks second to Lake Erie's 8.07 pounds per acre and ahead of Lakes Superior, Huron, and Ontario, all of which have productions less than one pound per acre.

Scattered early records indicate the existence of commercial fishery activity in some of the larger tributaries. Adverse environmental changes, restrictive legislation, and perhaps other factors eliminated this activity before systematic collection of catch records began. Although tributaries act as spawning habitat for certain species (especially the walleye) and influence localized areas of the open Lake, they currently support no commercial fishery.

4.1.3.2 Historical Background of the Lake Michigan Sport Fishery

Yellow perch has been the primary sport fish in Lake Michigan. Pier and jetty fishing has been popular in all four States. Surveys in the early 1960s indicated that more than one million fishermen annually fished primarily for yellow perch in the 30 miles of Illinois shoreline. Similarly yellow perch fishing is intense on all piers and jetties open to the public in the southern half of Lake Michigan in Wisconsin, Indiana, and Michigan.

Walleye, smelt, smallmouth bass, and suckers are seasonally important to sport fishing as they move into tributaries or near shore to spawn. Green Bay and the Bays de Noc offer almost year-round fishing for these warmwater species as well as localized fisheries for northern pike.

The sport fishery for lake trout was just beginning to expand in such areas as Grand Traverse Bay and Charlevoix when the lake trout population began to decline in the late 1940s and early 1950s. Steel head fishing has been a popular stream fishery in Lake Michigan tributaries since the 1920s, but it also suffered a decline during the 1950s when sea lamprey reached peak abundance.

Since the mid-1960s trout and salmon sport fisheries have undergone tremendous growth. Sea lamprey control programs and massive plantings of lake trout, coho, chinook, rainbows, browns, and steelhead have made trout and salmon fishing in Lake Michigan one of the most important sport fisheries in the Great Lakes Region.

4.1.3.3 Economics

The economics of the sport and commercial fisheries of the Great Lakes is discussed in detail in the introductory section. After several years of declining value the Lake Michigan fishery has grown tremendously in economic value largely on the strength of the expanding sport fishery.

TABLE 8–14 Commercial Operating Units and Productivity in Lake Michigan

Year	Number of Fishermen[1]	Pounds Landed per Fisherman	Value of Catch per Fisherman[2]	Number of Vessels	Number of Boats
1930	2,821	10,980	$1,621	307	793
1931	2,790	8,982	1,789	336	524
1932	2,527	7,118	1,193	330	569
1934	3,272	8,693	1,369	330	704
1936	2,295	11,234	2,101	329	392
1937	2,658	9,932	2,043	326	493
1938	2,902	8,401	1,830	318	447
1939	3,038	7,579	2,005	319	538
1940	2,126	10,731	2,242	271	279
1950	1,984	13,647	2,126	284	508
1954	1,716	17,652	2,004	268	362
1955	1,554	19,328	2,224	238	391
1956	1,456	21,152	2,472	216	236
1957	1,346	20,224	2,371	203	313
1958	1,470	18,891	2,143	223	387
1959	1,521	13,680	1,548	205	350
1960	1,337	18,183	1,817	187	336
1961	1,367	18,697	1,821	184	362
1962	996	23,569	1,896	171	342
1963	911	23,074	2,047	155	360
1964	939	27,903	2,756	171	369
1965	867	31,135	2,730	174	312
1966	758	56,417	3,508	159	252
1967	801	73,597	3,486	166	303
1968	734	66,502	3,869	166	202
1969	701	67,744	3,823	156	210

[1]Refers to all fishermen engaged in harvesting.

[2]Value deflated by wholesale price index (1957–1959=100).

4.1.4 Effects of Non-Fishery Uses on the Fish Resources

Lake Michigan is used for things other than fishing: navigation, water supply, waste disposal, and recreation. The following paragraphs discuss the physical, chemical, and biological changes generated by these other uses that directly or indirectly affect the fishery resource.

4.1.4.1 Effects of Chemical Changes

Lake Michigan has ranked third behind Lakes Erie and Ontario in increase in total dissolved solids, calcium, chlorides, sodium and potassium, and sulphates since the turn of the century (Figure 8–25). Green Bay and extreme southern Lake Michigan have been most affected and show unmistakable signs of accelerated eutrophication approaching rates found in Lake Erie.

Heavy metal concentrations in Lake Michigan do not appear to pose a threat to the fisheries, but DDT, dieldrin, and PCBs have reached such high concentrations that many fish, particularly larger predators, do not meet tolerance levels established for these materials. Recent restrictions on the use of DDT in Michigan and Wisconsin appear to have helped reduce the levels of DDT in fish flesh.

4.1.4.2 Effects of Physical Changes

Most physical changes in Lake Michigan have taken place on or near the shore areas. Shallow areas of Green Bay and the Bays DeNoc have been greatly affected because many former marsh areas were filled. Dredging and filling for navigation has had a pronounced effect on the character of the bottom in certain areas. Waste from sawmills had a major effect on estuary areas around the turn of the century, but mining waste has not been a major problem in the Lake Michigan watershed.

Filling and dredging, placement of shoreline stabilizing material, and dumping of harbor dredgings need to be closely controlled in order to protect nearshore spawning areas of important fish species.

4.1.4.3 Effects on Biological Changes

Effects of sea lamprey, smelt, and alewife have been most dramatic in Lake Michigan. The introduction and reestablishment of salmonids have been most successful in Lake Michigan because of the effective sea lamprey control program and the abundant forage base of alewife.

A decline in the larger species of chubs and whitefish early in the century was associated with overexploitation by the commercial fishery. Introduced smelt increased in abundance during the 1930s and became the second most important commercial species by 1940. Sea lamprey invaded the Lake in the 1940s and by 1950 it had destroyed or greatly reduced stocks of lake trout, burbot, whitefish, and larger species of chubs. With the disappearance of these species, particularly the lake trout and burbot that fed on small chubs, the small, slow-growing bloater increased to more than 90 percent of the coregonid population. The alewife was first recorded in Lake Michigan in 1949, but by 1959 it had become the most widely distributed and most abundant species in the Lake. The domination of alewife has been a further cause of the extreme imbalance in Lake Michigan. Some of the problems associated with their dominance are the severe biological stresses apparent in the bloater population, the continuing decline in abundance of the remaining chubs, the sharp decline in abundance and distinct change in the distribution of yellow perch, and the recent disappearance of the emerald shiner, an important forage species. Alleviation of problems presented by the alewife must come through control or suppression of their numbers. Steps taken by management agencies concern mainly the establishment and maintenance of efficient climax predators.

Fish management has been important in implementing position changes in the fish populations in Lake Michigan. Great Lakes management programs such as sea lamprey control, fish stocking programs, and regulation of the commercial harvest will determine the abundance of the more important species in the Lake, barring unforeseen environmental changes.

4.1.5 Fisheries Management

4.1.5.1 Past and Present Management

The broad goals of State management programs on Lake Michigan are similar to those for Lake Superior: to restore an optimum balance between prey and high-value predator species and then to apply management techniques that would establish the necessary balance between the fishing intensities of the recreational and commercial fisheries to assure maximum economic returns and to achieve optimum utilization of fish stocks. Management policies place high priorities on the recreational fishery. In the States of Michigan and Wisconsin where sizable commercial fishing operations are carried out, the aim is to enhance the commercial fishery by limited entry control.

Management measures under way on Lake Michigan include sea lamprey control, stocking of hatchery-reared salmonids, regulation of fishing, habitat improvement and maintenance, and development of public access.

Chemical treatment of the 99 lamprey streams on Lake Michigan by the U.S. Bureau of Commercial Fisheries commenced in 1960 and by 1966 the first round of treatments was completed. The effectiveness of these control measures is reflected in the resurgence of whitefish, rainbow trout, and burbot populations and the rapid growth and survival of planted coho salmon and lake trout. Chemical control will be continued to further reduce lamprey abundance.

The stocking program in Lake Michigan involves intensive annual plantings of lake trout, coho and chinook salmon and smaller annual plantings of rainbow, brook, and brown trout. This is aimed at restoring or providing optimum populations of high-value predator species.

Several agencies are cooperatively engaged in the lake trout program. The State of Michigan provides lake trout eggs from brood fish maintained in hatcheries. The U.S. Bureau of Sport Fisheries and Wildlife hatches and rears lake trout to yearling size and receives assistance from the States of Wisconsin and Michigan in distribution. The objective of lake trout stocking in Lake Michigan is similar to that in Lake Superior, to reestablish spawning stocks to a level where population can be sustained through natural reproduction. Annual plantings of lake trout in Lake Michigan began in 1965 and now total 7.3 million fish annually.

Coho and chinook salmon were introduced into Lake Michigan by the State of Michigan in 1966 and 1967 respectively, and annual plantings of both species have been carried out since that time. Coho plantings totaled 659,400 in 1966, 1,732,000 in 1967, and 1,177,000 in 1968. Chinook plantings totaled 801,400 in 1967 and 686,700 in 1968. The objective of the salmon program is to improve the recreational fishery and to develop control of the abundant alewife population by predation. Michigan's aims are to develop optimum salmon stocking rates from empirical data collected on growth, survival, and average size at harvest. The States of Wisconsin and Indiana are engaged in the coho program with modest plantings beginning in Wisconsin tributaries in 1968 and in Trail Creek of Indiana in 1970.

Annual plantings of less than 200,000 rainbow, brook, and brown trout have been made by Michigan and Wisconsin. Indiana initiated rainbow trout plantings in the east branch of the Calumet River in the fall of 1968 that will be continued annually if spawning runs develop. Current Michigan plans call for expansion of steelhead plantings in its waters using progeny of wild brood fish.

The commercial fishery of Lake Michigan operates under a series of regulations. Few are based on a biological understanding of current conditions within the Lake and some regulations are no longer useful. Most management agencies have adopted or proposed changes to correct the situation and to achieve greater uniformity of regulations on fish stocks of common concern.

Recent changes in commercial fishing regulations include the closure of all commercial fishing on lake trout, coho and chinook salmon, and migratory trout species. The objective is to provide maximum protection of these planted salmonids during the rehabilitation period. Michigan, Wisconsin, and Indiana have also employed permit and zoning systems to provide closer control over the gill-net fishery. These regulations attempt to provide more protection for planted salmonid species, to allow close surveillance of the gill-net fishery, and to prevent overexploitation of fish stocks.

Other regulatory procedures under way to improve management include Michigan's new authority to impose limited entry on the commercial fishery which is designed to control and promote the economic welfare of the commercial fishery. Methods of implementation are currently being developed. The entire Indiana Fish and Game Code was rewritten and approved in 1969. Generally speaking, the recodification removed regulatory authority from legislative action and placed it within the discretionary power of the Department of Natural Resources.

Sport fishing regulations have undergone a few basic changes in recent years. The four States recently enacted uniform sport fishing regulations governing seasons, size, and bag limits of salmonid species.

Michigan enacted legislation in 1968 requiring all Great Lakes anglers to be licensed. Anglers must also be licensed in Indiana, Illinois, and Wisconsin.

The States of Michigan, Wisconsin, and Indiana have established fishery stations on Lake Michigan and are currently developing monitoring programs to provide information on the abundance of fish of various species, sizes, and ages; distribution and existence as discrete populations; interrelations; and the extent utilized by sport and commercial fishermen. The State of Illinois has recognized the need for a similar program in its waters, but to date investigations have been limited to periodic observations of incidental catches of trout and salmon in the severely depressed commercial fishery that now subsists almost entirely on chubs.

Biological investigations carried out by the U.S. Bureau of Commercial Fisheries involve several long-range research projects to provide fundamental information on fish stocks of importance to State agencies for the solution of Lakewide management programs of interstate interest. The long-range objective is to understand the factors which influence changes in the survival and abundance of fish and to develop and maintain a balanced multispecies complex essential to realize the full productivity of the Lake.

Major investigations in Lake Michigan involve the evaluation of lake trout rehabilitation, assessment of coho, chinook, and other salmonid plantings, and monitoring of alewife and other commercial fish stocks. Sampling programs carried out by Michigan, Wisconsin, and Indiana are providing comparable information on the success and movement of different hatchery plantings, the incidence of lamprey wounding on trout and salmon, and growth and relative abundance of lake trout at various ages. In the future lake trout program emphasis will be placed on determining the relative abundance, age composition, and distribution of spawning stocks; the success of natural reproduction; recruitment rates; and mortality rates at various ages. The sampling program of the Bureau of Sport Fisheries and Wildlife provides information on changes in abundance, age composition, size distribution, and other biological characteristics of alewife and other important fish stocks. Considerable emphasis has been placed on all aspects of the life history of the alewife and its interrelations with other species and assessment of its year class strength in attempting to predict the magnitude and location of future alewife die-offs.

4.1.5.2 Cost of Fish Management and Development Programs

Some of the activities of the former Bureau of Commercial Fisheries (now National Marine Fisheries Service) have been taken over by the Bureau of Sport Fisheries and Wildlife and the estimated costs of these programs are included in Table 8–6.

Wisconsin estimates its annual enforcement costs at approximately $100,000, primarily for regulating the commercial fishery. Michigan's enforcement costs have ranged between $150,000 and $200,000 annually, primarily for the administration and enforcement of commercial fishing regulations. Illinois and Indiana each spend less than $15,000 a year.

The Bureau of Sport Fisheries and Wildlife estimates the annual cost of rearing and planting lake trout in Lake Michigan at $160,000. Wisconsin fish stocking costs have risen to more than $80,000 per year. Michigan costs for planting fish in Lake Michigan in 1971 hit an all-time high of $689,200. Indiana has a relatively minor stocking program that costs less than $15,000 a year. Illinois also has a small stocking program costing less than $5,000 a year.

The Bureau of Sport Fisheries and Wildlife operates a fishery research station on Lake Michigan at an annual cost of $77,900. Wisconsin estimates its fish management and research cost on Lake Michigan at $130,000 annually. Michigan operates a Great Lakes station on Lake Michigan at an estimated cost of $100,000 a year, and other management activities add another $100,000. Combined management and research costs for Illinois and Indiana are less than $50,000 a year.

4.1.6 Projected Demands

Projected demands for Lake Michigan commercial fish species are identical to those discussed in the introductory section on the Great Lakes.

Recreational demand is expected to follow the trends projected for the planning subareas in Plan Area 2.0. The Summary contains projected demand for each Lake by planning subarea (Table 8–75).

4.1.7 Problems and Needs

4.1.7.1 Natural Resource Base

Considered as a whole, Lake Michigan has exceptionally high water quality capable of supporting even the most intolerant aquatic organisms. However, because Lake Michigan's exchange rate is measured in years, the addition of nutrients and persistent toxic substances is cumulative over time. Therefore, Lake Michigan is vulnerable to waste inputs that might not affect lakes with more rapid exchange rates.

The shoreline areas and tributaries of Lake Michigan are essential to the maintenance of the high quality fishery resource. Any appreciable change in quality of shore waters or in tributaries will affect nearly all species in Lake Michigan.

Water quality standards must be rigidly enforced and anticipated development of nuclear power facilities must be carefully monitored if the high quality water and the fishery it supports is to be preserved.

4.1.7.2 Problems and Needs of the Total Fishery

Four major problems hampering the effective use of the fishery resources of Lake Michigan have been cited by the State management agencies:

(1) An optimum balance must be established between the prey and predator species in the Lake. Requirements for the solution of this problem are:

(a) reduction and maintenance of the sea lamprey at a level low enough to allow recovery or establishment of desirable predator species

(b) supression of the dominant alewife stocks through predation by large salmonids and prudent use of the commercial fishery

(c) intensive biological and environmental studies to provide fundamental information on factors controlling changes in survival and abundance of fish stocks. An understanding of these factors and their interactions is essential for the establishment and maintenance of a well-balanced multispecies complex in the Lake.

(2) Coordinated management programs must be developed to assure that fish populations are utilized on a sustained basis for maximum economic and sociological benefit. The solution of this problem requires:

(a) intensive biological and economic studies to provide the information needed to properly balance the fishing intensities of the sport and commercial fisheries

(b) development and public acceptance of limited entry control to improve the economic efficiency of the commercial fishery which is currently hampered by excessive operators and nonselective fishing gear

(c) full cooperation among agencies in developing coordinated and compatible management policies, philosophies, and programs

(3) Stringent pollution control measures must be enacted to curb the growing discharge of untreated domestic and industrial wastes into the Lake. These wastes have already caused distressing increases in the enrichment of waters in lower Lake Michigan and Green Bay. If the commercial and sport fisheries are to be fairly considered, pollution abatement agencies (State, Federal, or international) should consider the requirements of aquatic organisms in establishing water quality standards for Lake Michigan.

(4) Fishery agencies must obtain the necessary funds to sustain long-range management and research programs on Lake Michigan.

4.2 Planning Subarea 2.1

4.2.1 Species Composition, Relative Importance, and Status

Planning Subarea 2.1 (Figure 8–28) has diverse habitat conditions which contribute to a broad range of fisheries. Panfish (black crappies, bluegills, yellow perch) dominate the sport fishery in number of fish caught. However, most sport fishing interest is generated by the muskellunge, walleye, largemouth bass, northern pike, and trout fisheries of major lakes and streams within the region. Winnebago is the largest lake in the region, and although it is shallow, it provides outstanding fishing for walleye, yellow perch, white bass, sauger, and other species.

The region lying inland from the Lake Michigan and Green Bay shore counties has a high density of trout streams of major significance. These streams start out in shallow glacial drift overlying impervious bedrock, and as a result, have abundant supplies of high quality water.

Although this region does not encompass the original range of muskellunge, its introduction into larger lakes and reservoirs within the region has been successful and unparalleled muskellunge fisheries currently exist in both Michigan and Wisconsin waters.

A unique sturgeon fishery in the Menominee River is worthy of special mention. This is perhaps the largest naturally reproducing population of sturgeon in Wisconsin and Michigan and is the stronghold of a relict species threatened elsewhere by deteriorating water quality.

The interlobate glacial moraine extends through the region and has left numerous small "kettle" lakes characterized by their largemouth bass and panfish fisheries. Because of insufficient public access, these populations are presently largely unexploited.

4.2.2 Habitat Distribution and Quantity

Inland lakes and impoundments provide more than 315,948 acres of water for fishing. Lake Winnebago occupies 137,708 acres and is the largest single contributing body of water.

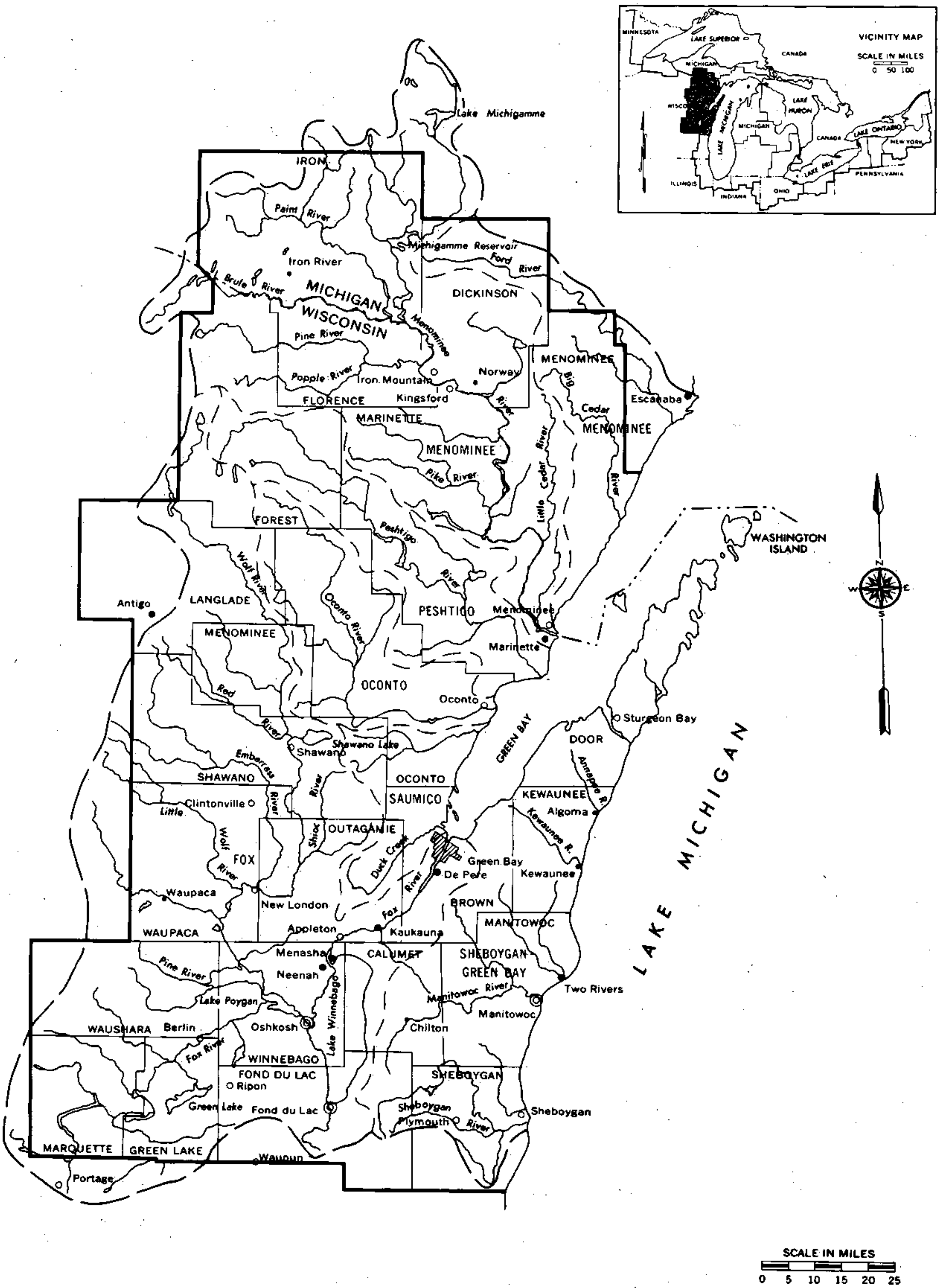


FIGURE 8-28 Planning Subarea 2.1

With this exception the bulk of the water area is distant from large population centers. The two counties with the lowest population (Florence, Forest) have the highest rate of ponded water per capita, and the county with the highest population (Brown) has the lowest rate of ponded water per capita. With the exception of Winnebago County, those counties with the highest ratios of ponded water per capita also have the highest ratios of licenses per capita. However, the largest number of licenses are sold in counties (except Winnebago County) with lesser areas of water available.

4.2.3 Habitat Problems Affecting Production and Distribution of Important Fish Species

That part of the region which has not experienced urbanization, the Michigan waters and headwaters areas in Wisconsin, has remained relatively unchanged in recent years. Improvements in sewage effluent handling in smaller communities may be enhancing the quality of the resource over what existed 10 or 20 years ago.

Extensive urbanization and industrialization in the area of the Fox River valley has threatened several bodies of water with pollution and nearly eliminated the sport fishery in much of the lower Fox River. Toxic substances at sublethal levels in fish in this area are threatening the use of fish for food in the industrialized Fox River valley.

With deterioration of the environment in the southern and eastern counties of the region, tolerant fish species, notably carp and white suckers, have increased. The southernmost counties in the basin encompassing the upper Fox River valley have been invaded by carp to the detriment of northern pike and largemouth bass populations. This is the only part of the basin that was heavily farmed and subjected to various drainage schemes. Northern pike used marshes for spawning areas. When these marshes were drained to facilitate crop production, the northern pike disappeared. Carp were introduced and further deteriorated conditions by destroying the remaining aquatic vegetation in their feeding activities.

As the basin was settled in the late 19th century, small communities were established on nearly all significant streams. Mills were constructed in these communities to utilize water power for timber and grain processing. These mills blocked seasonal migrations of northern pike and walleye and created pools which warmed many miles of trout streams.

The paper industries in the lower Fox River valley have had serious effects on fish population. The warming effect, fiber deposition, and chemical deterioration produced by these industries eliminated both warm- and coldwater fisheries in this, the principal stream in the basin.

4.2.4 History of Sport Fishery

Sport fishing license sales have remained relatively stable over the last 20 years. The greatest participation occurred in 1954 when 170,046 fishing licenses were sold in the basin. Changes in sport fishing license sales generally have been reflections of socio-economic changes rather than resource-related changes.

Improved management (introduction of muskellunge) and increased public access in recent years appear to have successfully countered the recent trend to more restrictive land tenancy (posting against trespass).

4.2.5 Existing Sport Fishing Demand and Current Needs

Current demand expressed by people living and buying licenses in this planning subarea is estimated to exceed 5.4 million angler days. This demand approximates 16 angler days per acre of pounded water. However, demand is not uniformly distributed throughout the planning subarea. Populous Winnebago County exerts a heavy demand on the lakes in the Winnebago complex, while counties in Michigan with extensive ponded water and less populous counties in Wisconsin may experience less than two angler days per acre of ponded water.

In-migration of licensed anglers from areas outside the planning subarea is substantial and may more than double this calculated demand. Recently improved highways have put the planning subarea in reach of Chicago area residents.

At present, demand for sport fishing is sufficiently exceeded by the supply of ponded water. Quality fishing can be easily experienced within the present capacity of the resource.

TABLE 8–15 Summary of Base Year Fish Habitat and Management Efforts, Planning Subarea 2.1

County	Total Area (sq.mi.)	Acres Ponded Waters	Number Ponded Waters	Number Intensively Managed	Acres Intensive Warmwater	Acres Intensive Trout	Miles Total Streams	Miles Trout Streams	Miles Anadromous Streams
Michigan									
Dickinson	763	6,324	119	4	748	97	645	203.0	---
Iron	1,219	24,593	528	16	396	4,101	902	313.2	---
Menominee	1,044	4,510	52	2	180	5	815	131.6	70
Wisconsin									
Brown	524	42	1	---	-----	------	30	1.8	---
Calumet	322	124	8	1	-----	10	75	------	---
Door	518	3,011	10	1	273	------	93	12.5	1
Florence	499	5,350	80	11	399	304	320	251.3	---
Fond du Lac	728	1,619	33	2	105	-----	271	13.8	---
Forest	1,055	20,451	155	19	5,532	1,239	570	480.4	---
Green Lake	388	14,336	10	5	789	7,370	218	6.4	---
Kewaunee	330	221	9	3	48	46	140	22.1	28
Langlade	867	7,879	167	27	2,764	809	450	326.0	---
Manitowoc	590	1,367	55	7	287	91	265	6.7	25
Marinette	1,402	13,134	159	9	4,332	465	685	550.0	3
Marquette	465	4,892	53	2	211	85	249	66.7	---
Menominee	359	2,419	49	6	-----	440	395	279.6	---
Oconto	1,189	12,759	142	12	2,660	120	400	261.1	---
Outagamie	631	66	2	1	62	------	140	------	---
Shawano	1,106	10,294	54	6	582	2	594	330.5	---
Sheboygan	508	2,050	35	10	533	463	264	31.8	10
Waupaca	766	6,660	117	16	453	531	337	158.6	---
Waushara	633	4,297	64	15	2,024	431	223	144.1	---
Winnebago	858	169,550	6	1	3,070	------	70	------	---
Total	16,764	315,948	1,908	176	25,448	16,609	8,151	3,591.2	136

4.2.6 Ongoing Programs

Northern pike, muskellunge, and walleye are the principal warmwater species managed in this planning subarea. The current warmwater stocking program includes more than 60 lakes (Figure 8–29) and a total of 25,448 acres of ponded water (Figure 8–30 and Table 8–15).

Trout stocking management encompasses 72 lakes in Wisconsin and more than 16,609 acres of water. Those species included in this program are brown trout, splake, brook trout, chinook salmon, and coho salmon. The inland coho program is currently conducted on only one lake in the planning subarea.

Coho are also stocked in eight streams within the planning subarea, all tributaries of Lake Michigan or Green Bay. Chinook salmon has been stocked in two streams, the Menominee and Strawberry Rivers, and is expected to provide a fishery in future years. Salmon plantings will exhibit their greatest influence in the Great Lakes, but they may also attract anglers who utilize other fisheries within the planning subarea (Figure 8–31).

An extensive ongoing program of chemical rehabilitation of lakes and river systems is being conducted. In 1969, 14 lakes and river systems underwent chemical rehabilitation to eliminate carp and stunted panfish populations.

Acquisition of fish habitat and access is intended to provide greater utilization of the existing resource base. This ongoing program has established annual goals, but its accomplishments are unpredictable.

4.2.7 Future Trends in Habitat and Participation

Future demand based on the current relationship of habitat base to number of fishermen indicates that there will be an increase of 800,000 angler days by 1980. While the present resource supply is sufficient for 1980 demands on this basis, increases in in-migration of anglers will dramatically affect the supply-demand relationship (Table 8–16).

Future supplies of ponded water will not change appreciably, but as a result of ongoing programs, particularly lake rehabilitation, carrying capacity for optimum fishing will be increased. This possibility exists on more than 10,000 acres in Wisconsin waters alone.

Acquisition of water frontage will increase the availability of the existing resource supply and therefore, the attractiveness of the area

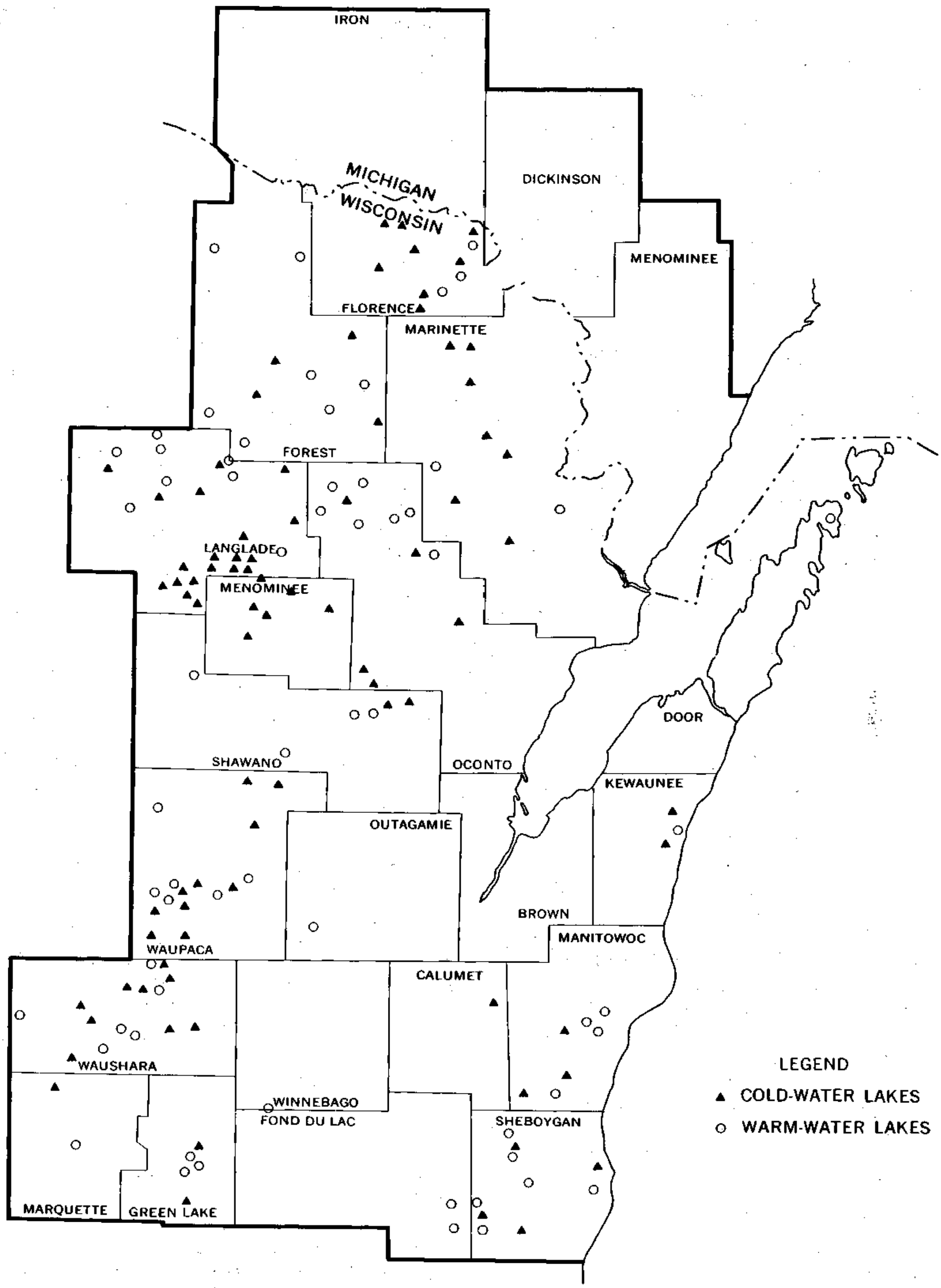


FIGURE 8–29 Current Fish Stocking Program, Planning Subarea 2.1, Wisconsin Portion

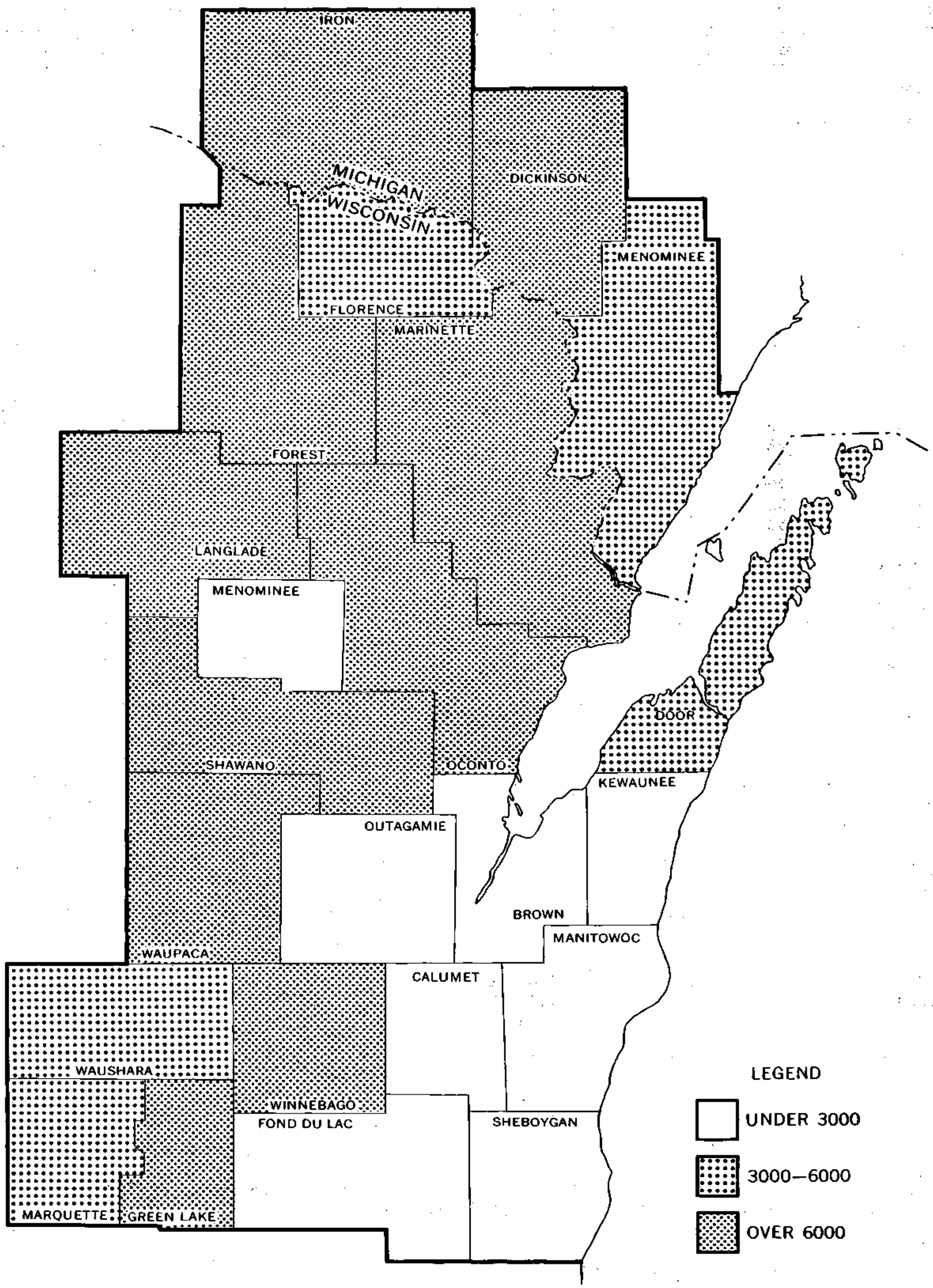


FIGURE 8–30 Acres of Ponded Water, Planning Subarea 2.1

TABLE 8–16 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 2.1

States and Counties	Land Area (sq.mi.)	Population (1000s)	Population per sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
Michigan								
Dickinson	755	24.6	32.6	6,324	.0257	2,830	3,967	.0161
Iron	1,165	15.2	13.0	24,593	.1618	5,493	3,213	.0211
Menominee	1,034	23.1	22.3	4,510	.0195	1,525	3,292	.0143
Total	2,954	62.9	21.3	35,427	.0563	9,848	10,472	.0166
Wisconsin								
Brown	524	137.7	262.8	42	.0003	173	13,598	.0988
Calumet	322	24.1	74.8	124	.0051	212	4,633	.1922
Door	491	20.4	41.5	3,011	.1476	612	1,813	.0889
Florence	486	3.2	6.6	5,350	1.6719	1,397	1,646	.5144
Fond Du Lac	724	80.0	110.5	1,619	.0202	1,494	14,061	.1758
Forest	1,005	7.5	7.5	20,451	2.7268	2,143	5,027	.6703
Green Lake	354	15.5	43.8	14,336	.9249	6,739	7,213	.4654
Kewaunee	330	19.4	58.8	221	.0114	65	2,282	.1176
Langlade	848	20.6	24.3	7,879	.3825	2,537	7,661	.3719
Manitowoc	587	78.6	133.9	1,367	.0174	205	10,086	.1283
Marinette	1,370	34.2	25.0	13,134	.3840	4,001	10,163	.2972
Marquette	452	7.6	16.8	4,892	.6437	4,676	3,537	.4654
Menominee	353	----[1]	----[1]	2,419	-----[1]	114	240	-----[1]
Oconto	1,158	25.2[1]	21.8	12,759	.5063	2,450	9,250	.3671
Outagamie	631	111.8	177.2	66	.0006	907	19,341	.1730
Shawano	1,081	35.7	33.0	10,294	.2883	2,041	11,762	.3295
Sheboygan	503	94.1	187.1	2,050	.0218	371	11,964	.1271
Waupaca	750	38.1	50.8	6,660	.1748	8,426	12,068	.3167
Waushara	623	13.8	22.2	4,297	.3114	2,534	6,278	.4549
Winnebago[2]	448	117.6	262.5	169,550	1.4418	7,565	23,874	.2030
Total	12,687	885.1	69.8	278,102	.3142	48,548	176,617	.1995

States and Years	Land Area (sq.mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand: Resident[3]	Projected Angler Day Demand: Total[4]
Michigan					
1980	2,954	66.1	22.4	53,000	108,000
2000	2,954	74.1	25.1	59,422	126,000
2020	2,954	86.1	29.1	69,045	150,000
Wisconsin					
1980	12,687	1,016.1	80.1	7,094,107	12,979,000
2000	12,687	1,283.5	101.2	8,961,015	16,082,000
2020	12,687	1,639.9	129.3	11,449,293	20,065,000
Total PSA 2.1	15,641	948.0	60.6		
1980	15,641	1,082.2	69.2	7,147,113	13,087,000
2000	15,641	1,357.6	86.8	9,020,437	16,154,000
2020	15,641	1,726.0	110.4	11,518,338	20,215,000

[1] Menominee County included in Shawano County. Menominee County was created since 1960 from Menominee Indian Reservation, formerly part of Shawano and Oconto Counties.

[2] Includes Lake Winnebago.

[3] Demand generated within planning subarea.

[4] Total demand including in- and out-migration.

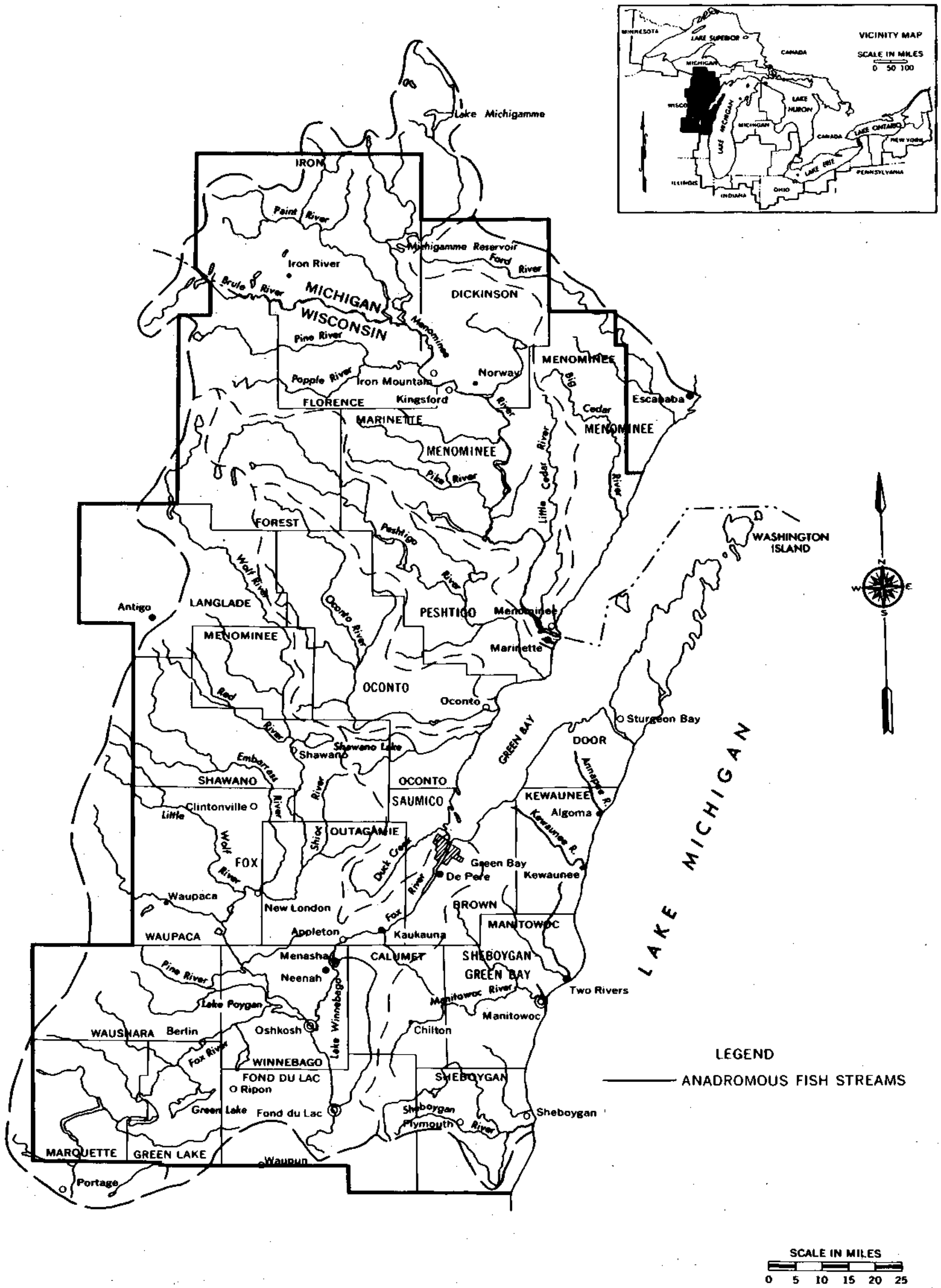


FIGURE 8–31 Anadromous Stream Fishery, Planning Subarea 2.1

for tourist fishing. There are more than 70 active acquisition projects at present, all with long-range goals of completion.

4.2.8 Fishery Development Plans

A new anadromous fish hatchery now being developed in Wisconsin will have a great effect on streams. By assuming the responsibility for production of salmon for this planning subarea, it will free other rearing stations to provide additional fish for inland stocking.

Similarly, a new warmwater hatchery planned for Planning Subarea 4.1 will insure maintenance and perhaps enhancement of the unique sturgeon and muskellunge fisheries. Wisconsin's muskellunge propagation program shows continual increases in production which will substantially enhance the muskellunge fishery in Planning Subarea 2.1

Lake and watershed fishery rehabilitation and development programs are ongoing programs which will enhance warmwater fisheries most noticeably in the southernmost counties of the planning subarea.

4.2.9 Michigan's Comments on Species Composition, Relative Importance, and Status

Two unique fisheries are found in this planning subarea. The Menominee River sturgeon represents the largest naturally reproducing population of this rapidly disappearing species in the State. Iron Lake in Iron County supports a population of muskellunge unparalleled in Michigan. Both of these fish populations are utilized as sources of eggs for hatchery propagation of these species to expand their current range. The small streams and headwaters of major rivers in the area provide excellent brook trout fishing. Larger rivers and streams too warm for trout have good populations of intermediate warmwater fish such as smallmouth bass and northern pike. Nearly all streams directly tributary to Lake Michigan have runs of both trout and smallmouth bass which are seasonally important fisheries.

Although panfish dominates the inland lakes and reservoir catches in number, smallmouth bass, largemouth bass, walleye, muskellunge, northern pike, and trout keep angler interest high and may account for a majority of the angling effort in the three counties in Michigan. The river fisheries are also sustained by high quality fishing for trout and the larger warmwater species.

In general, the water quality of lakes and streams is excellent, and does not restrict the range of important species.

4.2.9.1 Habitat Distribution and Quantity

Inland lakes and impoundments of the three counties provide more than 35,000 acres of water for fishing (although 25,000 acres are located in Iron County). The distribution of water is directly related to license sales. Iron County, which has the highest ratio of ponded water per capita, has the largest number of fishermen.

4.2.9.2 Habitat Problems Affecting Production and Distribution of Fish Species

Unlike areas in southern Michigan, fishing quality in this area has remained relatively stable for the last 20 years.

Many of the lakes and most of the streams remain relatively undeveloped. Local water quality problems associated with the few urban areas are in the process of being improved, and existing State standards are designed to protect the waters of the area from further degradation in quality.

If good zoning laws and development plans are initiated, habitat problems common to more urbanized areas can be avoided in Planning Subarea 2.1.

4.2.9.3 History of Sport Fishery

Sport fishing license sales in the Michigan portion have been relatively stable for the last 20 years. The highest number of resident licenses, 11,082, was sold in 1969. There has been a slow upward trend in fishing license sales since 1964.

These license sales figures generally indicate that fishing quality has remained the same.

4.2.9.4 Existing Sport Fishing Demand and Current Needs

Demand in the Michigan portion of Planning Subarea 2.1 is unusual in that approximately the same number of residents and nonresidents buy fishing licenses. Many Wisconsin residents utilize the fishing opportunities available in the Michigan portion of this planning subarea. The current fishing demand, 50,000 angler days, does not include the inmigration of licensed anglers from other portions of the State which may more than double this calculated demand based on license sales.

This area could sustain more fishing activity on the present resource. The existing pressure is probably less than two angler days per acre of ponded water.

The present long travel time from urban areas discourages full use of the fishery resources of this area. Improved transportation and promotion could increase the use of fishery resources.

4.2.9.5 Ongoing Programs

Northern pike, muskellunge, and walleye are the primary warmwater species managed in this planning subarea through artificial propagation. The current warmwater management program involves approximately 1,300 acres of water (Figure 8–32 and Table 8–15).

Trout management in lakes involves more than 20 lakes and approximately 4,000 acres. In 1969 more than 154,250 brook, brown, and rainbow trout were stocked primarily in Iron County.

The anadromous fish management program was initiated in 1969 when 62,000 coho salmon were stocked in the Big Cedar River in Menominee County. In 1970 the Menominee River was also stocked with 50,000 coho and 100,000 chinook salmon. Both of these rivers are expected to provide fisheries for salmon in the few miles open to anadromous fish. Perhaps this new attraction will draw sportsmen who will also use other area fishing opportunities.

4.2.9.6 Future Trends in Habitat and Participation

Future demand based on the current relationship of habitat base to number of fishermen indicates that the current 110,000 angler days will increase to 138,000 by 1980. This small increase can be supplied easily by existing programs. However, this planning subarea should be attracting fishermen from other planning subareas where the resource base is limited.

High quality and unique fisheries should be promoted and developed to attract fishermen from other areas. Latent fishing demand within the planning subarea is probably small (Table 8–16).

4.2.9.7 Fishery Development Plans

The new warmwater hatchery planned for Planning Subarea 4.1 will insure maintenance and perhaps enhance the unique sturgeon and muskellunge fisheries. This hatchery may also provide limited walleye for these lakes. No capital expansions are planned at this time outside of the small watershed project now being considered on the Sturgeon River in Dickinson County. Acquisition of key lands may become important in the future, but no money will be put to this purpose on Planning Subarea 2.1 before 1980.

4.3 Planning Subarea 2.2

This planning subarea encompasses parts of Illinois, Indiana, and Wisconsin along the southwestern portion of Lake Michigan (Figure 8–33).

4.3.1 Illinois

4.3.1.1 Existing Sport Fishing Demand and Current Needs

The total angler day demand on inland waters has stabilized since the mid-1950s in this highly urbanized basin area. The 455,866 (licensed and unlicensed) fishermen (1970) generate a fishing demand of about 8.2 million days per year of which 10.5 percent (861,586 days) are generated by Lake Michigan. The total inland water areas approximate 30,364 acres of impoundments and 11,520 acres of public streams and should provide 816,700 angler days per year based on 25 angler days per year per acre of impoundment and 5 angler days per year per acre of stream. However, much of this water area is not available for fishing for the following reasons: poor fish populations, multiple use conflicts, poor fish habitat and water quality, or water not manageable for sustained quality sport fishing. Lake Michigan has increased in popularity due to the improved salmonid fishery.

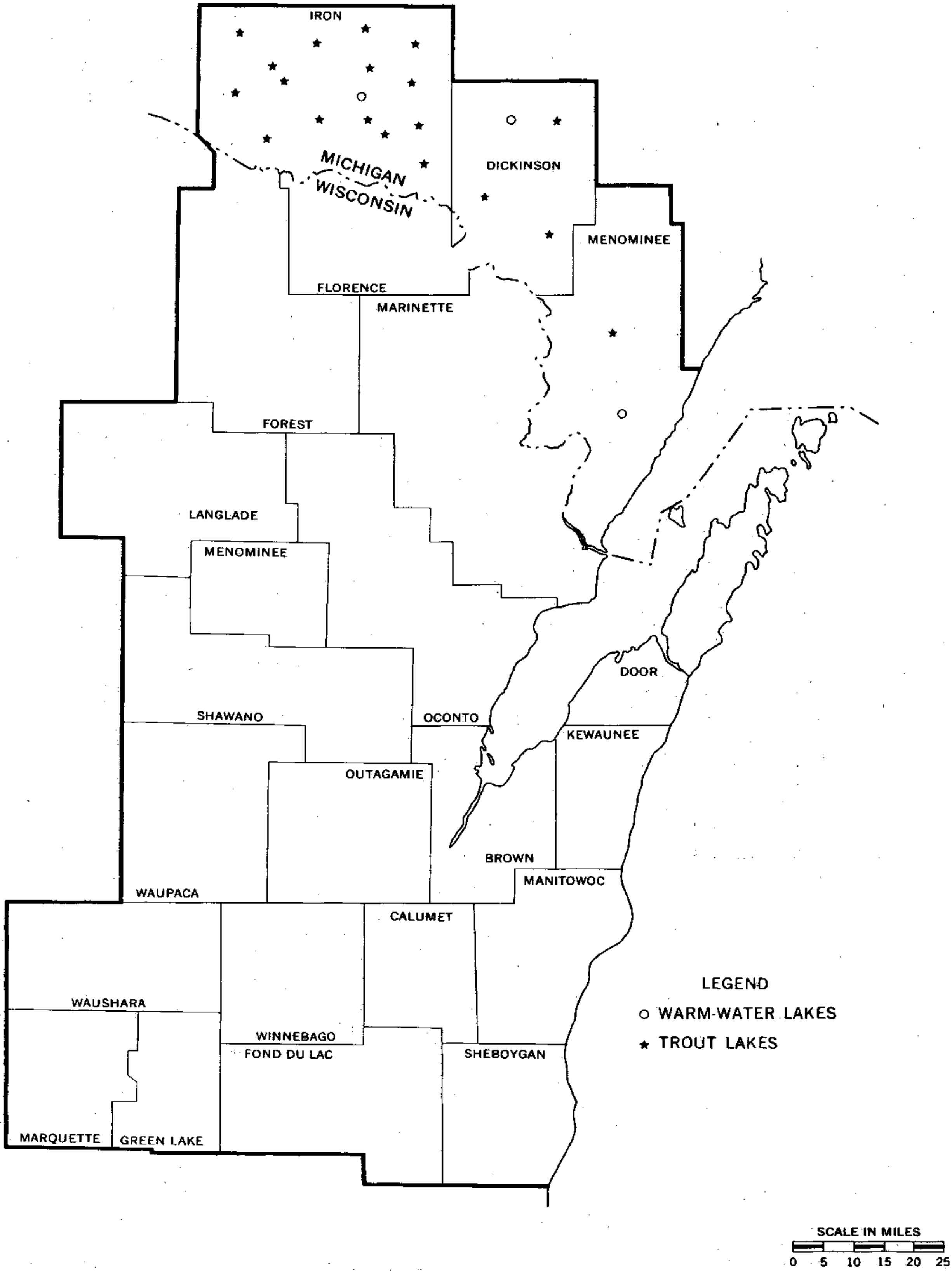


FIGURE 8-32 Current Fish Stocking Program, Planning Subarea 2.1, Michigan Portion

The Lake has generated more than 800,000 angler days of fishing in recent years. Improved salmonid, yellow perch, and smelt fishing have been the major attraction.

Resident sport fishing license sales have increased slowly since the mid-1950s. This is attributable to population growth and possibly to the new salmon and trout fishery in Lake Michigan. Resident licenses sold in the planning subarea totaled 273,520 in 1970 with only 1,267 non-resident licenses sold. This indicates very little in-migration from other States. Licensed fishermen represent 3.9 percent of the area population while the total licensed and unlicensed fishermen are estimated to represent 6.5 percent of the total population (7,000,000).

Most of the demand is on a short-term basis (near home) while long-term fishing demand (vacations and weekends) is usually satisfied outside the area. If more quality fishing opportunities were available, more people would go fishing in the area. An estimated 1.6 million angler days are provided in the area with the remaining demand supplied by other areas, principally Michigan and Wisconsin and the larger rivers and reservoirs throughout Illinois.

The sport fishery has the following needs:

(1) more sport fishing opportunities within urbanized areas, particularly an urban fishing program in poverty areas within cities

(2) an accelerated public and State lake construction program

(3) more intensive fish management to improve the quality of fishing

(4) expansion of the salmonid program in Lake Michigan through increased hatchery production and fish planting

(5) stricter enforcement and monitoring regarding water pollution laws

(6) protection and enhancement of desirable fish habitat

(7) additional public access to fishable waters

4.3.1.2 Ongoing Programs

The primary function of the Division of Fisheries is to provide technical fishery management services and advice. Management practices, such as lake and stream surveys, population analysis, fish rehabilitation projects, aquatic weed control, and public relations work, are but a few of the activities undertaken in the area. During 1971, 84 water areas in the six county area underwent 29 population analyses, 4 weed control projects, and 11 fish rehabilitation projects. Considerable time was spent on the Lake Michigan salmonid project. Several access areas were proposed and surveyed on the heavily used Chain O'Lakes, and several State lake development sites were investigated.

Fish stocking of new or rehabilitated inland waters and of Lake Michigan is an essential part of the overall fisheries program. Fingerling largemouth bass, bluegill, and redear sunfish are provided to approved water areas each year. During 1971, 63 approved water areas received a total of 39,165 fingerling bass, 212,845 fingerling bluegill, and 19,700 fingerling redear sunfish. In addition, Lake Michigan received 4,621 yearling coho, 7,604 yearling chinook salmon, 18,065 yearling rainbow, 8,263 brown trout, and 100,000 yearling lake trout during 1971. Since experimental plantings of salmon began in 1969 in the Illinois portion of Lake Michigan, the upgrading of the Spring Grove Hatchery, which will produce at least 50,000 coho and 50,000 chinook fingerlings, is an important part of the current hatchery program.

4.3.1.3 Future Trends in Habitat and Participation

The current angler day demand generated cannot provide quality fishing with the amount, type, and availability of the water that presently exists let alone meet the future needs within the area. The estimated demands generated in 1980 will be 9.2 million angler days, in 2000 there will be a demand of 11.2 million days, and in 2020 the demand anticipated is 13.8 million days. Presently, only about 1.6 million days of fishing are satisfied in the area on a short-term basis. There will be a deficit of 6.6 million angler days in the area if it is assumed that inland waters consisting of 30,364 acres of impoundments and 11,520 acres of public streams will satisfy approximately 816,000 angler days and that the Illinois portion of Lake Michigan consisting of 1,024,000 acres will satisfy close to 861,000 angler days. If 25 angler trips per year per new acre of new or rehabilitated water can be provided, it would take an additional 268,000 acres of such impounded water to satisfy fishing needs within the area. National surveys indicate that an estimated 8 percent of the population would like to start fishing and another 13 percent would like to fish more. This would add a substantial number of angler days to the

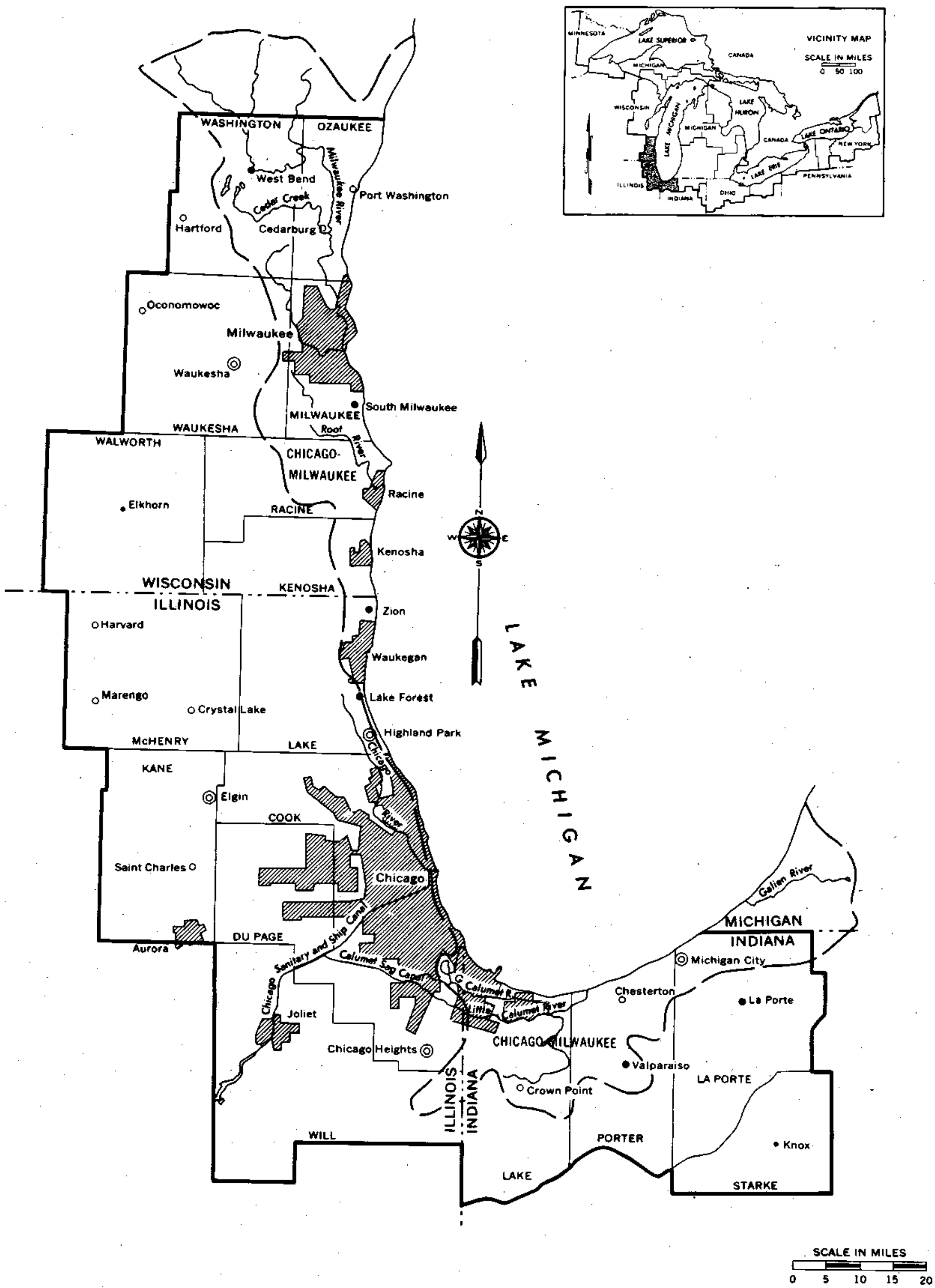


FIGURE 8–33 Planning Subarea 2.2

existing deficit. The continual urbanization of this area will not permit the satisfaction of future anticipated demand within the area because lake sites of this magnitude are not available and if such lake projects were feasible, the costs would be prohibitive. The only alternative is for the generated demand to be met outside of the planning subarea, preferably in the urban fringe area not more than a 2-hour drive from the urban center, and by Lake Michigan.

Protection and enhancement of existing fisheries habitat is essential, but difficult because of urbanization. Habitat can be created on less valuable land at great expense by excavating lakes, impounding wet, marshy areas, rebuilding existing bodies of water, and improving water quality.

4.3.1.4 Fishery Development Plans

Present capital and operational expenditures each run about 1.2 million dollars. Capital requests funded for major projects included the DeKalb County Shabbona Lake Construction ($850,000), deficit area lake site feasibility studies ($100,000), a pilot urban fishing program ($20,000), and salmon rearing and imprinting project ($50,000). A source of funds in the amount of 4 million dollars has not been found for the much needed cold- and warmwater fish hatchery, nor has the $150,000 needed annually to operate the hatchery. None of the above expenditures are completely located in the planning subarea except the urban fishing and salmon projects. However, all partially involve the planning subarea and, coupled with other expenditures, will probably exceed 6 million dollars by target year 1980 if funded.

4.3.2 Indiana

4.3.2.1 Species Composition of the Fishery

The sport fishery in this planning subarea is as varied as any five-county area in the State. Fishing waters range from Lake Michigan to the north to the Kankakee and Yellow Rivers to the south, to a small portion of the St. Joseph River to the east. They also include a few trout streams and several lakes (up to 1,850 acres).

The Lake Michigan sport fishery centers around coho and chinook salmon, lake trout, steelhead, brown trout, and yellow perch. In the months of March, April, and May, there is a concentration of young (2 to 4 pounds) coho salmon in the southernmost part of the Lake. During a recent spring catch, sport fishermen landed an estimated 80,000 coho salmon.

A few steelheads, brown trout, chinook, and lake trout are also taken during these months, but many more are caught in the fall. Steelhead and chinook salmon spawning runs start in Trail Creek in La Porte County and in the Little Calumet River in Porter County in early September. Lake trout and yellow perch fishing is also good in the Lake at about the same time or a few weeks later. Brown trout are not abundant, but more are caught in the fall and winter (around hot-water discharges) than in the spring.

The Kankakee and Yellow Rivers are two of the better fishing streams in Indiana. The Kankakee provides one of the few walleye fisheries in the State. Both rivers contain northern pike, channel catfish, largemouth bass, smallmouth bass, and rock bass. These sport fish are accompanied by a broad range of rough species: carp, buffalo, shad, bullheads, carp-suckers, whitesuckers, and redhorse.

The St. Joseph River has lower water quality but it does support a surprisingly good smallmouth bass population in the South Bend area. However, rough species dominate, with carp probably the most abundant.

Trout streams stocked on a put-and-take basis are found in Porter, La Porte, and St. Joesph Counties. These streams are generally small and offer limited opportunity.

The natural lakes in the planning subarea range from highly eutrophic to water capable of supporting trout year around. Some lakes in Marshall County have been stocked with trout. Most of the lakes support bass and bluegill fisheries and have a long list of other species which is presented on page 109. The commercial fishery of the planning subarea is confined to Lake Michigan. Reported catch of the most important species for the last several years is presented on page 109. The 1972 commercial catch was valued at $126,465.

4.3.2.2 Habitat Problems Affecting Production and Distribution of Fish Species

Water quality degradation and channelization are probably the biggest threats to sport fish habitat in this planning subarea. Water quality ranges from excellent to horrible

Species	1970	1971	1972	1973
yellow perch	205,764	333,850	340,213	252,957
suckers	——	208,984	17,659	12,647
chubs	74,390	28,489	38,262	35,701
whitefish	3,816	22,636	999	815
lake trout	8,079	25,790	13,903	7,049
coho salmon	3,227	5,083	1,157	217

Common Name	Scientific Name
yellow perch	*Perca flavenscens*
rock bass	*Ambloplites rupestris*
bluegill	*Lepomis macrochirus*
longnose gar	*Lepisosteus osseus*
white bass	*Roccus chrysops*
gizzard shad	*Dorosoma cepedianum*
white sucker	*Catostomus commersoni*
longear sunfish	*Lepomis megalotis*
carp	*Cyprinus carpio*
black crappie	*Pomoxis nigromaculatus*
spotted sucker	*Minytrema melanops*
pumpkinseed	*Lepomis gibbosus*
smallmouth bass	*Micropterus dolimieui*
black bullhead	*Ictalurus melas*
warmouth	*Chaenobryttus gulosus*
spotted gar	*Lepisosteus oculatus*
yellow bullhead	*Ictalurus natalis*
lake chubsucker	*Erimyzon sucetta*
largemouth bass	*Micropterus salmoides*
golden shiner	*Notemigonus crysoleucas*
bowfin	*Amia calva*
walleye	*Stizostedion vitreum*
grass pickerel	*Esox americanus*
northern hog sucker	*Hypentelium nigricans*
channel catfish	*Ictalurus punctatus*
green sunfish	*Lepomis cyanellus*
brook silverside	*Labidesthes sicculus*
mud minnow	*Umbra limi*

within the same county. Municipal, domestic, and industrial wastes appear to be the primary causes of low water quality. This degradation is widespread in the large industrial and residential complexes.

Almost all the streams and rivers in this area have been channelized to varying degrees. Certainly one of the major habitat losses occurred with the draining of the Grand Kankakee Marsh. Only remnants are left of the hundreds of thousands of wetland acres which fed the Kankakee River.

4.3.2.3 Ongoing Programs and Current Needs

The diversity of the sport fishery in this planning subarea has been described. It should also be pointed out that the fishery is limited in terms of the resource versus demand (Table 8–17). This is an area which probably has all the water it will ever have with the exception of farm ponds. Realizing this, we believe that the maximum sport fishing potential must come from existing waters. Therefore, salmon and steelhead runs have been established in Lake Michigan tributaries, and a hatchery is being constructed to support this program.

A gradual improvement in water quality through the efforts of the Indiana State Board of Health will greatly benefit the sport fishery of the area. This will be a slow process, but progress is being made, especially near Lake Michigan. Most of the natural lakes in the planning subarea will probably be placed under intensive management as fishing demand grows. It may also be necessary to revise our present philosophy which limits use of the put-and-take concept if the projected demand in Table 8–17 is to be met. Regardless of what future course is followed, expansion of present capabilities will be prerequisite to meeting need.

4.4 Planning Subarea 2.3

4.4.1 Species Composition, Relative Importance, and Status

Planning Subarea 2.3 (Figure 8–34) contains a wide range of fishery habitat. Crappie, perch, rock bass, bluegill, and other sunfish dominate the sport catch in the inland waters of this area. Large- and smallmouth bass, trout, walleye, northern pike, and muskellunge are highly prized for their sporting value. Anadromous salmonids, including steelhead, brown trout, and coho salmon, have added a new dimension to the stream fishery. Catfish, bullhead, sucker, cisco, carp, gar, bowfin, and sturgeon add variety to traditional hook-and-line fishing and to specialized netting, spearing, and bow-and-arrow fisheries of this area.

Inland lakes provide the majority of angling opportunities. However, many of the lakes are dominated by stunted panfish and rough species instead of larger more desirable game fish. Selective exploitation of larger fish is greatly responsible for the decline in quality of the inland lake fishery.

The stream fishery is dominated by warmwater species such as smallmouth bass, northern pike, rock bass, and suckers. A few good trout streams consistently provide a high intensity fishery in the few miles available.

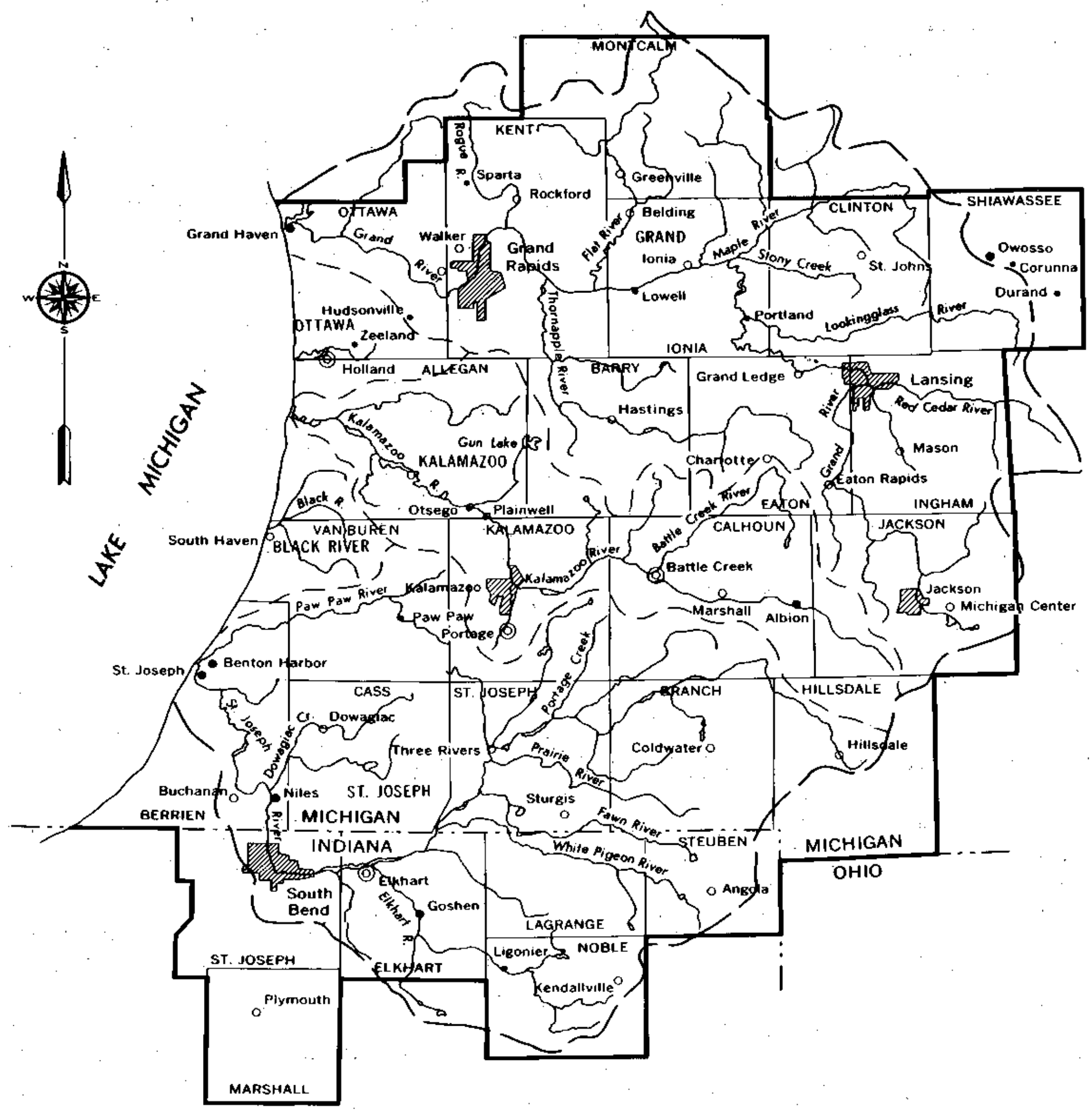
TABLE 8–17 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 2.2

States and Counties	Land Area (sq.mi.)	Population (1000s)	Population per sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
Illinois								
Cook	949	5,492.4	5,787.6	7,174	.0013	837	152,190	.0277
Du Page	330	491.9	1,490.6	1,206	.0024	5	12,053	.0245
Kane	518	251.0	484.6	786	.0031	25	21,127	.0842
Lake	454	382.6	842.7	13,333	.0348	349	61,916	.1618
McHenry	608	111.5	183.4	4,001	.0358	21	8,234	.0738
Will	841	245.5	291.9	3,864	.0157	30	18,000	.0733
Total	3,700	6,974.9	1,885.1	30,364	.0043	1,267	273,520	.0392
Indiana								
Lake	511	523.9	1,025.2	1,024	.0020	1,724	38,333	.0732
La Porte	590	105.1	178.1	1,605	.0153	803	11,320	.1077
Porter	423	75.5	178.5	375	.0050	217	7,226	.0957
Starke	310	19.4	62.6	1,822	.0939	871	3,759	.1938
Total	1,834	723.9	394.7	4,826	.0067	3,615	60,638	.0838
Wisconsin								
Kenosha	272	113.7	418.0	3,423	.0301	10,767	12,482	.1098
Milwaukee	236	1,038.5	4,400.4	96	.0001	2,563	92,201	.0888
Ozaukee	234	44.6	190.6	270	.0061	71	4,384	.0983
Racine	337	156.3	463.8	3,608	.0231	1,291	17,356	.1110
Walworth	552	58.8	106.5	12,526	.2130	14,501	9,161	.1558
Washington	427	53.7	125.8	3,168	.0590	301	9,663	.1799
Waukesha	553	193.8	350.5	14,872	.0767	1,449	34,769	.1794
Total	2,611	1,659.4	635.5	37,963	.0229	30,801	180,016	.1085

States and Years	Land Area (sq.mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand	
				Resident[1]	Total[2]
Illinois					
1980	3,700	7,884.8	2,131.0	8,256,000	1,500,000
2000	3,700	9,625.8	2,601.6	10,079,000	2,000,000
2020	3,700	11,782.0	3,184.3	12,338,000	2,000,000
Indiana					
1980	1,834	914.6	498.7	2,352,342	200,000
2000	1,834	1,221.6	666.1	3,141,942	400,000
2020	1,834	1,611.2	878.5	4,143,990	400,000
Wisconsin					
1980	2,611	2,199.6	842.4	7,857,053	1,500,000
2000	2,611	2,997.0	1,147.8	10,705,395	2,000,000
2020	2,611	3,992.5	1,529.1	14,261,358	2,000,000
Total PSA 2.2	8,145	9,358.2	1,148.9		
1980	8,145	10,999.0	1,350.4	18,465,395	3,200,000
2000	8,145	13,844.4	1,699.7	23,926,337	4,400,000
2020	8,145	17,385.7	2,134.5	30,743,348	4,400,000

[1]Demand generated within planning subarea.

[2]Total demand including in- and out-migration.



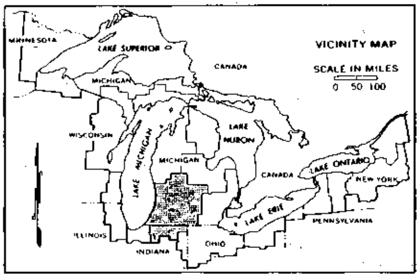


FIGURE 8–34 Planning Subarea 2.3

Decline in fish habitat is the primary cause for poor quality and lower angler interest in warmwater streams and rivers in this area.

The steelhead and salmon fisheries have generated new angler interest in the large rivers of this area, particularly in the lower Grand, Kalamazoo, and St. Joseph, all of which had an adult run of coho salmon for the first time in the fall of 1970. Dams on these rivers now block migration and exclude large upstream areas that could benefit from an anadromous trout and salmon fishery.

Considerable room for improvement exists, and new fishing opportunities can be provided. Warmwater lake, trout lake, warmwater stream, trout stream, and anadromous stream fisheries all can be improved by stocking and maintenance of high-value sport species. In many cases water quality improvement, chemical rehabilitation, fish passage, and land acquisition should precede, or at least coincide with predator stocking programs.

4.4.2 Habitat Distribution and Quantity

The impoundments and natural inland lakes in Planning Subarea 2.3 provide more than 104,000 surface acres of fishable water (Figure 8–35). The ponded water per capita varies from a high of .299 in Barry County to a low of .003 in Ingham County. This sporadic distribution of fishable water does affect license sales: Barry County has the highest resident fishing license sales per capita, .248, and Ingham has the lowest, .069 (Table 8–18). Ingham, Clinton, and Eaton Counties encompass the second largest population center in the planning subarea and yet have a total of less than 2,500 acres of water.

4.4.3 Habitat Problems Affecting Production and Distribution of Important Fish Species

Many factors affect the production and distribution of game fish in southwest Michigan. The quantity and distribution of inland waters is important, but, except for constructing impoundments, little can be done to change the size or placement of the resource base. However, the quality of this water resource and kinds of game fish available can be altered through direct management.

Many inland lakes in this area show effects of eutrophication caused by domestic sewage. While eutrophic lakes are often more productive in a total biological sense, desirable game fish and the quality of fish habitat are seriously diminished.

Urban development near inland lakes has created other problems. Filling and dredging of inland lakes have destroyed many natural spawning areas used by valuable game fish such as northern pike, bass, and panfish. Heavy selective fishing in many lakes has resulted in the reduction of fish populations to stunted panfish. Competing uses such as water skiing and speed boating have reduced the aesthetics of the fishing experience, and in some cases, the surface area available for angling.

Inland lake levels also affect fish reproduction. In general, reproduction of valuable species increases during periods of high lake levels. However, the actual fluctuation of the level may be the important factor in increasing reproduction. If marshes and impoundments are allowed to drain periodically, they can enhance fish production. Depending upon the time of year it occurs, high water may have positive effects.

Rivers and streams in southwest Michigan have suffered from both physical abuse and pollution. These problems are now partially controlled, but in many cases, damage to fishing cannot be repaired without extensive chemical rehabilitation and maintenance stocking of valuable species. More than 60 miles of the Grand, Kalamazoo, and Black (Holland) river systems have severe water quality problems related to dissolved oxygen. These problems restrict even the most minimal types of sport fishing.

Increases in stream temperatures due to municipal and industrial waste discharge and impoundments are significant factors in the present range of intermediate warmwater species such as smallmouth bass and northern pike. Increased stream temperatures are also an adverse factor in extending the range of anadromous salmonids.

The changing watershed in this area has affected the quality of river fishing. Water quality is critical during periods of low flow, and as urban development covers more of the natural drainage area with asphalt and concrete, low flows are more intense and their duration lasts longer. Flood damage to fish habitat also occurs when river flows are left uncontrolled in highly developed areas.

Soil erosion from construction and agricultural practices in the watersheds of this area has deposited enormous quantities of silt in

TABLE 8-18 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 2.3

States and Counties	Land Area (sq.mi.)	Population (1000s)	Population per sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
Indiana								
Elkhart	464	121.2	261.2	3,640	.0300	320	13,602	.1122
LaGrange	381	19.0	49.9	3,460	.1821	834	6,209	.3267
Marshall	442	32.4	71.3	4,296	.1325	472	7,180	.2216
Noble	409	29.4	71.9	4,620	.1571	872	12,624	.4293
St. Joseph	466	238.7	512.2	1,215	.0050	323	19,146	.0802
Steuben	307	18.0	58.6	10,640	.5911	5,111	8,153	.4529
Total	2,469	458.7	185.8	27,871	.0607	7,932	66,914	.1458
Michigan								
Allegan	824	60.6	73.5	7,760	.1280	2,050	8,869	.1463
Barry	549	34.8	63.4	10,407	.2990	2,601	8,623	.2477
Berrien	576	165.7	287.7	2,761	.0166	4,391	19,423	.1172
Branch	505	37.7	74.7	8,111	.2151	14,110	7,209	.1912
Calhoun	706	142.1	201.3	4,794	.0337	938	18,877	.1328
Cass	487	39.5	81.1	9,427	.2386	11,188	8,156	.2064
Clinton	571	44.7	78.3	809	.0180	128	4,582	.1025
Eaton	569	55.9	98.2	659	.0117	189	6,946	.1242
Hillsdale	594	34.7	58.4	3,881	.1118	3,713	5,177	.1491
Ingham	558	246.9	442.5	700	.0028	329	17,123	.0693
Ionia	574	42.7	74.4	1,796	.0420	275	6,488	.1519
Jackson	692	136.9	197.8	9,630	.0703	1,793	16,188	.1182
Kalamazoo	559	188.3	336.9	9,471	.0502	1,182	20,638	.1096
Kent	852	391.2	459.2	8,022	.0205	1,237	50,721	.1296
Montcalm	707	40.4	57.1	7,263	.1797	538	8,955	.2216
Ottawa	563	112.4	199.6	5,095	.0453	916	11,591	.1031
St. Joseph	538	60.2	111.9	9,042	.1501	8,793	8,876	.1474
Shiawassee	498	45.4	91.2	911	.0200	53	5,284	.1163
Van Buren	601	55.0	91.5	4,217	.0766	4,397	8,691	.1580
Total	11,523	1,935.1	167.9	104,756	.0541	58,821	242,417	.1252

States and Years	Land Area (sq.mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand: Resident[1]	Projected Angler Day Demand: Total[2]
Indiana					
1980	2,469	527.2	213.5	2,103,816	1,242,000
2000	2,469	635.5	257.4	2,535,992	1,497,000
2020	2,469	778.3	315.2	3,105,842	1,834,000
Michigan					
1980	11,523	2,386.8	207.1	10,265,317	6,060,000
2000	11,523	3,136.3	272.2	13,488,820	7,964,000
2020	11,523	4,098.1	355.6	17,625,000	10,405,000
Total PSA 2.3	13,992	2,393.8	171.1		
1980	13,992	2,914.0	208.3	12,369,133	7,302,000
2000	13,992	3,771.9	269.6	16,024,812	9,461,000
2020	13,992	4,876.4	348.5	20,731,239	12,239,000

[1]Demand generated within planning subarea.

[2]Total demand including in- and out-migration.

the rivers and impoundments. Large sections of rivers that were once productive continue to be destroyed by heavy siltation.

In spite of the long list of fishery problems, sport fishing activity in southwest Michigan is high compared to other areas of the country. Well planned use of the water and related land area could upgrade the resource with minimal effect on the present sport fishery.

Because of recent improvements in water quality in the rivers of this planning subarea and new controls over habitat abuse, the

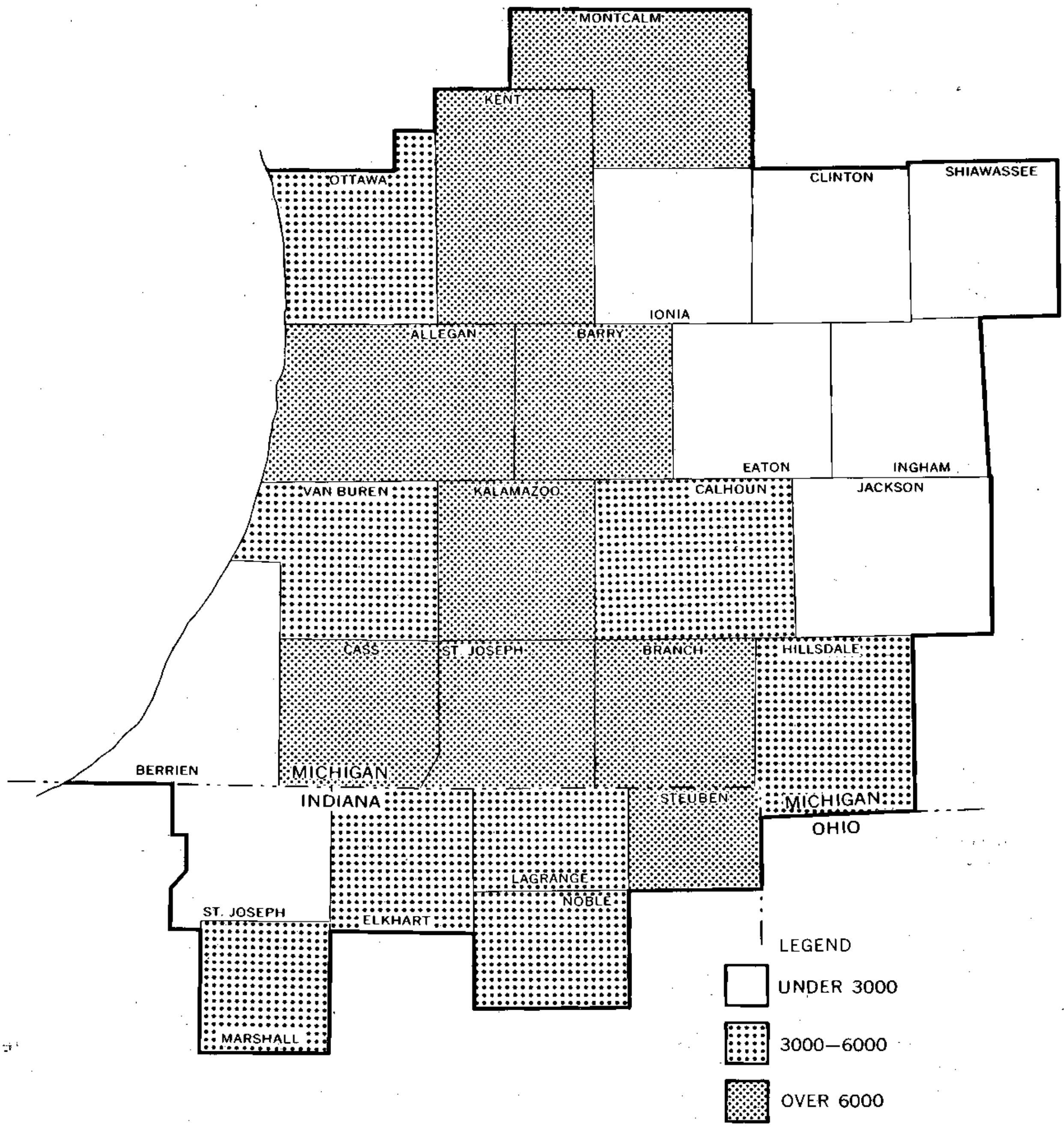


FIGURE 8–35 Acres of Ponded Water, Planning Subarea 2.3

Michigan Department of Natural Resources plans to build a major warmwater fish hatchery to service the waters of this area.

4.4.4 History of Sport Fishery

The former record for fishing license sales in this area occurred in 1955. As the fishery declined in quality and recreational uses of the water increased, fishing license sales decreased steadily until 1966. Since 1966, license sales have increased by 10 percent or more per year. Despite increased license fees, a new record high was established in 1968. Increased sales are partially due to the new salmon program in the State. However, fishing interest has also increased on inland waters.

The sport fishery on inland waters had been comprised of primarily warmwater species. Although the Lake Michigan and anadromous stream fishery will continue to grow in importance, bass, walleye, northern pike, muskellunge, and assorted panfish still offer the best potential for full development of the inland lakes.

4.4.5 Existing Sport Fishing Demand and Current Needs

The total angler day demand expressed within the inland water of this planning subarea has remained relatively constant since the late 1950s. However, the number of licensed sport fishermen and the number of angler days per capita from this planning subarea has increased. The current angler day demand expressed by people living or buying licenses in Planning Subarea 2.3 exceeds 9.0 million angler days. Approximately 60 percent of the current demand is supplied within this planning subarea, leaving nearly 3.6 million angler days to be supplied in other areas, primarily northern Michigan and the Great Lakes.

In-migration from other areas represents a small percentage of the total number of angler days recorded in the planning subarea. The purchase of licenses by residents of Planning Subarea 2.3 in other areas of the State is substantial and this demand will be considered in the counties in which the licenses were purchased. Nonresident license sales were used as an index to the number of angler days expressed by out-of-State fishermen. Latent fishing demand will be discussed later.

4.4.6 Ongoing Programs

Many of the current fishery programs in Planning Subarea 2.3 involve protection and maintenance of the resource base. However, direct or intensive manipulation of fish populations is often employed by fish management agencies. Figure 8–36 and Table 8–19 summarize the intensive fish management efforts in the planning subarea. Obviously, the specific lakes, total acreage involved, and number of lakes change from year to year, but Figure 8–36 and Table 8–19 fairly represent the magnitude and distribution of the current program.

Intensive warmwater management includes spawning marsh operations, partial or total chemical rehabilitation, and warmwater fish plantings. Intensive trout management in lakes includes trout plantings and chemical rehabilitation. Nearly half the trout streams require trout stockings because of the lack of natural reproduction and the failure of chemical rehabilitation to remove competing species.

In 1968, 646 pounds of warmwater species and 18,272 pounds of trout were planted in lakes and streams. The 1,120,185 fry and fingerling warmwater fish stocked included northern pike, muskellunge, walleye, bluegill, smallmouth bass, and hybrid sunfish. Brown and rainbow trout were the only coldwater species planted for the inland fishery. Anadromous fish stocking began in 1968, when 6,000 steelhead were planted in the Black River, in Allegan County. Salmon plants began in 1969 when a total of 300,000 coho were stocked in the Grand, Kalamazoo, and St. Joseph Rivers. Figure 8–37 shows the current extension of the anadromous stream fishery. The small tributary streams used by anadromous fish for spawning are not shown.

4.4.7 Future Trends in Habitat and Participation

Future demand based on the current relationship of habitat base to number of fishermen indicates that the number of angler days generated from Michigan's portion will increase to more than 11.8 million by 1980 (Table 8–18). The extension of the anadromous stream fishery for steelhead and salmon will spread this demand to the St. Joseph, Black, Kalamazoo, and Grand Rivers. Pollution abatement, habitat manipulation programs,

TABLE 8–19 Summary of Base Year Fish Habitat and Management Efforts, Planning Subarea 2.3

County	Total Area (sq.mi.)	Acres Ponded Waters	Number Ponded Waters	Number Intensively Managed	Acres Intensive Warmwater	Acres Intensive Trout	Miles Total Streams	Miles Trout Streams	Miles Anadromous Streams
Michigan									
Allegan	837	7,760	97	10	873	351	517	33.5	41.5
Barry	571	10,407	165	16	4,227	2,394	272	18.6	18.0
Berrien	584	2,761	32	2	0	12	500	8.2	62.5
Branch	517	8,111	71	5	355	650	325	0.0	----
Calhoun	716	4,794	91	3	628	136	540	55.3	----
Cass	505	9,427	103	9	148	965	229	54.6	----
Clinton	573	809	27	1	0	2	319	0.0	----
Eaton	572	659	25	0	0	0	207	0.0	----
Hillsdale	604	3,881	89	5	0	331	298	3.2	----
Ingham	560	700	22	0	0	0	234	0.0	----
Ionia	578	1,796	27	4	1,205	0	464	10.8	----
Jackson	717	9,630	96	8	1,715	751	324	23.7	----
Kalamazoo	580	9,471	74	8	515	288	365	25.0	----
Kent	868	8,022	186	10	576	278	772	131.4	7.5
Montcalm	720	7,263	160	9	557	248	477	97.2	----
Ottawa	572	5,095	24	5	1,918	4	307	21.8	40.0
Shiawassee	540	911	23	0	0	0	307	0.0	----
St. Joseph	518	9,042	80	4	211	1,045	292	7.2	----
Van Buren	615	4,217	88	5	0	752	324	39.7	50.5
Total	11,747	104,756	1,480	104	12,928	8,207	7,073	530.2	220.0

and the proposed warmwater hatchery will increase the quality of the area fisheries.

In order to calculate the future supply of fishing opportunities in the area, additional anadromous streams, new impoundments, and the acres of water improved with fish from the new warmwater hatchery were estimated. The number of new angler days provided by these management efforts was estimated at 250 angler days per year per mile of new anadromous stream; 25 angler days per year per acre of new impounded water; and 25 angler days per year per new acre of water stocked with warmwater fish.

Future latent demand is estimated by increases in disposable income and leisure time. Leisure time preferences compiled from census interviews were used to estimate what portion of the population would like to begin fishing or fish more often. These national surveys indicated that 8 percent of the population would like to begin to fish and 13 percent would like to fish more. Eighty-seven percent of the respondents indicated that lack of time, money, transportation, equipment, or facilities prevented them from participating in the given outdoor activity. Because increases in available facilities (new impoundments) were considered in projected future demand, a small portion of the latent demand has been considered. However, the impact of improved warmwater fishing, new anadromous fishing streams, and the new Great Lakes fish opportunities on disposable income and leisure was not considered. It is hoped that these factors will encourage fishermen to express their latent fishing demand.

In the first three years of the Great Lakes salmon fishery, 1967 through 1969, 50,000 new fishermen bought licenses in the area. This figure equals three percent of the 1966 population of southwest Michigan. If the latent fishing demand fulfilled by a Great Lakes fishery was three percent of the 1966 population, the total latent demand must be higher because all the people would not necessarily take advantage of the new salmon fishery. A minimum estimate of latent demand for the area would be six percent of the population.

The latent demand will increase the calculated total angler days (Table 8–18) in Michigan by 3,322,426 in 1980, 3,204,570 in 2000, and 5,597,012 in 2020.

4.4.8 Fishery Development Plans

The operational and capital outlay of funds required to implement the previously mentioned ongoing programs are not assured. Although preliminary planning has been completed, land acquisition, the new warmwater hatchery, and anadromous fish passages have not yet been funded. An estimated $250,000 will be required in annual operational funds to produce and stock the warmwater fish

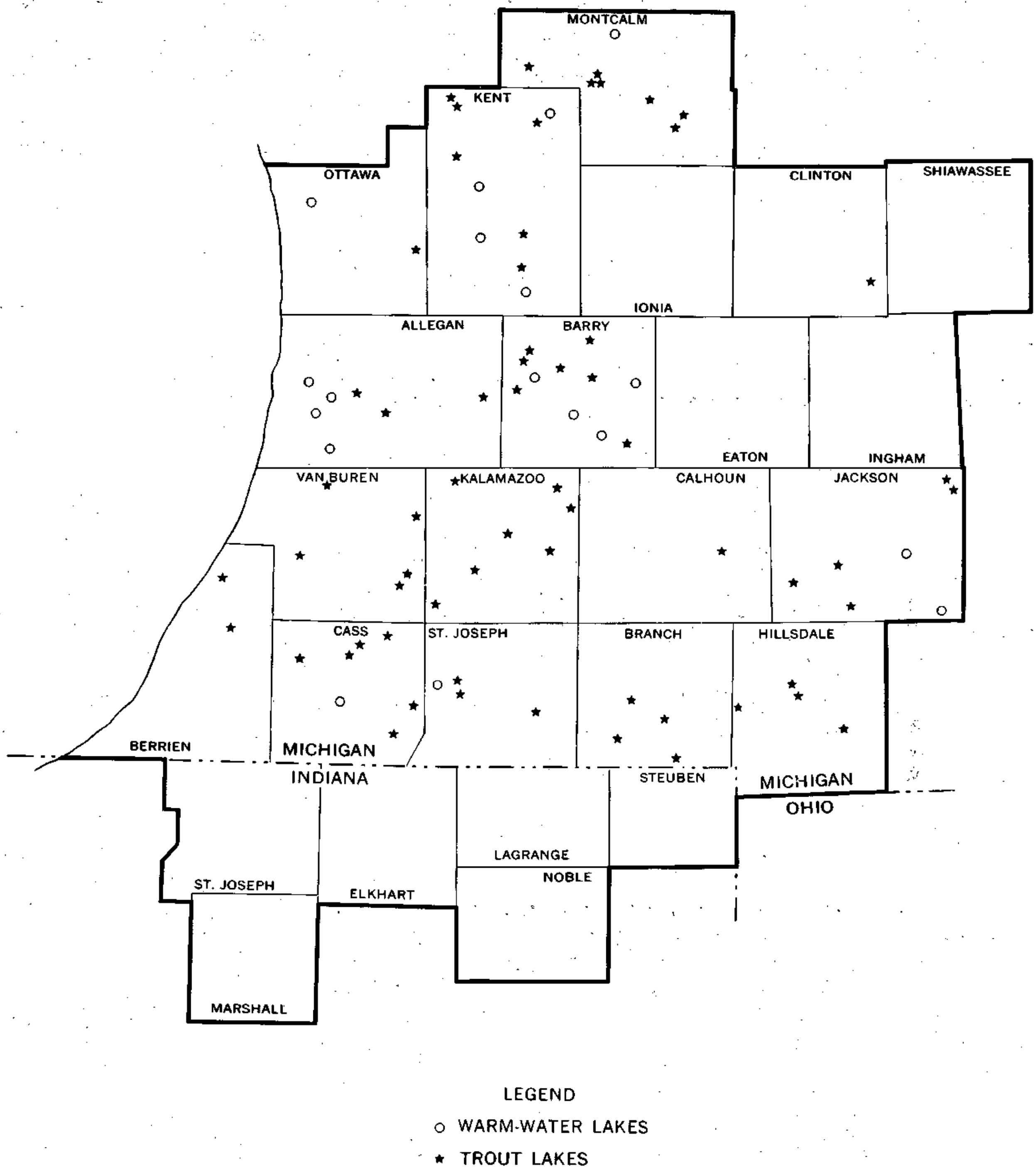


FIGURE 8–36 Current Fish Stocking Program, Planning Subarea 2.3

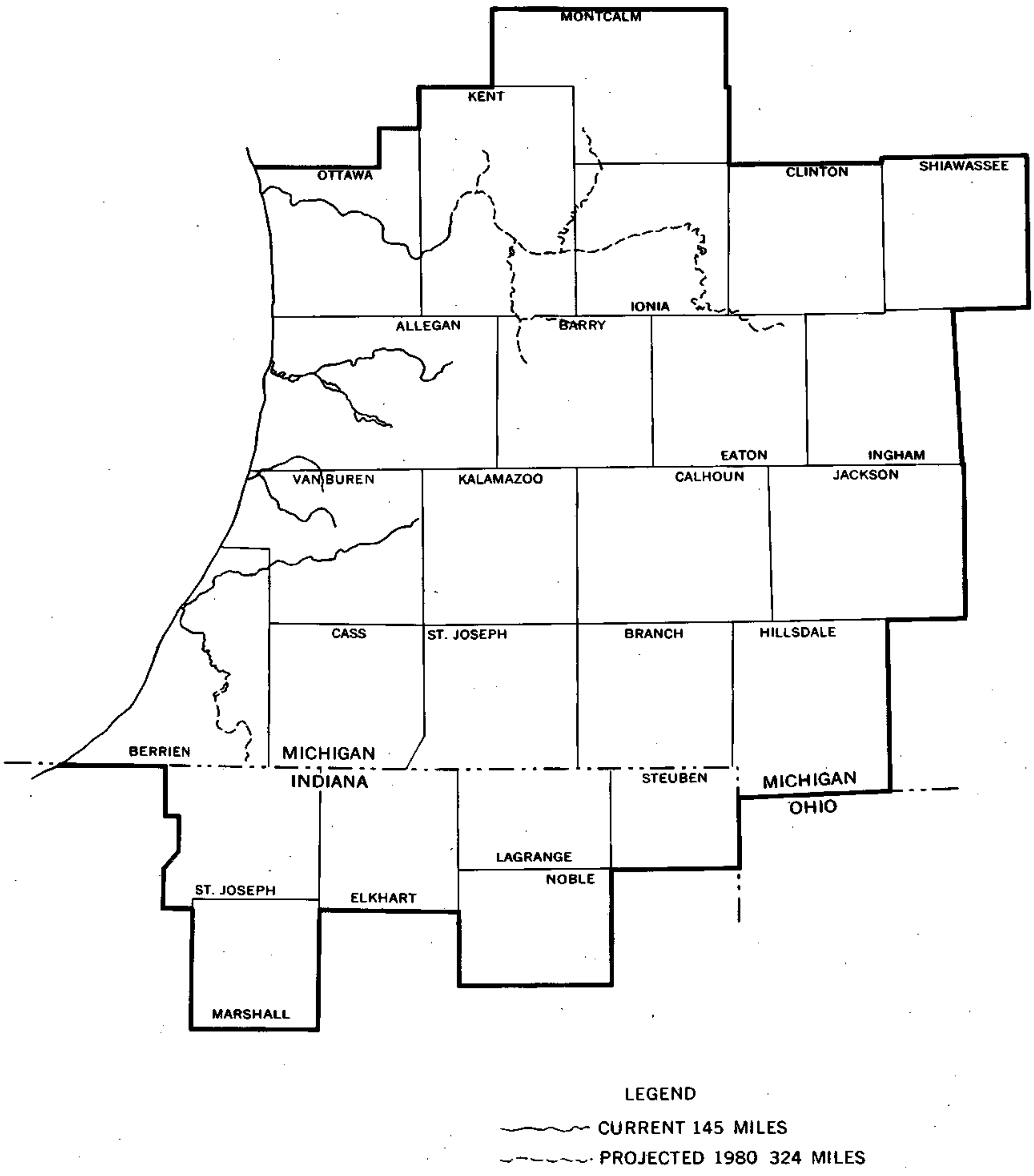


FIGURE 8–37 Anadromous Stream Fishery, Planning Subarea 2.3

scheduled for the planning subarea by 1980. Capital outlay costs attributable to the fishery programs in the planning subarea, exclusive of impoundment construction, will probably exceed 3.0 million dollars by 1980.

The extension of the anadromous stream fishery indicated in Figure 8–37 will require capital expenditures for fish passage and dam removal. Land acquisition detailed in Figure 8–38 and Table 8–20 is essential in providing fishermen access and habitat protection to both the developing anadromous fishery and to the existing high quality trout and warmwater stream fisheries. Planting of warmwater species from the new hatchery will be concentrated in those counties with the largest acreage of natural lakes. However, efforts will be made to intensify fish management in lakes near metropolitan centers. Approximately 50,000 acres of lakes will be enhanced through the warmwater planting stock produced by the warmwater hatchery.

Nearly all new programs designed to make further use of the water and land-related resources of the area can potentially damage the fishery habitat. Impoundment construction on any stream or river should be carefully evaluated for costs (including damages) and benefits. Anadromous fish passage is critical to the potential fishery development of the three major river systems. Fish passage on smaller streams may be equally important to the local fishery. The destructive effects of warming and siltation caused by some impoundments should be considered.

Plans for fishery development beyond 1980 are purely speculative. However, they would include expansion of the warmwater stocking program into large stretches of rivers and additional lakes and extension of the anadromous stream fishery into the Kalamazoo River. Acquisition of key lands for access and habitat protection will be a growing need. Capital funding for such programs during the period from 1980 to 2000 would demand more than six million dollars.

TABLE 8–20 Priority Land Acquisition Areas, Planning Subarea 2.3

County	River	Acres	Cost
Allegan	Rabbit	160	$ 16,000
Allegan & VanBuren	Black	240	24,000
Berrien	Paw Paw	400	60,000
Berrien	Pipestone Creek	200	10,000
Eaton	Grand	200	60,000
Ionia	Libhart Creek	120	20,000
Kalamazoo	Kalamazoo	600	100,000
Kent	Rogue	300	100,000
Montcalm	Fish Creek	400	30,000
Ottawa	Grand	120	36,000
Total		2,740	$456,000

4.4.9 Indiana's Comments

Indiana's portion of Planning Subarea 2.3 contains a wide range of habitat. Four of the six counties fall within the natural lakes region. All but Marshall County contain trout streams stocked on a put-and-take basis. Nineteen streams within the planning subarea are annually stocked with catchable-size trout, but even these streams are marginal coldwater habitat. Bluegill is probably the most sought-after species in inland lakes. Largemouth bass, bluegill, redear, yellow perch, black crappie, and northern pike dominate the sport catch in this area. The stream fishery is predominately for smallmouth bass, rock bass, and northern pike. Destruction of habitat by dredging and impoundments represents a threat to the existing stream fishery.

Spring sucker fishing, rough fish spearing, and cisco netting are only locally important. The latter is declining in popularity as cisco populations dwindle. Eutrophication is believed to be the cause for reduced cisco numbers.

Habitat improvement and provisions for new fishing opportunity are badly needed in Indiana. Severe personnel limitations and a relatively new fisheries program (since 1962) have made even routine survey work a slow process. As a result, little is known about many of the lakes and streams.

There is no maintenance stocking. Limited resources go where they will do the most good (newly eradicated or impounded waters). Indiana has not stocked exotic fish in the past, but it is now making limited introductions of walleye and salmonids.

Although quality of the habitat is declining, habitat distribution in the planning subarea is fair. Ponded waters per capita range from 0.591 in Steuben County to 0.005 in St. Joseph

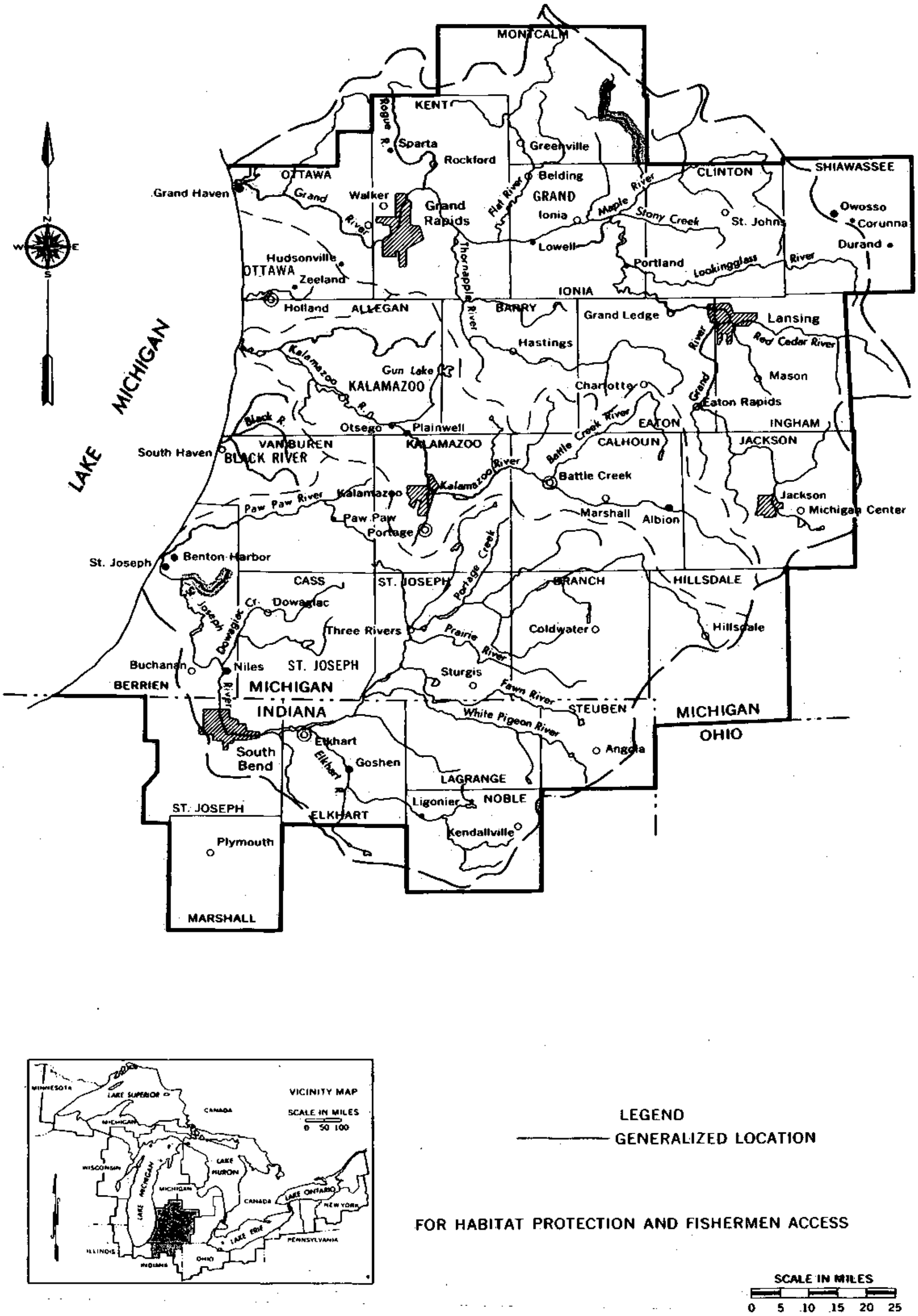


FIGURE 8–38 Priority Land Acquisition, Planning Subarea 2.3

County. License sales per capita somewhat reflect this distribution.

Habitat problems encountered in Indiana's portion of Planning Subarea 2.3 closely parallel those in southwest Michigan. Nothing can be added to the Michigan narrative except to emphasize the roles of unwise land use and municipal and industrial waste in the decline of river and stream habitat and in the accelerated eutrophication of lakes.

4.5 Planning Subarea 2.4

4.5.1 Species Composition, Relative Importance, and Status

Planning Subarea 2.4 (Figure 8–39) encompasses some of the best fishing waters in the State of Michigan. Nearly all the rivers are managed for trout. Brook trout, brown trout, and steelhead are common to each river system. Steelhead makes annual runs in every major river tributary to Lake Michigan in Planning Subarea 2.4. Brown trout is the dominant species in upstream sections of the major rivers, and brook trout is of primary importance in the smaller colder streams and headwater areas. Where natural lakes of impoundments alter the character of a river system, northern pike, walleye, large- and smallmouth bass, and assorted panfish are the most important species.

Inland lakes have traditionally provided the majority of fishing opportunities in the area. Walleye, large- and smallmouth bass, northern pike, muskellunge, lake trout, and panfish such as yellow perch and bluegill are the most commonly sought species. Annual maintenance of brook, brown, and rainbow plantings adds to the importance of the inland lake fishery. Recent improvements in steelhead plantings and the introduction of salmon may now place river and stream fishing effort in the planning subarea on a par with the inland lake fishery of Planning Subarea 2.4. Specialized and seasonal fisheries for suckers, smelt, lake run walleye, and whitefish add to the variety of the sport fishery of the area.

The inland lake fisheries have been so exploited that the larger predators are no longer dominant. Perch, bluegill, and other panfish populations are often overabundant and individual fish are sometimes too small to attract anglers. Fishing quality and fishing pressure for warmwater species on inland lakes has declined in the past 20 years.

4.5.2 Habitat Distribution and Quantity

The inland ponded waters of Planning Subarea 2.4 provide more than 285,565 acres available for fishing. The distribution of water within the planning subarea is reasonably good. Twenty-eight percent of the population of the area is licensed to fish. In five of the counties of Planning Subarea 2.4, more than 50 percent of the population is licensed. Ponded water per capita ranges from a high in Roscommon County of 4.8 to a low of .07 in Muskegon County (Figure 8–40).

Water areas in Planning Subarea 2.4 attract fishermen from outside the planning subarea. For example, the resident license sales per capita in Roscommon County is 2.07. Thus, fishing license sales are more than double the Roscommon County population (Table 8–21).

4.5.3 Habitat Problems Affecting Production and Distribution of Important Fish Species

Many factors affect production and distribution of game fish in this area. The detrimental effects of man's activities are discussed in detail in the part of this report dealing with Planning Subarea 2.3. However, resident population of the planning subarea is small compared to Planning Subareas 2.3 and 4.1 and the degree of lakeside and streamside development is tremendous. Therefore, the accompanying problems are growing faster than the means to cope with them.

Generally, water quality is excellent and problems associated with industrial waste are isolated to bay harbor lakes such as Manistee and Muskegon or in Great Lakes harbors. Current programs to remove waste outfalls from these lakes and provide advance treatment facilities are designed to solve present problems.

One of the major habitat problems is the indiscriminate damming of small trout streams for real estate development or private use. This practice has become so widespread that the ability of some mainstream areas to sustain trout population is in danger. If left uncontrolled, the damming of small feeder streams could destroy trout fishing on such

TABLE 8–21 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 2.4

State and Counties	Land Area (sq.mi.)	Population (1000s)	Population per sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
Michigan								
Antrim	474	10.7	22.6	30,060	2.8093	2,644	5,504	.5144
Benzie	314	6.9	22.0	17,634	2.5557	2,335	4,239	.6143
Charlevoix	413	14.1	34.1	25,040	1.7759	1,433	4,734	.3357
Delta	1,173	33.3	28.4	4,439	.1333	1,549	3,759	.1129
Emmet	459	16.5	35.9	7,958	.4823	3,144	4,865	.2948
Gr. Traverse	460	36.0	78.3	13,899	.3861	3,026	8,807	.2446
Kalkaska	564	4.9	8.7	5,316	1.0849	709	2,688	.5486
Lake	568	5.1	9.0	4,300	.8431	1,824	3,620	.7098
Leelanau	344	9.7	28.2	17,369	1.7906	2,105	3,030	.3124
Mackinac	1,010	10.1	10.0	28,538	2.8255	5,870	3,459	.3425
Manistee	548	19.6	35.8	7,559	.3857	3,654	6,028	.3076
Mason	489	21.7	44.4	8,986	.4141	4,084	5,235	.2412
Mecosta	558	25.8	46.2	8,498	.3294	1,747	9,272	.3594
Missaukee	564	6.1	10.8	4,396	.7207	295	1,994	.3269
Muskegon	500	152.1	304.2	10,713	.0704	1,990	18,830	.1238
Newaygo	846	25.7	30.4	11,493	.4472	3,044	9,124	.3550
Oceana	535	17.0	31.8	3,711	.2183	2,146	4,501	.2648
Osceola	578	13.9	24.0	2,614	.1881	420	4,065	.2924
Roscommon	519	8.1	15.6	39,089	4.8258	4,999	16,803	2.0744
Schoolcraft	1,173	8.0	6.8	27,480	3.4350	2,551	2,787	.3484
Wexford	559	19.5	34.9	6,473	.3319	1,790	6,502	.3334
Total	12,648	464.8	36.7	285,565	.6144	51,359	129,846	.2794

State and Years	Land area (sq. mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand Resident[1]	Total[2]
Michigan					
1980	12,648	547.2	43.3	5,719,528	9,020,000
2000	12,648	671.4	53.1	7,017,710	11,011,000
2020	12,648	841.4	66.5	8,794,611	13,627,000

[1]Demand generated within planning subarea.

[2]Total demand including in- and out-migration.

famous rivers as the Pere Marquette and the upper Manistee.

4.5.4 History of Sport Fishery

Resident fishing license sales reached an all-time high in 1969 when 144,630 were sold. License sales in the most southern and populous county, Muskegon, have declined in the last 20 years, while license sales have more than doubled in Manistee County and other counties where fishing opportunities have expanded.

The recovery of steelhead and the introduction of salmon from 1966 through 1970 have had a tremendous impact on this area. The most important salmon and steelhead fishing streams in the Great Lakes Basin are located in this planning subarea.

The variety of high quality fishing opportunities available will continue to attract anglers from Michigan and ajdacent States.

4.5.5 Existing Sport Fishing Demand and Current Needs

The total angler-day demand expressed within the inland water of Planning Subarea 2.4 has increased steadily since the early 1950s. The current estimate of 4,850,000 angler days (base year 1970) does not include the large number of anglers who buy their licenses outside the area but do most of their fishing within Planning Subarea 2.4 (Table

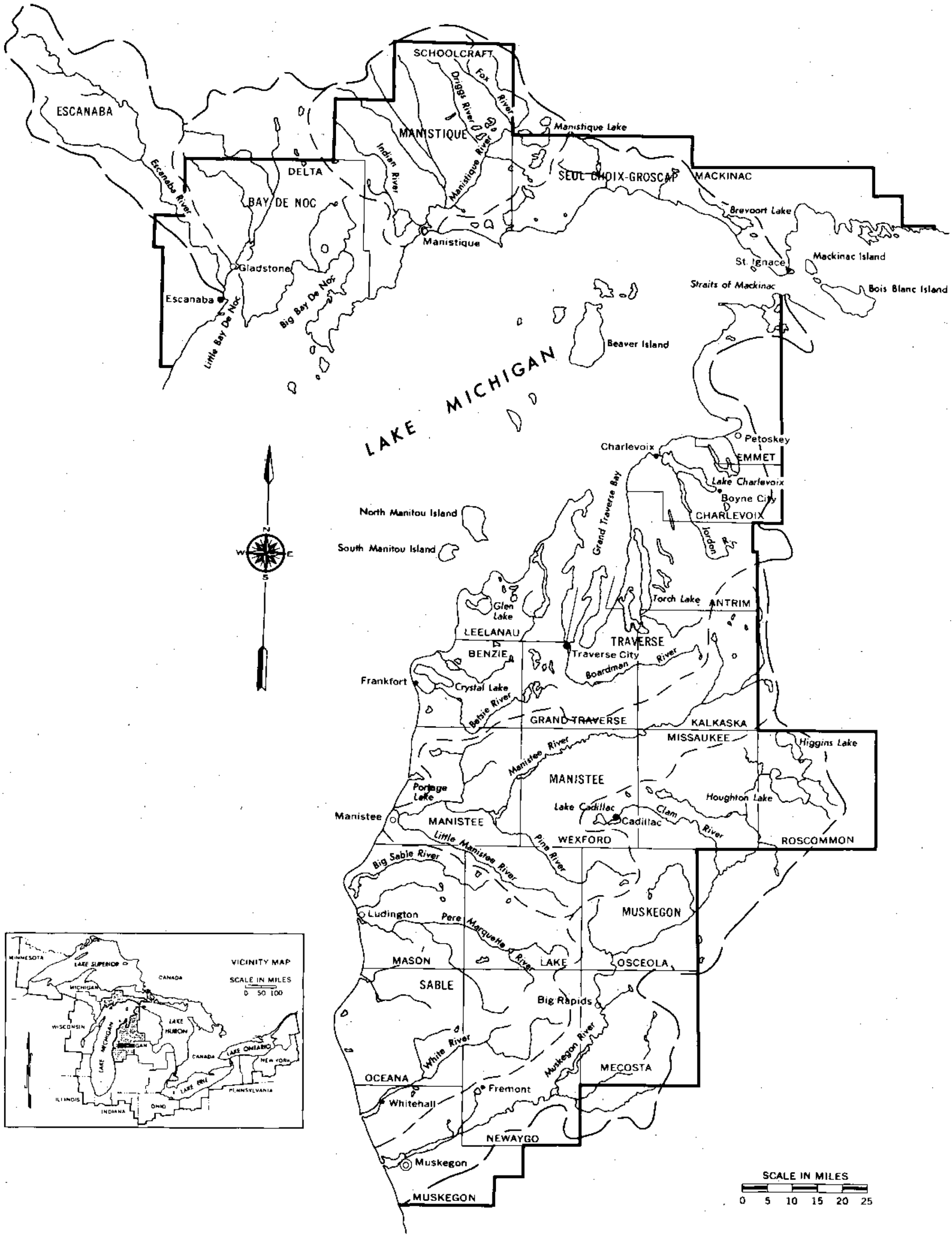


FIGURE 8–39 Planning Subarea 2.4

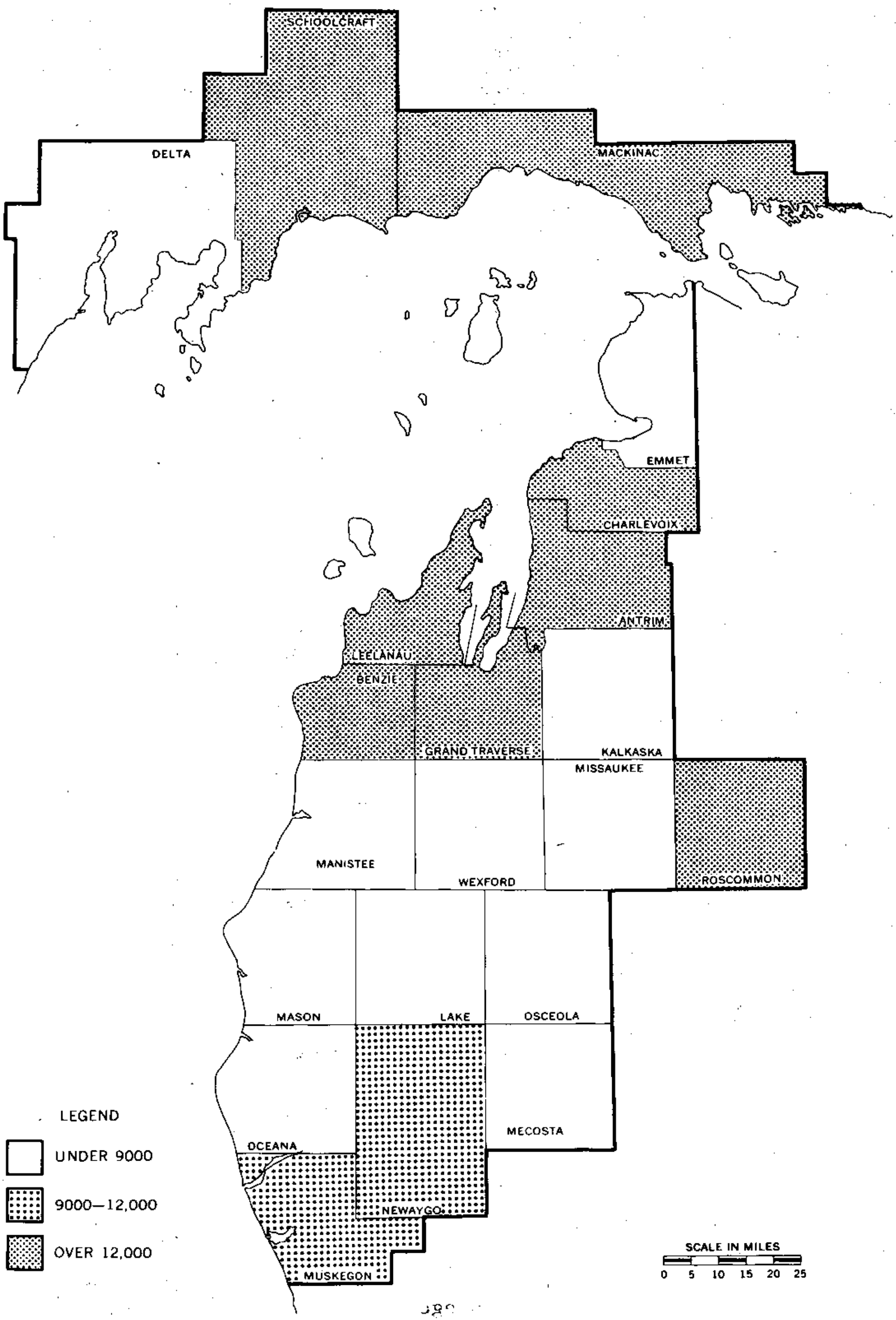


FIGURE 8–40 Acres of Ponded Water, Planning Subarea 2.4

TABLE 8–22 Summary of Base Year Fish Habitat and Management Efforts, Planning Subarea 2.4

County	Total Area (sq.mi.)	Acres Ponded Waters	Number Ponded Waters	Number Intensively Managed	Acres Intensive Warmwater	Acres Intensive Trout	Miles Total Streams	Miles Trout Streams	Miles Anadromous Streams
Michigan									
Antrim	520	30,060	45	4	--------	26,560.5	264	112.1	1.6
Benzie	342	17,634	55	6	771	10,808	104	55.3	32.6
Charlevoix	451	25,040	41	3	--------	17,752.5	215	140.2	----
Delta	1,202	4,439	116	10	214	246.5	581	542.9	34.4
Emmet	477	7,958	18	1	--------	4,320	98	64.4	----
Gr. Traverse	490	13,899	81	9	--------	4,957.4	186	168.5	12.2
Kalkaska	573	5,316	96	13	--------	1,049	284	117.8	10.8
Lake	577	4,300	119	6	912	218.9	250	156.4	70.5
Leelanau	374	17,369	31	8	--------	13,895.2	124	97.9	6.1
Mackinac	1,081	28,538	172	5	6,236	1,072.7	521	390.7	68.2
Manistee	568	7,559	41	2	--------	69	276	140.7	86.5
Mason	505	8,986	72	2	333	--------	238	116.2	55.5
Mecosta	570	8,498	91	4	512	553.2	293	141.0	----
Missaukee	572	4,396	32	4	73.5	60.5	209	54.9	----
Muskegon	519	10,713	72	2	--------	73	394	45.0	
Newaygo	867	11,493	143	7	4,080	608.2	484	219.1	51.0
Oceana	541	3,711	66	2	--------	81.6	224	169.3	53.5
Osceola	585	2,614	80	3	--------	168.5	301	199.8	----
Roscommon	573	39,089	61	3	20,044	9,735.4	204	36.1	----
Schoolcraft	1,229	27,480	430	23	9,482.1	449.9	734	411.3	.5
Wexford	570	6,473	26	3	--------	35	313	283.6	----
Total	13,186	285,565	1,888	119	42,657.6	92,715	6,297	3,663.2	507.2

8–21). Nearly all of the current demand is supplied within the planning subarea. In addition, Planning Subarea 2.4 supplies a minimum of 3,000,000 angler days to fishermen who buy their licenses in other Michigan counties, primarily Planning Subareas 2.3, 4.1, and 3.2. Many out-of-State tourists fish in Planning Subarea 2.4. In 1966, 51,000 nonresident licenses were sold in the area adding a minimum of another 500,000 angler days to the current demand in Planning Subarea 2.4.

The projected demand and latent demand for Planning Subareas 2.3, 4.1, and 3.2 must be considered in future fisheries programs because residents from these three planning subareas are now the largest users of the fishery resources of Planning Subarea 2.4.

Current demand is measured in license sales. Supply equals current demand in this planning subarea. However, because Planning Subarea 2.4 offers perhaps the greatest potential for expanding the quality and quantity of fishing opportunities in Michigan, one can expect that the latent fishing demand in the more populated areas of southern Michigan will be supplied in Planning Subarea 2.4.

4.5.6 Ongoing Programs

Much of the current fish management effort involves protection and maintenance of the existing fishery resources. The current fish planting and spawning marsh programs are important in maintaining the present fishery. Figure 8–41 and Table 8–22 summarize the fishery programs.

In 1969, slightly more than 2.5 million warmwater fish were planted including walleye, northern pike, largemouth bass, tiger musky, bluegill, and hybrid sunfish. Approximately two million brown trout, rainbow trout, brook trout, steelhead, splake, and lake trout were planted the same year.

Since 1966 several million salmon have been planted in the streams. Table 8–23 summarizes the size and location of the 1970 plants of salmon in the planning subarea.

TABLE 8–23 1970 Salmon Stocking, PSA 2.4

Location	Coho	Chinook
Bear River	276,982	200,034
Big Sable River	199,990	100,000
Brewery Creek	200,074	-------
Carp River	100,000	-------
Little Manistee R.	550,012	308,900
Manistee River	100,000	-------
Manistique River	50,000	-------
Muskegon River	201,622	500,000
Platte River	777,640	-------
Porter Creek	75,031	-------
Thompson Creek	73,100	-------
Whitefish River	100,000	-------
Total	2,704,451	1,108,934

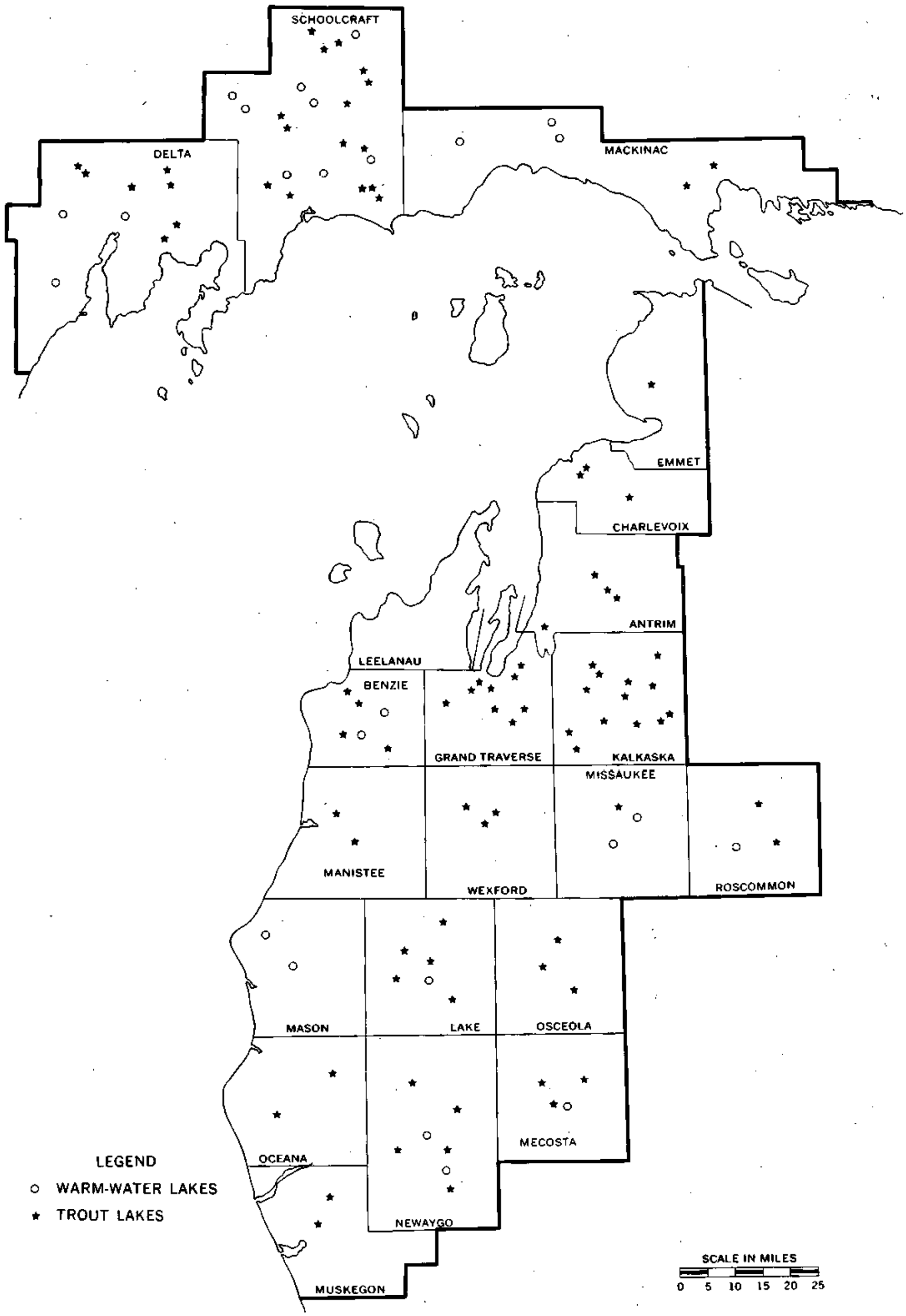


FIGURE 8–41 Current Fish Stocking Program, Planning Subarea 2.4

Figure 8–42 shows the current extension of the anadromous stream fishery for steelhead and salmon in major rivers. Smaller tributaries to Lake Michigan and tributaries to major rivers, which are important to both the anadromous fishery and natural spawning, are not shown.

4.5.7 Future Trends in Habitat and Participation

Estimates of future demand based on the current relationship of habitat base to number of licensed fishermen indicate that the number of angler days will increase by more than 800,000 by 1980 (Table 8–21). Demand on the resources from in-migration will increase by an additional 500,000 angler days by 1980. Because abundant inland ponded water is available, new impoundments in the planning subarea could not be justified by an increase in fishing opportunities except in isolated local situations. The problem is in maintaining and rebuilding fish populations to support a high intensity sport fishery.

The new warmwater hatchery is expected to provide enough fish to add 40,000 acres of well-managed water by 1980. This new management program will supply nearly 1,000,000 new angler days.

One of the most important problems will be preservation of the quantity and quality of the present fishery. With expanded use and development of this planning subarea the more fragile resources such as trout streams and the fisheries of oligotrophic lakes could easily be damaged by the people who use them. If the present resource base is to be preserved, stream improvement, proper zoning, and wild frontage acquisition need to be stepped up.

4.5.8 Fishery Development Plans

The new warmwater hatchery will cost $3 million with $750,000 of the capital cost being charged to Planning Subarea 2.4 (Table 8–24). In addition, $250,000 in annual operating cost will be required to raise and stock warmwater fish scheduled for PSA 2.4 by 1980.

Land acquisition for habitat protection and fishermen access is detailed in Figure 8–43 and Table 8–25 and will cost $162,000 before 1980. Fish passages and dam removal to provide for the extension of the current anadromous fishery will cost at least $350,000 by 1980.

One of the greatest needs of this planning subarea to maintain the current trout management in lakes and streams and to enhance the quality of the fishery is a new modern trout hatchery. The current hatcheries supporting the inland trout management program were built between 1901 and 1931 and need to be replaced. Phasing out some existing facilities and constructing a new hatchery for trout are planned before 1980 at a capital cost of $3.7 million. Approximately 1.8 million dollars of this capital cost will be charged to the inland programs of Planning Subarea 2.4.

Stream improvement was once an important program in the maintenance of the trout fishery. This program was phased out because of increasing costs of other programs. But it is still important in the total trout fishery management program and should be reinsti-

TABLE 8–24 1980 Projected Capital and Operating Costs and Benefits, PSA 2.4

Item	Capital Costs	New Operational Costs	Benefits
Warmwater Hatchery[1]	$ 750,000	$250,000	1,000,000 angler days/year
Trout Hatchery	1,800,000	150,000	---------[2]
Land Acquisition	162,000	-------	---------[2]
Fish Passage	350,000	-------	200,000 angler days/year
Stream Improvement	---------	100,000	---------[2]
Total	$3,062,000	$550,000/year	1,200,000 angler days/year

[1]To be built in Planning Subarea 4.1.

[2]To maintain current benefits and increase quality plus increase in angler days not yet calculated.

TABLE 8–25 Priority Land Acquisition Areas, Planning Subarea 2.4

County	River	Acres	Cost
Antrim	Jordan	80	$ 35,000
Benzie	Platte	120	10,000
Benzie	Betsie	380	32,000
Charlevoix	Deer Creek	200	10,000
Delta	Schaawe Lake Outlet	40	1,000
Grand Traverse	Boardman	80	8,000
Mason	Pere Marquette	240	20,000
Newaygo	White	80	8,000
Newaygo	Muskegon	200	30,000
Oceana	Pentwater	80	8,000
Total		1,500	$162,000

tuted with a $100,000 annual operating cost.
Fish management programs beyond 1980 have not been detailed, but they would include new land acquisition and fish passage facilities. Operating costs will increase even without expansion in programs.

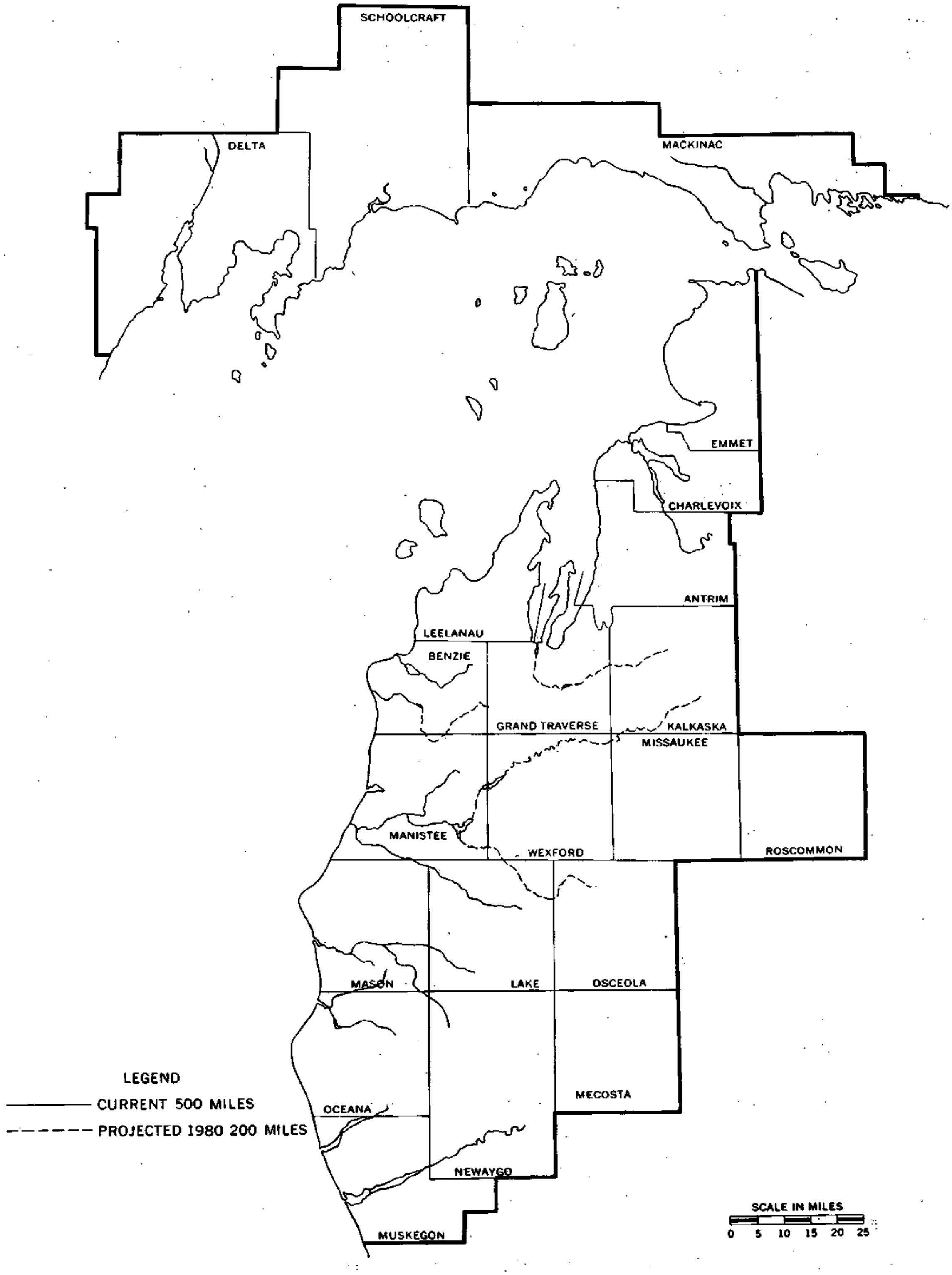


FIGURE 8-42 Anadromous Stream Fishery, Planning Subarea 2.4

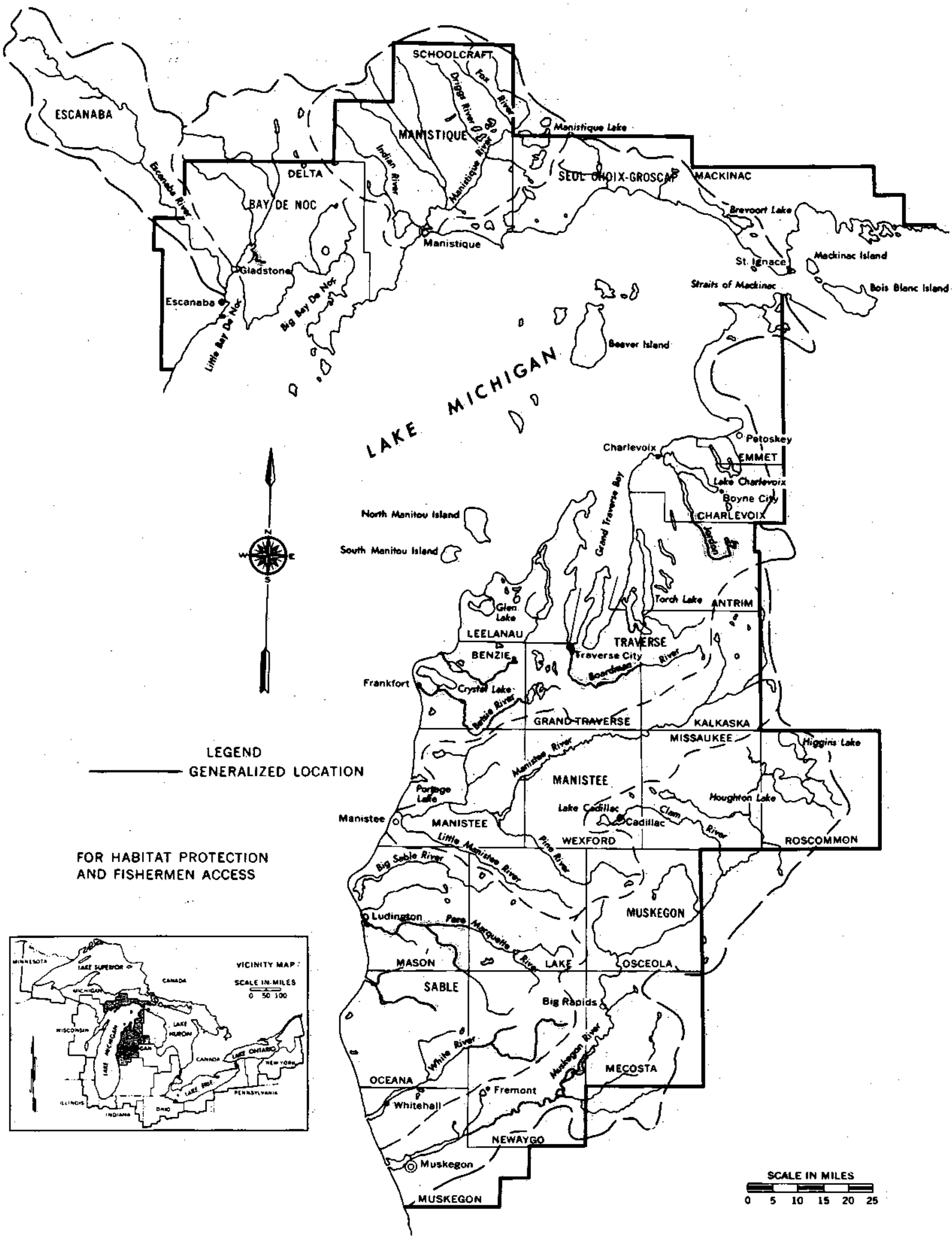


FIGURE 8–43 Priority Land Acquisition, Planning Subarea 2.4

Section 5

LAKE HURON BASIN, PLAN AREA 3.0

The comments on Plan Area 3.0 (Figure 8–44) are divided into two major parts. The first deals with Lake Huron, and the second treats the individual planning subareas of the Lake Huron basin.

5.1 Resources, Uses, and Management

5.1.1 Habitat Base

In addition to the information included in the introductory section of the appendix, the following statements characterize Lake Huron more specifically:

(1) Lake Huron is the fifth largest lake in the world and the second largest in the St. Lawrence-Great Lakes system.

(2) The Lake receives approximately 122,000 cubic feet of water per second from Lakes Michigan and Superior. Two-thirds of this flow comes from Lake Superior. Most water exits the Lake through a single outlet, the St. Clair River. The exit rate is approximately 177,000 cfs.

(3) Lake Huron is 206 miles wide, 183 miles long, and occupies 32 percent (23,000 sq. mi.) of its watershed. The volume of the Lake is approximately 850 cubic miles.

(4) Georgian Bay and the North Channel, which are almost exclusively within Canadian waters, are nearly isolated by a barrier formed by the Bruce Peninsula, Manitoulin Island, and other islands. This area contains more than 20,000 islands.

(5) Saginaw Bay, a shallow (generally 60 feet or less) arm 51 miles long and 25 miles wide, is the largest bay on the U.S. side of the Lake.

(6) The Lake reaches a depth of 750 feet, but also contains significant areas of shallow water. It ranks second to Lake Erie in proportion of water less than 100 feet in depth.

(7) Lake Huron exhibits a well-defined thermocline during the warmer months and a thermal bar during the spring and fall.

(8) Total dissolved solids are low, but they have exhibited a distinct acceleration in rate of increase during the last 35 years. This increase is primarily due to a substantial increase in sulfate and a lesser, but significant increase in chloride (Figure 8–45).

5.1.2 Fish Resources—A Summary of Major Changes

Changes in fish resources of Lake Huron closely follow those indicated in our discussion of the historical background of the commercial fisheries of the Great Lakes in Subsection 2.3.1.

The United States sector of Lake Huron can be divided into four general ecological areas, each of which has traditionally yielded a characteristic combination of fish species. The large central basin, which extends from above Rogers City south to below Harbor Beach, was the habitat of chubs and lake trout. The habitat in the far northern straits was similar to the adjacent habitat of Lake Michigan. Both supported lake trout, whitefish, and suckers. The southern portion of the Lake yielded yellow perch, lake herring, walleye, and suckers near the shore and whitefish offshore. Saginaw Bay provided a highly productive habitat for yellow perch, smelt, walleye, lake herring, suckers, catfish, and carp.

Except for the appearance of carp and the near disappearance of sturgeon in the early 1900s, there were few major changes in the Lake's fish population prior to 1930. However, fish population has undergone considerable change since then. Many of the species present today were deliberately introduced or entered the Lake as a result of man's activities. After the invasion of the sea lamprey in the 1930s, lake trout and whitefish populations underwent rapid declines. This allowed the smelt and small (bloater) chub populations to increase in the 1940s and the alewife population to explode in the 1950s. Walleye and sucker also experienced declines beginning in the 1940s, and continuing to the present time. The lake herring population fell sharply in the

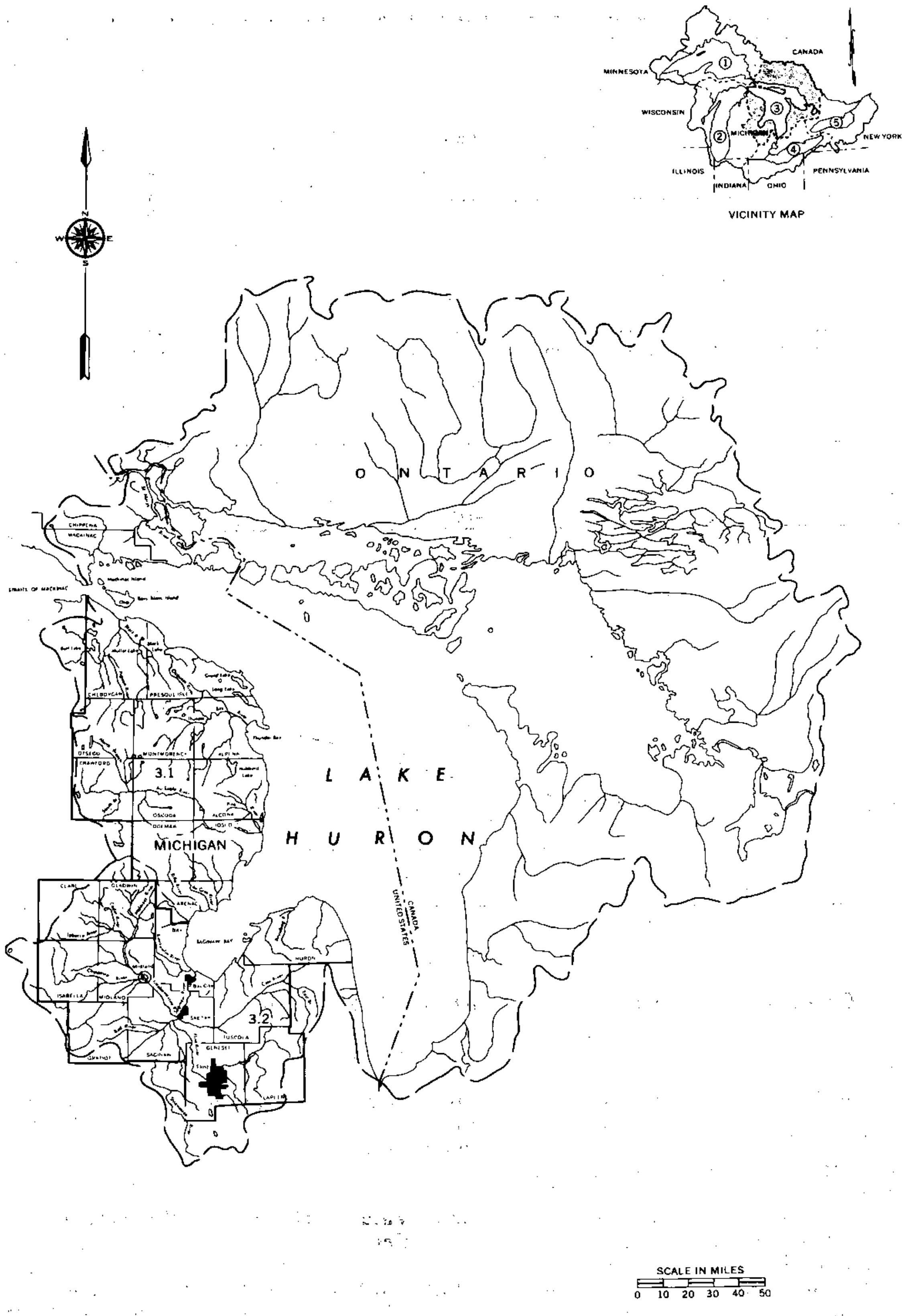


FIGURE 8–44 Plan Area 3.0

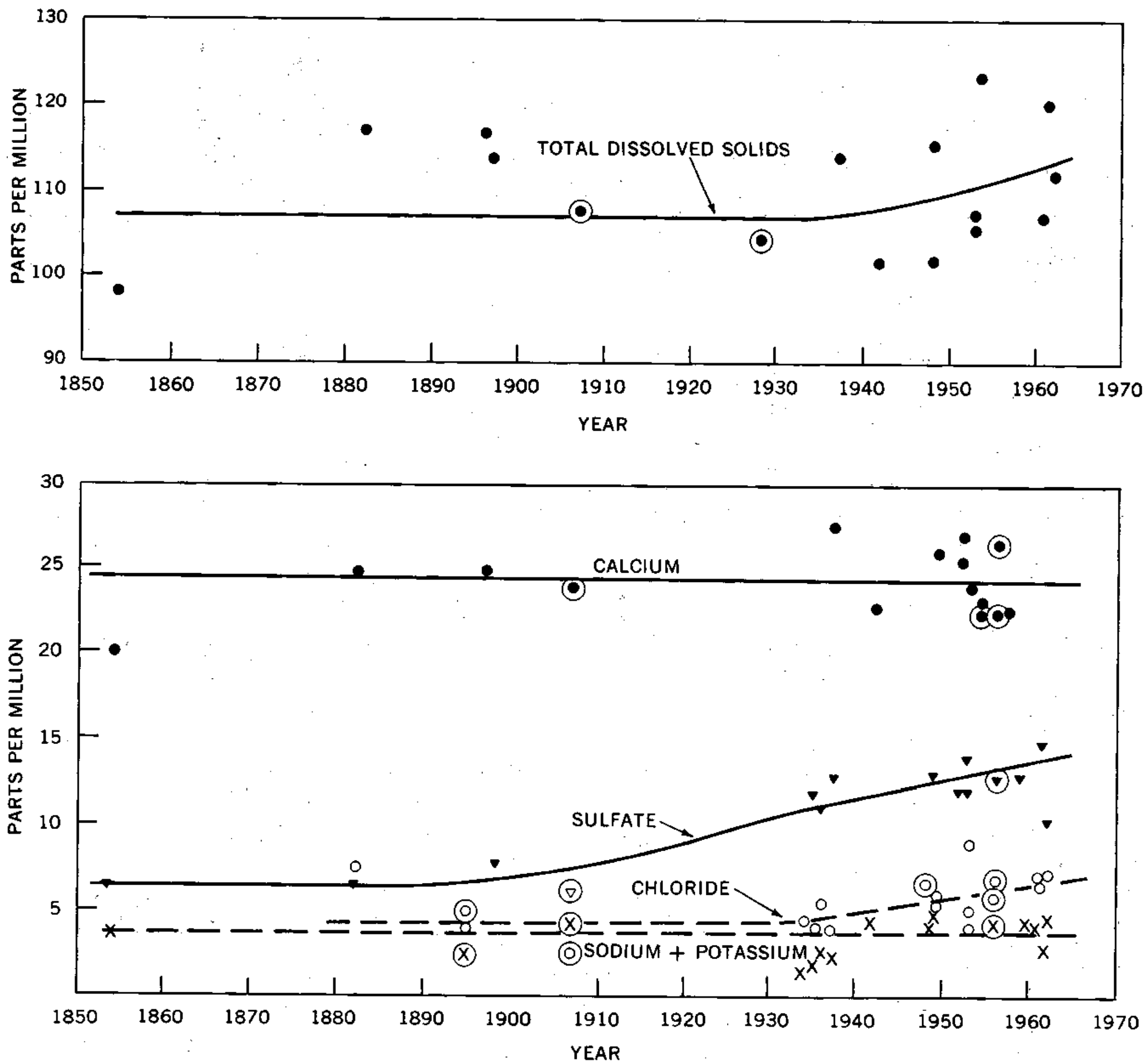


FIGURE 8–45 Changes in the Chemical Characteristics of Lake Huron

1940s and suffered an extreme decline during the 1950s and 1960s. In 1966 the chub population collapsed.

Today alewife dominates the Lake and the presence of sea lamprey hinders the reestablishment of high-value predator species. The effects of sea lamprey predation in Saginaw Bay are less serious. The shallow waters are inhabited by carp and yellow perch, and the deeper waters support large populations of smelt and limited populations of chub, salmon, and splake. The fish population of Lake Huron is in a state of extreme imbalance and additional changes are anticipated in fish population structure.

5.1.2.1 Value of The Individual Species to the Ecosystem

Major contributions of individual species to the Lake Huron ecosystem have already been discussed in Subsection 2.3.1.

Other contributions to the ecosystem of the

Lake include the position which each species occupies in the food chain. For instance, seven of the 15 species with which we are concerned are primarily predators: lake trout, coho salmon, chinook salmon, splake, walleye, yellow perch, and sea lamprey. Five of the remaining eight, lake whitefish, smelt, herring, bloater chub, and alewife, are mainly plantivores. Suckers and catfish are true omnivores, and carp is an herbivore.

Of all these species, lake whitefish occupies a unique niche in the ecosystem of the Lake. Although the adult is basically a plantivore, it can also convert bottom fauna into high-value protein in one step. This contrasts directly with secondary and tertiary piscivores such as walleye and lake trout which occupy the upper layers of the food webs with primarily planktonic and partially benthic bases.

Carp are also important to the ecosystem. Their spawning and feeding habits usually result in increased turbidity in extensive shallow water areas, making these areas generally uninhabitable for other species.

Although the ecological interactions of these species with one another and their common environment are tremendously complex, present day influences of these species can be recorded in a number of ways. For example, 1969–1970 data indicated that 72 percent of returning age II coho, and 20 percent of age II, III, and IV lake whitefish were wounded by sea lamprey. The general decline of the large coregonids and suckers confirms the fact that sea lamprey will greatly affect the ecosystem of the Lake until its residual populations are controlled.

The success of the alewife has resulted in changes in the abundance of other species. For example, alewife has had a direct effect on smelt and possibly chub populations. It has caused decreased growth rates and delayed sexual maturity in smelt. Roving schools of alewife sometimes cause other species to vacate an area, and thus, have an indirect effect on the ecosystem by causing the underutilization of a stationary food supply. Alewife has also caused changes in zooplankton populations of the Lake. Studies in Lake Michigan have documented severe reduction of several of the larger species of *cladocerans* and *calanoid copepods* by alewife. This directly affects the food supply available to other zooplankton feeders. Although detailed plankton studies have not been carried out in Lake Huron, one expects that the same effects have occurred.

On the positive side, alewife has provided the food base for planted lake trout and salmon in Lake Michigan and is expected to do the same in Lake Huron.

It is not yet possible to predict the effect that the introduction of trout (including the hybrid splake) and salmon will have on the ecosystem. Successful control of the sea lamprey will result in the firm establishment of large stocks of high-value salmonids, depending of course on the prey species available.

It is also impossible to predict the effect of the recently imposed zone management system, limited entry, and future management approaches.

In short accurate portrayal of species' contributions to the Lake Huron fishery resource depends heavily upon the stability of the overall ecosystem.

5.1.2.2 Contribution of Individual Species to the Commercial Fishery

The contribution of individual species to the commercial fishery through 1966 has been summarized in the *Great Lakes-Illinois River Basin Report, Fish and Wildlife as Related to Water Quality in the Lake Huron Basin* by the Fish and Wildlife Service. Information from that report has been concentrated, revised, and summarized in Tables 8–26 and 8–27, and Figures 8–46 and 8–47.

Commercial landings during the last five years reflect the concentration on medium- and low-value species because of depressed stocks or near absence of many high-value species like walleye, lake whitefish, and lake trout. Recently introduced high-value species such as salmon, rainbow trout, and brown trout are reserved for the sport fishery.

Except for chub and yellow perch, the total average annual values for all commercially important species have followed the general downward trends established prior to 1965 (Figure 8–48). In the case of catfish and walleye, these downward trends have continued despite upward trends in the value per pound of these species. This indicates that both these species are declining in abundance.

Chub catches for the last five years have decreased substantially resulting in a sharp decrease in total value despite increased prices. On the other hand, the total volume of yellow perch landings increased dramatically through 1966. Prices and consequent total value similarly increased.

TABLE 8–26 Average Pound and Percent Contribution of 11 Major Species in the U.S. Waters of Lake Huron

Species	1935–1939	1940–1944	1945–1949	1950–1954	1955–1959	1960–1964	1965–1969
Alewife							
Lbs.	---[1]	---[1]	---[1]	---[1]	980	6,220	880
% of Volume	---[1]	---[1]	---[1]	---[1]	---[2]	.1	---[2]
Carp							
Lbs.	779,625	916,160	1,555,200	1,457,660	1,483,200	1,411,450	1,108,380
% of Volume	6.2	11.1	21.0	26.4	34.2	24.0	32.2
Catfish							
Lbs.	145,125[3]	389,380[3]	244,270	256,260	315,880	203,720	145,520
% of Volume	1.2	4.7	3.3	4.6	7.3	3.5	4.2
Chub							
Lbs.	222,825	140,780	132,540	122,860	923,780	2,322,640	525,340
% of Volume	1.8	1.7	1.8	2.2	21.3	39.5	15.2
Lake Herring							
Lbs.	5,127,500	2,390,460	1,498,960	1,514,620	127,840	39,540	16,690
% of Volume	41.1	28.9	20.2	27.4	3.0	.7	.5
Lake Trout							
Lbs.	1,345,750	668,920	45,640	---[2]	---[2]	---[1]	210
% of Volume	10.8	8.1	.6	---[2]	---[2]	---[1]	---[2]
Smelt							
Lbs.	---[2]	6,500	4,100	186,340	143,580	30,200	40,330
% of Volume	---[2]	.1	.1	3.4	3.3	.5	1.2
Suckers							
Lbs.	1,677,375	1,300,300	1,361,900	1,140,400	606,360	531,900	248,670
% of Volume	13.4	15.7	18.4	20.7	14.0	9.0	7.2
Walleye							
Lbs.	1,547,325	1,589,440	512,320	171,980	135,880	122,460	50,200
% of Volume	12.4	19.2	6.9	3.1	3.1	2.1	1.4
Lake Whitefish							
Lbs.	818,525	146,600	1,450,300	133,780	62,460	271,940	239,310
% of Volume	6.6	1.8	19.6	2.4	1.4	4.6	6.9
Yellow Perch							
Lbs.	697,125	613,940	449,980	445,700	375,520	564,360	1,015,400
% of Volume	5.6	7.4	6.1	8.1	8.7	9.6	29.5
Average Total Volume	12,485,700	8,266,500	7,412,600	5,517,100	4,332,800	5,885,840	3,445,750

[1]Absent from the commercial catch

[2]Less than 100 pounds or .1%

[3]Includes bullhead catch

TABLE 8–27 Average Value and Percent Contribution of 11 Major Species in the U.S. Waters of Lake Huron

Species	1936–1939	1940–1944	1945–1949	1950–1954	1955–1959	1960–1964	1965–1969
Alewife							
Dollars	---[1]	---[1]	---[1]	---[1]	---[2]	132	---[2]
% of Value	---[1]	---[1]	---[1]	---[1]	---[2]	---[2]	---[2]
Carp							
Dollars	53,147	65,126	90,064	81,954	62,613	66,628	55,463
% of Value	2.6	3.9	6.7	13.4	11.0	7.0	11.0
Catfish							
Dollars	28,415	98,614	74,558	69,507	71,427	51,758	36,692
% of Value	1.4	5.9	5.5	11.3	12.5	5.4	7.3
Chub							
Dollars	70,066	52,942	40,378	26,377	205,996	483,033	97,774
% of Value	3.4	3.2	3.0	4.3	36.1	50.5	19.4
Lake Herring							
Dollars	338,404	228,083	131,954	115,613	13,906	5,176	2,690
% of Value	16.7	13.8	9.8	18.9	2.4	.5	.5
Lake Trout							
Dollars	488,583	291,314	29,612	---[2]	---[2]	---[1]	115
% of Value	24.1	17.6	2.2	---[2]	---[2]	---[1]	---[2]
Smelt							
Dollars	---[2]	339	351	7,514	4,372	6,269	1,411
% of Value	---[2]	---[2]	---[2]	1.2	---[2]	.7	.3
Suckers							
Dollars	109,989	108,705	110,432	65,389	35,261	24,457	9,862
% of Value	5.4	6.6	8.2	12.1	6.2	2.6	2.0
Walleye							
Dollars	423,247	468,074	178,247	63,389	52,284	52,591	25,314
% of Value	20.9	28.2	13.2	10.3	9.2	5.5	5.0
Lake Whitefish							
Dollars	360,857	80,771	566,350	69,808	40,662	150,138	130,566
% of Value	17.8	4.9	42.0	11.4	7.1	15.7	25.9
Yellow Perch							
Dollars	132,671	154,345	98,016	87,306	76,115	91,664	137,473
% of Value	6.5	9.3	7.3	14.2	13.3	9.6	27.2
Average Total Value	2,027,390	1,658,669	1,349,487	612,847	570,528	955,556	504,353

[1]Absent from the commercial catch

[2]Less than $100 or .1%.

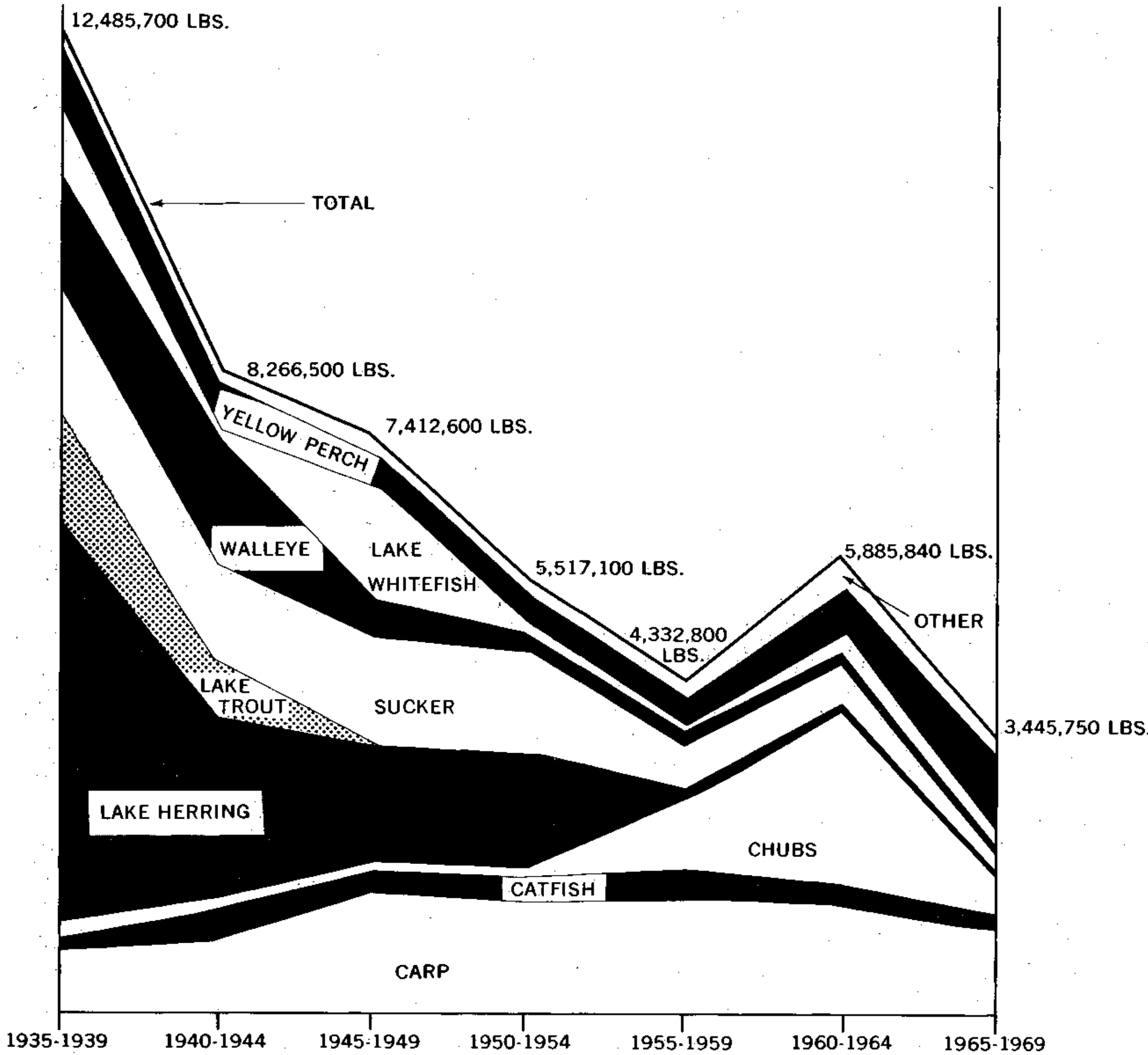


FIGURE 8–46 Average Annual Production (Pounds) of Major Species by the U.S. Lake Huron Commercial Fishery for 5-Year Periods, 1935–1969

5.1.2.3 Contribution of Individual Species to the Sport Fishery

Michigan's 1970 creel census of the Lake Huron sport fishery indicated that in numbers of warmwater fish caught, smelt ranked first followed by yellow perch, centrarchid panfish, suckers, bass, northern pike, and muskellunge. In total weight of warmwater fish taken, perch ranked first with 912,225 pounds, followed by northern pike, 594,920 pounds; suckers, 556,920 pounds; bass, 183,232 pounds; panfish, 177,375 pounds; walleye, 97,370 pounds; smelt, 62,544 pounds; and muskellunge, 4,000 pounds. Although fishing interest in catfish remains low, it is gaining in importance to the sport fishery. The majority of warmwater sport fishing occurs in either in Saginaw Bay or in the extreme northern portion of Lake Huron in the Les Cheneaux and Drummond Island areas.

The total catch of Lake Huron salmonid species in Michigan waters was 158,600 in 1970 (more than 150,000 pounds). Trout and salmon

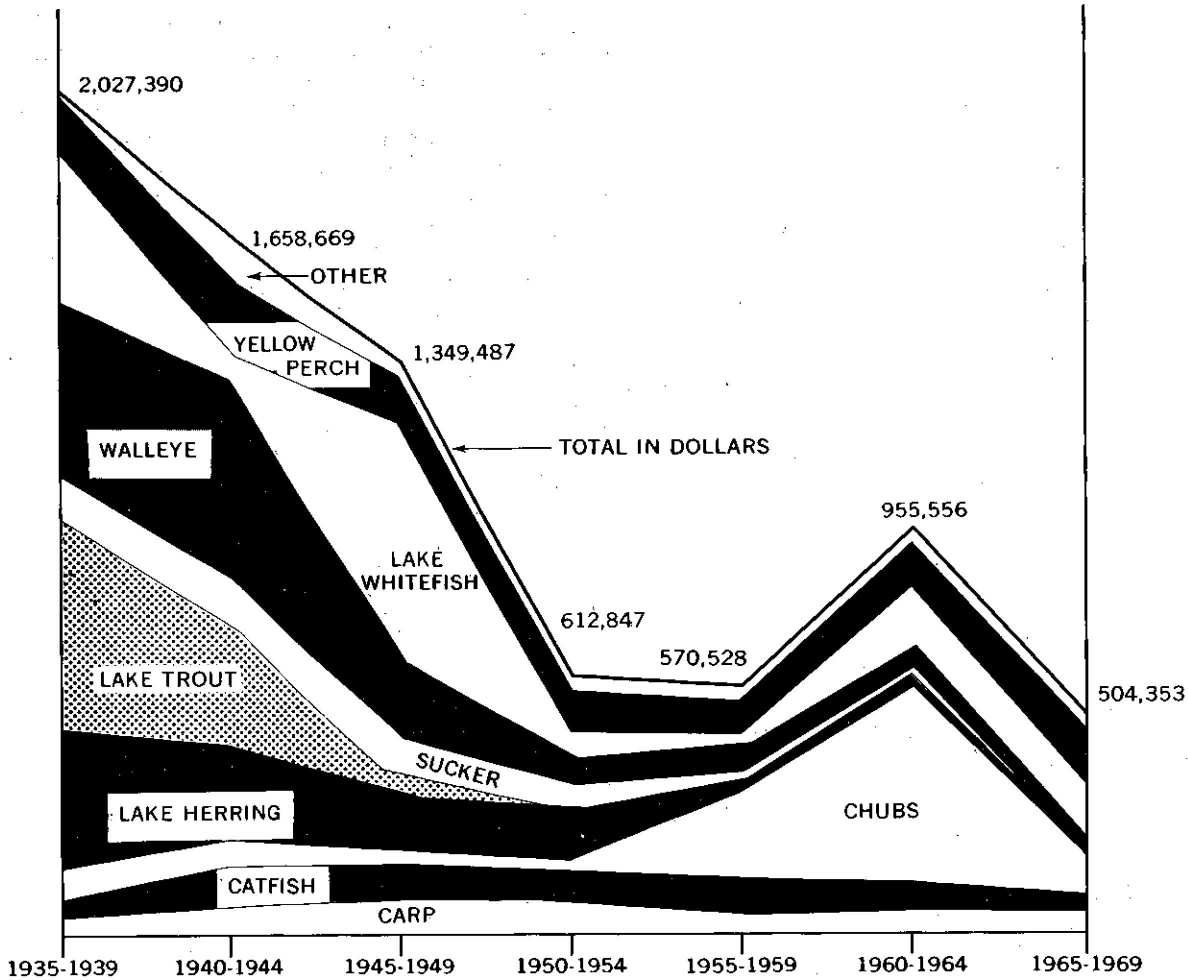


FIGURE 8–47 Average Annual Production (Dollars) for Major Species by the U.S. Lake Huron Commercial Fishery for 5-Year Periods, 1935–1969

fishermen took 76,000 coho, 18,000 chinook, 64,000 steelhead, and 600 lake trout in Lake Huron and tributaries during 1970.

5.1.3 The Fisheries

5.1.3.1 Historical Background of the Lake Huron Commercial Fishery

Commercial fishing began on the U.S. side of Lake Huron in the early 1800s and consisted largely of the capture of lake trout, lake whitefish, and sturgeon by various Indian tribes using spears, dip nets, hook and line, and elm bark gill nets. The introduction of conventional gill nets in the mid-1830s led to a well-established fishery by mid-century. Although seines were first used in approximately 1840, their use did not gain wide acceptance until the early 1900s when carp production began in Saginaw Bay. Fyke net fishing was represented by a through-the-ice fishery for yellow perch, suckers, and catfish in the Saginaw River.

The pound net was introduced around 1860, and the trap net first appeared in the 1890s. These nets were the most prevalently used gear at the turn of the century and accounted for more than 75 percent of the landings at that time.

Except for the introduction of the deep trap net from Lake Ontario in 1929 (a gear ex-

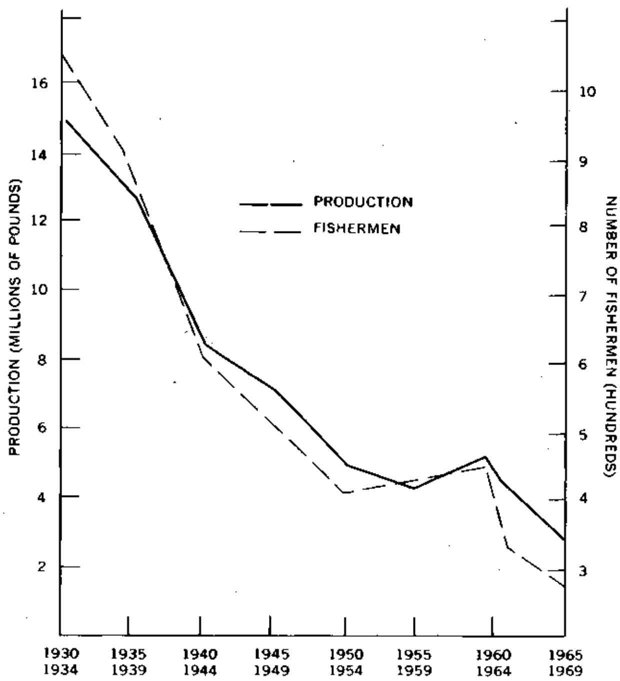


FIGURE 8–48 U.S. Lake Huron Commercial Fishery Production and Numbers of Fishermen

tremely efficient in the capture of whitefish and consequently severely restricted in 1935) and the conversion from conventional to nylon gill nets in the early 1950s, no other major equipment changes have occurred since the turn of the century. Figure 8–48 and Table 8–28 reflect the profound changes which have occurred in the fishery over the last 40 years.

The landed value of the U.S. Lake Huron commercial catch has averaged approximately $500,000 annualy in recent years. A high proportion of the catch is marketed within the Lake Huron basin. Although the total impact of the fishery on the basin economy is relatively small, it does contribute significantly to the economy of some smaller lakeside communities by providing both temporary and permanent employment and supplying local restaurants with fresh fish, an important aspect of the tourist trade. Additional benefits provided by the fishery include a capability for manipulation of fish stocks and a relatively inexpensive method of obtaining crucial stock assessment data.

The present condition of Lake Huron fish stocks does not warrant stabilization or expansion of the commercial fishery for the next 10 years. The success of fishery rehabilitation programs will determine the future of the commercial fishery beyond 1980. Creation of an economically viable commercial fishery must be based on the rational allocation of fish stocks and the maximum utilization of the commercial fishery in directly manipulating fish stocks.

5.1.3.2 Historical Background of the Lake Huron Sport Fishery

Yellow perch, northern pike, smallmouth bass, walleye, and smelt have been the primary sport fish of Lake Huron. Although walleye, bass, and northern pike fisheries have always been restricted to large protected bays and northern island areas, yellow perch fishing was once good from Port Huron to the Straits of Mackinac. Every port had small boats or charter-head boats available to sportsmen.

Until recently sport and commercial fishermen were in direct competition for all the species mentioned except smallmouth bass which were reserved for sport fishing early in the century. In 1966 northern pike fishing was closed to the commercial fishery, and the sport fishery for this species has increased substantially since the closure. In 1970, walleye fishing was closed to the commercial fishery. However, walleye population is so low and the habitat damage so severe that they may not respond to their increased protection without the assistance of artificial propagation. Commercial yellow perch fishing was restricted to Saginaw Bay in 1970. It was hoped that this restriction would allow the population to expand to its former abundance and range, but recent investigations indicate that yellow perch need further protection to regain their former prominence in the sport fishery.

Salmonid plants were started by Michigan in 1968 when 402,000 coho, 200,000 chinook, and 42,000 steelhead were planted in Lake Huron tributaries. Plantings were continued at about the same rate through 1970. Brown trout and rainbow trout were added to the list of species stocked in 1970 when a combined total of 600,000 were planted in Lake Huron.

Little is known about the present economic contribution of the Lake Huron sport fishery. The new programs will undoubtedly increase the economic contribution of the sport fishery. Its economic importance should soon exceed that of Lake Superior and at least equal that of Michigan's portion of Lake Michigan.

TABLE 8–28 Commercial Operating Units and Productivity in the U.S. Waters of Lake Huron

Year	Number of Fishermen[1]	Pounds Landed per Fisherman	Value of Catch per Fisherman[2]	Number of Vessels	Number of Boats
1930	1,118	13,700	$2,502	60	363
1931	1,182	13,931	3,203	65	337
1932	1,228	12,552	2,630	66	341
1934	1,293	11,129	1,800	61	299
1936	836	15,232	2,706	43	232
1937	931	12,722	2,167	36	246
1938	954	12,613	1,851	33	260
1939	1,039	12,852	1,974	35	296
1940	667	13,641	2,369	44	175
1950	513	9,889	924	48	184
1954	491	11,041	1,242	35	186
1955	373	12,228	1,394	30	137
1956	376	9,667	1,062	35	157
1957	346	9,656	1,262	29	152
1958	446	11,421	1,510	44	172
1959	499	10,102	1,625	65	161
1960	566	11,199	2,191	81	172
1961	569	12,158	2,090	82	172
1962	485	12,124	1,838	70	208
1963	426	12,220	1,836	71	182
1964	404	10,134	1,671	62	163
1965	353	13,238	2,169	59	149
1966	303	12,439	1,712	45	49
1967	259	12,399	1,731	39	121
1968	252	10,626	1,602	35	125
1969	222	13,050	1,967	29	102

[1]Refers to all fishermen engaged in harvesting.

[2]Value deflated by wholesale price index (1957-1959=100).

5.1.4 Effects of Non-Fishery Uses on the Fish Resources

Lake Huron has uses other than fishing: navigation, water supply, waste disposal, and recreation. These uses result in chemical, physical, and biological changes in the Lake which in turn affect fish resources.

5.1.4.1 Effects of Chemical Changes

Table 8–29 lists yearly loadings of chemical substances to Lake Huron. Although large amounts of pollutants have been added, the main body of the Lake has shown only slight changes with increases evident in total dissolved solids, chlorides, and sulfates. However, most Great Lakes experts feel that environmental changes have been partially responsible for changes in fish populations particularly because of their strong influence on tributaries, shore zones, and bays. For instance, during the 1930s sauger production in Saginaw Bay declined to insignificance despite the absence of an intensive fishery. This would indicate that changing environmental conditions were partially responsible for their

TABLE 8–29 Loadings to Lake Huron in Tons per Year

Parameter	Inflow Lake Superior	Inflow Lake Michigan	U.S. Tributaries	Outflow Lake Huron
Chlorides (Cl)	78,000	280,000	950,000	1,000,000
Total Solids	3,900,000	6,400,000	5,200,000	22,000,000
Suspended Solids	78,000	95,000	290,000	1,600,000
Volatile Susp. Solids	78,000	95,000	90,000	520,000
Total Iron (Fc)	36,000	13,000	6,000	35,000
Total Phosphate (PO_4)	2,900	5,700	5,000	15,000
Soluble Phosphate (PO_4)	1,400	2,800	3,300	12,000
Nitrate-Nitrogen (N)	10,000	9,500	5,200	31,000
Ammonia-Nitrogen (N)	5,700	9,000	4,900	19,000
Organic-Nitrogen (N)	5,700	7,600	2,300	19,000
Calcium (Ca)	930,000	1,400,000	810,000	4,700,000
Magnesium (Mg)	210,000	520,000	230,000	1,600,000
Sodium (Na)	140,000	190,000	400,000	700,000
Potassium (K)	72,000	94,000	74,000	170,000
Sulfate (SO_4)	210,000	900,000	470,000	3,000,000
Alkalinity ($CaCO_3$)	3,000,000	4,400,000	1,800,000	14,000,000
Hardness ($CaCO_3$)	3,200,000	5,200,000	2,700,000	16,000,000
Phenol	140	95	68	520
COD	430,000	240,000	260,000	1,200,000
BOD	72,000	94,000	39,000	170,000
DO	720,000	530,000	110,000	1,900,000
Flow (in cfs)	72,600	48,000	11,000	176,900

demise. Similarly, pollution may have been a significant factor in the decline of the walleye. It may also be responsible for the current absence of walleye reproduction.

Inputs of pollutants have had profound effects on a local level. Many harbor beach bottoms have been covered by a fine black ooze which has created areas of anaerobic decomposition. In these areas this bottom cannot be used for spawning or feeding. As far back as 1943 investigations in Saginaw Bay have indicated that pollution has tainted fish taken from the Bay. Therefore commercial production of some species has been limited. Dissolved oxygen levels in Saginaw Bay as low as 66 percent saturation have been recorded. Were it not for the rapid flushing rate, 186 days, conditions would be worse.

If remedial measures are not applied, the water quality of Saginaw Bay and other inshore areas will decline. Because these shallow areas are important to the life cycles of many fish species of Lake Huron, this decline will undoubtedly have adverse effects. Conditions in the open waters of the Lake will largely depend on the quality of inflows from Lakes Michigan and Superior.

5.1.4.2 Effects of Physical Changes

The major physical changes that have occurred in the Lake are concentrated in the Saginaw Bay region where dredge and fill operations have reduced or altered fish habitat. However, lakewide physical changes have been minor.

Studies are being conducted on the feasibility of regulating the water levels and extending the navigation season of the Great Lakes. Both studies propose alternatives which would grossly affect physical conditions and fish resources. If the Lakes were controlled at a high level, the fish habitat would probably be enhanced by increasing shoal areas. However, lower levels would reduce the shoal areas and adversely affect fish resources.

Certain proposals for extending the navigation season involve procedures which would maintain channels ice-free. These include the use of air curtains (which could block and retard fish movement), the building of ice-stabilizing islands (which could adversely affect local lake environment), and thermal discharges from strategically located power plants (which could adversely affect the ecosystem).

5.1.4.3 Effects of Biological Changes

In summary, major changes have occurred in Lake Huron's fish resources. The principal factors for these changes have been sea lamprey predation, increase in alewife abundance, and fishing exploitation. Localized changes in the chemical and physical environment have added to the problems in Lake Huron and decreased the value of the fish resources of the Lake.

5.1.5 Competition between Fishing and Other Uses

There is little direct competition between fishing and other uses of Lake Huron. Shoreline property for access sites or for the land-based operations of a commercial fishery has not become prohibitively expensive, and the State of Michigan's zone management plan is designed to separate users and reduce conflicts. Presently, only minor problems exist in areas (such as parts of Saginaw Bay, which receive heavy recreational pressures) where commercial fishing is voluntarily curtailed during the summer months to allow recreational boating and water-skiing.

5.1.6 Fisheries Management

5.1.6.1 Past and Present Management

Until the latter part of the 19th century, a laissez-faire management policy existed in the Michigan waters of Lake Huron. The Michigan Fish Commission was formed in 1873 and continued this policy until the mid-1940s. During the time, management efforts were designed to increase the number of fish available through massive stocking programs.

Regulation of commercial fishermen has been limited to adjusting regulations on closed seasons, fish size, and gear rather than controlling fishing effort. These laws have had negative effects on both the commercial fishery and the fish resources. They have restricted the fishery to inefficient harvesting techniques, and they have not provided adequate protection for the fish stock. There have been few regulations on sport fishing. Sport fishing licenses were not required on Lake Huron until 1968.

Michigan's management objective on Lake Huron is to achieve a viable, high-value sport fishery and at the same time develop a profitable and progressive commercial fishing industry. Both goals necessarily involve intensive efforts to build up species that would contribute to both fisheries.

The State and Federal governments and the Provincial government of Ontario are conducting several such programs on the Lake: sea lamprey control, stocking of hatchery-reared salmonids, habitat improvement and maintenance, regulation of fishing, and other investigations.

Sea lamprey control in U.S. waters of Lake Huron is carried out by the Bureau of Sport Fisheries and Wildlife under a contract with the Great Lakes Fishery Commission. In Canadian waters, it is under the direction of the Department of Fisheries and Forestry. Chemical treatment of Lake Huron streams began in 1960 but was discontinued in 1962 because of lack of funds. Treatment was resumed in 1968, and the first round of treatment was completed in 1970.

Michigan has concentrated on developing hatchery stocks of rainbow and brown trout and coho and chinook salmon, as well as rearing splake obtained from the Province of Ontario. Michigan started stocking salmon in 1968. Although Canada experimentally introduced F_1 splake in 1958, selected splake (F_3 or greater) were not planted until 1969. This marked the beginning of an attempt to establish a self-sustaining population of splake. A second, substantially larger planting was made in 1970. At this time the Bureau of Sport Fisheries and Wildlife made the first Michigan water planting of splake. The Province of Ontario is also involved in plantings of kokanee salmon. To complement these stocking programs several habitat improvement programs are under way to improve access and provide release ponds for anadromous fish.

To facilitate management activities, the Department of Natural Resources presently operates five hatcheries, two rearing stations, and one brood stock station (for lake trout). It also operates the Hatchery Biology Service Center, which diagnoses and treats hatchery disease. Michigan also operates two management surveillance vessels and two converted law enforcement vessels.

Michigan recently started requiring sport fishing licenses for Lake Huron. The State is also moving toward greater control of the commercial fishery through outright prohibition of the commercial capture of certain species, establishment of a partial form of limited entry by limiting licenses to fishermen who have met certain standards for minimum activity and production, and initiation of a zone management plan in 1970 by which commercial fishing is limited to specific areas.

Implementation procedures for limited entry are being contested in court by some commercial fishermen. Zone management has been successful in eliminating some conflicts between the sport and commercial fisheries by removing the commercial fishery from certain areas. This has simplified enforcement procedures for the management agency. Implementation of limited entry and zone management has not had a significant effect on either the total commercial fishery production or value of the catch per fisherman in comparison to previously established levels.

Both the State of Michigan and the Federal government are conducting investigations of fish resources (including the habitat base) and the fishery of Lake Huron. Programs of the Federal Great Lakes Fishery Laboratory are designed to develop an understanding of factors which influence fish survival and abundance and to contribute to the knowledge needed by the DNR to establish and maintain a balanced, multispecies complex in the Lake. In 1968 the Fisheries Division established a fishery station at Alpena to develop a monitoring program to assess salmon plantings. Other current or proposed investigations by Michigan include creel censuses, delineation of populations and habitat requirements of northern pike, walleye, and smallmouth bass, and stock assessment of important sport and commercial species.

5.1.6.2 Cost of Fish Management and Development Programs

The cost of fish management and development programs can be found in Table 8–30. Costs mentioned in the following discussion and rendered by the former Bureau of Commercial Fisheries (BCF) are not included in the table because of the recent dissolution of the BCF Inland Region 3. It is not yet known whether some other agency will pick up these activities and associated costs, which were estimated at $43,000 annually for Lake Huron. These costs represent the single greatest State expenditure for any activity other than fish stocking specified in Table 8–30 and reflect the serious problems encountered when Michigan attempted to exert control over the commercial fishery. Developing a climate of greater mutual confidence could result in reduced costs.

Michigan's Department of Natural Resources, assisted by Federal aid programs of the Bureau of Sport Fisheries and Wildlife, is currently involved in planting salmonids in U.S. Lake Huron waters. The sport fishery has already realized the limited benefits of these initial stocking programs. However, commercial fishermen are restricted from taking salmonid species in Michigan waters of Lake Huron. In addition rainbow trout, brown trout, and salmon will not be utilized by an open water commercial fishery as we now know it.

Fishery research on the open Lake has been done primarily by the Great Lakes Fishery Laboratory of the old Bureau of Commercial Fisheries. The name Bureau of Commerical Fisheries suggests that research conducted by this agency was intended to benefit the commercial fisheries. However, the actual end result of the Bureau's research was a basic understanding of ecological processes in the Great Lakes. Biological research findings have sometimes been applicable to the total fishery, but direct, specific benefits to the commercial fishery are rare.

The Branch of Marketing of the National Marine Fisheries Service carries on programs to educate consumers on the advantages of fish as a diet item. However, this effort is directed towards the consumption of saltwater fish and is rarely applied to species currently produced by the Lake Huron commercial fishery. The dissolution of the BCF Inland Regional Office may result in further deemphasis on freshwater fish.

The BCF Exploratory Fishing and Gear Research Program has assisted the Lake Huron commercial fishery in the past. However, with the dissolution of the BCF Inland Regional Office, this program is currently nonexistent. The limited level of BCF technological (processing) assistance to the commercial industry has been useful, but the costs assigned to the Lake Huron commercial fishery were rela-

TABLE 8–30 Annual Expenditures on Fisheries Programs in Thousands of Dollars, Lake Huron

	Michigan Dept. Natural Resources					Bureau of Commercial Fisheries				
Program	1965	1966	1967	1968	1969	1965	1966	1967	1968	1969
Fish Management										
Stocking	----	----	----	----	----[1]	----	----	----	----	----
Habitat Improvement	----	----	----	----	----[2]	----	----	----	----	----
Lamprey Control[3]	----	----	----	----	----	----	46.0[4]	182.0[4]	----	210.9[4]
Fishery Management										
Enforcement										
Sport	----[5]	----[5]	----[5]	----[5]	13.4	----	----	----	----	----
Commercial	----[5]	----[5]	----[5]	----[5]	43.0	----	----	----	----	----
License Overhead	5.4	5.1	5.3	9.7	10.5	----	----	----	----	----
Research										
Habitat Base	----	----	----	----	----	----	.5	----	1.0	----
Fish	30.0	30.0	30.0	30.0	30.0	44.6[6]	41.0[6]	46.2[6]	43.5[6]	66.8[7]
Fishery										
Commercial Fishery	----	----	----	----	----	----	----	----	----	----
Statistics[8]	----[5]	----[5]	----[5]	----[5]	----[5]	----	----	----	----	----
Creel Census	----[5]	----[5]	----[5]	.5	2.5	----	----	----	----	----
Total	35.4	35.1	35.3	40.2	99.4	44.6	87.0	228.2	44.5	277.7

[1]Stocking initiated in 1970 at $344,822

[2]Habitat improvement initiated in 1970 at $5,342

[3]New (FY1971) handled by Bureau Sport Fishery and Wildlife

[4]Funds provided by Great Lakes Fishery Commission

[5]Unavailable

[6]Research on Lamprey--funds provided by Great Lakes Fishery Commission

[7]Research on Lamprey--funds provided by Great Lakes Fishery Commission (includes $20,000 of Bureau of Commercial Fisheries' money for population assessment)

[8]1970 cost--$33,000

tively negligible. The program's technological research was unable to develop product forms that would increase the acceptability of currently underutilized, low-value species.

Sea lamprey control has been initiated on the U.S. side of Lake Huron at an approximate cost of $200,000 annually. Based on results in Lakes Superior and Michigan, it will take a few years to reduce lamprey populations and restore or establish salmonids and other high-value species. Because stock allocations of these species are made to the commercial fishery, it would be appropriate that the fishery pay a portion of the costs. Although high-value fish are not significantly present in the current commercial catch, their future inclusion will greatly increase the approximately $500,000 annual landed value of the current harvest.

5.1.7 Projected Demands

Projected demands for Lake Huron commercial fish species are identical to those discussed in Subsection 2.5.1.

5.1.8 Problems and Needs

The economic and recreational value of the Lake Huron basin depends directly upon the

Lake, its bays, and inshore waters. High quality water, which meets the various biological requirements for feeding, growth, reproduction, and survival, is vital to fish and wildlife.

Lake Huron has not exhibited the signs of water quality degradation apparent in Lakes Michigan and Erie except for inner Saginaw Bay and other previously mentioned inshore areas. Water quality changes have not had significant adverse effects on fish and aquatic life resources in the open Lake. Although water quality is relatively good for fish and wildlife, some changes have developed. In the open Lake, there has been a slight increase in total dissolved solids. Although dissolved oxygen is usually near saturation, it has been reported as low as 66 percent saturation in Saginaw Bay. Were it not for the rapid flushing rate of the bay, serious oxygen depletion problems would have already developed. Nuisance growths of *Cladophora* have occurred in certain inshore areas and *Oligochaetes*, often a biological indicator of enriched or polluted habitat, are dominant in the vicinity of several harbors. These indications of changing water quality should be taken seriously and steps should be taken to slow down, and eventually halt, inputs of pollution. In addition many tributaries such as the Saginaw River have displayed extensive deterioration of water quality.

Although it is important to control pollutants entering Lake Huron from its own basin, the overriding determinant of Lake Huron water quality is the quality of waters received from Lakes Michigan and Superior. Except for bacteria levels, water quality standards that meet fish and wildlife needs should meet the needs of most other uses. Therefore, it is in the public interest to preserve and enhance Lake Huron and its basin.

After the passage of the 1965 Water Quality Act, Michigan developed water quality standards to protect the fish and wildlife resources of Lake Huron. However, these standards may prove to be inadequate for aquatic life. Additional research may demonstrate the need for redefinition and refinement to meet fish and wildlife requirements. Moreover, water quality standards are generally the minimum necessary to maintain various conditions of habitat quality. Because of the rapid changes occuring in the Great Lakes ecosystem, every effort should be made to maintain the quality of those areas currently exceeding minimum standards. Existing water quality in most of the Lake Huron basin is better than the minimum standards for almost all parameters. Until careful research demonstrates that degradation of existing water quality to State and Federal levels will not result in harmful effects upon fish and aquatic life resources, the Fish Work Group contends that pollution abatement in Lake Huron is best served by retention of the existing high quality. In order to maintain the present water quality, conditions in the Saginaw River and inner Saginaw Bay, which are significant sources of pollution input, should be improved. Immediate efforts should also be made to restore the water quality of Lake Michigan because programs to maintain present water quality in the open waters of Lake Huron are meaningless unless the quality of water that flows in from Lake Michigan is improved.

Because of their inherent sensitivity to subtle, long-range environmental changes, fish and other aquatic organisms make excellent indicators of changes in water quality. Therefore, problems should be recognized and corrected before they become critical to humans. Unfortunately, these indicators have not been used in the past. In the future more emphasis should be placed on research and monitoring of the fish and wildlife-aquatic organism sector of water quality.

To obtain maximum benefits from an environmental research program and to assure continuity in data collection, information must be coordinated and exchanged. Because fishery agencies presumably have the responsibity to maintain a harvestable surplus of aquatic life and to contribute to man's understanding of aquatic resources and their environment, these agencies should also coordinate and conduct research related to long-term water quality changes. This latter function could be partially exercised through the Great Lakes Fishery Commission, where an approach encompassing all the Great Lakes can be adopted.

5.1.8.1 Fish Resource Problems and Needs

Although the Michigan Department of Natural Resources is experiencing problems common to all Great Lakes management agencies, its coordination and allocation problems in Lake Huron are accentuated by local conditions and deserve special consideration.

In anticipation of the success of the sea lamprey control program, Michigan and the Province of Ontario have initiated plantings of various salmonid species, some of which have already entered the fishery in limited numbers. Coordination problems between the two management agencies have arisen as a result of conflicting agency objectives.

In an attempt to reestablish a viable, high-value fishery resource in Lake Huron, the Province of Ontario has been developing a lake trout-brook trout hybrid, the splake. The splake combines the large size and deep swimming ability of the lake trout and the early sexual maturity of the brook trout. It is hoped that the splake, because of its earlier sexual maturity, will exhibit more adaptability than late-maturing species and will therefore perpetuate itself despite residual sea lamprey populations.

Michigan is more concerned with planting lake trout in order to develop an immediately viable sports fishery. This program is influenced by mounting pressure from sports fishermen, and the fact that no large-scale plantings of splake were possible until after 1972. However, it is possible that planting large numbers of lake trout will cause a dilution of the gene pool thus negating the positive characteristics of the splake.

If reestablishment of a high-value fish resource is to be realized, these coordination problems must be resolved. The Great Lakes Fishery Commission is the only existing agency capable of achieving this kind of coordination and is currently engaged in efforts to realize this goal.

5.1.8.2 Problems and Needs of Lake Huron Commercial Fishery

General problems and needs of the Lake Huron commercial fishery are identical to those of the Great Lakes discussed in Subsection 2.7. Specific problems will be discussed in this subsection.

Lake Huron suffers from depressed stocks of high-value species. Various programs are under way which hopefully will lead to the rehabilitation of those stocks and restoration of a desired ecological balance. Because of increased sport fishing demand in both inshore and open waters, constraints on the allocation of rehabilitated fish stocks to the commercial fishery are inevitable. Even without sport fishing pressure, management agencies believe that there are too many commercial fishermen for the present, and even the future resources.

There are several management approaches to this problem:

(1) total restrictions against the commercial harvest of certain species
(2) limited entry
(3) zone management
(4) possible contract fishery

A mixture of approaches geared to meet specific Lake Huron situations is needed. If this process is to succeed, the following guidelines must be considered:

(1) The goal is balanced development of the total fishery in the light of the best biological, economic, and sociological information.

(2) All those who use and benefit from the fishery resources must participate in selecting and implementing the approaches necessary to achieve a balanced total fishery. Implementation is difficult at the practical administrative level and requires communication between management agencies and the commercial fishing industry.

(3) Programs should be flexible enough to meet changing conditions and permit modification in solving problems of allocation and regulation. At the same time, enough continuity and stability should prevail (particularly in allocation decisions) to permit rational investment decisions.

(4) The amount of accurate biological information should be increased by using all available sources.

(5) The Great Lakes, including the Canadian portion, should be viewed as a total system in approaching fishing problems.

5.1.8.3 Problems and Needs of Lake Huron Sport Fishery

Sea lamprey control and trout and salmon stocking are the greatest needs of the Lake Huron sport fishery. Promotion is essential in the early stages of development to attract and educate fishermen. Safe and adequate launching facilities are also needed in many locations to assure access to the better fishing areas.

The problem for any Great Lakes sport fishery is that of competing commercial interests. A sport fishery must have an abundance of highly desirable species in order to sustain fisherman interest. The sport fishery cannot develop unless commercial exploitation of the sport species or the forage base is controlled.

5.1.9 Probable Nature of Solutions, Natural Resource Base

The solutions for deteriorating water quality proposed in the Introduction are generally applicable to Lake Huron as well. However, Lake Huron has some particular problems to be considered:

(1) Saginaw Bay is a major focal point of water problems because of its large size, sheltered waters, shallow depths, and the magnitude of waste loads delivered by the Saginaw River (which services every major U.S. city in the Lake Huron basin). Smaller streams, such as the Kawkawlin, also contribute to the pollution of the bay. The bay has the highest fishery productivity of the entire Lake Huron ecosystem, and demand for water-dependent and water-enhanced recreational activities in the Saginaw Bay area is expected to triple. Therefore, a need exists for more efficient treatment plants. Improvement of the Saginaw Bay waters would also require:

(a) continued monitoring and assessment of effluent discharges in the Lake Huron basin, especially those in the Saginaw River basin. Special emphasis should be placed on identifying and halting those likely to cause damage to the receiving waters and biota.

(b) accelerated construction of waste treatment plants which were funded by Michigan's 1968 $335 million pollution bonding program

(c) stringent implementation of present laws including the Federal Water Pollution Control Act Amendment of 1972 and updated State water quality standards. This would include continuation of present State policies and regulations related to dredging and depositions of spoils.

(d) preservation and enhancement of the shallow water habitat (and associated wetlands) which characterize much of Saginaw Bay and which represent the largest single block of this habitat in the Lake Huron ecosystem. Dredging, dumping, and developmental encroachment have already eroded this habitat base. These procedures are expected to increase. Further consideration should be given to establishing Saginaw Bay as a National Estuary under the provisions of the National Estuary Protection Act.

(2) Because Lake Huron receives approximately 30 percent of its waters from Lake Michigan, it is important to insure that Lake Michigan waters are of high quality.

Solutions to the problems and needs of the fishery resources of Lake Huron are not substantially different from those of the Great Lakes discussed in the Introduction of this appendix.

5.2 Planning Subarea 3.1

5.2.1 Species Composition, Relative Importance, and Status

Planning Subarea 3.1 (Figure 8–49) is similar to Planning Subarea 2.4. Trout is the most important sport fish in the river systems. The Black, Sturgeon, Pigeon, Au Sable, and Rifle Rivers offer some of the best fishing for brook and brown trout in the State. Impoundments and natural lakes are common throughout the lower reaches of major rivers, and warmwater species such as smallmouth bass, walleye, and northern pike are the most important species in these areas.

The inland lakes have traditionally supported sport fisheries for perch, bluegill, and other panfish. Big fish which attract anglers to the inland lakes include large- and smallmouth bass, northern pike, muskellunge, walleye and, in rare cases, sturgeon.

Populations of large warmwater predators in the inland lakes are restricted due to destruction of spawning habitat and selective overexploitation by fishermen. Populations of panfish and rough species have expanded and now dominate many lakes to the detriment of the total sport fishery.

Some large inland lakes are deep enough to support trout as well as warmwater species. Many smaller lakes are managed exclusively for trout through periodic chemical treatment and annual maintenance plantings.

Anadromous runs are limited because of the location of hydroelectric dams and the current lack of adequate sea lamprey control in Lake Huron. The few streams that do support runs of steelhead and salmon are very important.

5.2.2 Habitat Distribution and Quantity

The distribution of ponded water (Figure 8–50) has little direct effect on license sales. In counties where ponded water is lowest, the available trout stream resources more than make up the difference. Resident license sales per capita range from 1.0 to .25 and ponded water per capita averages more than 1.0 for the entire planning subarea (Table 8–31).

This planning subarea offers more than 138,000 acres of ponded water. Cheboygan County alone has 51,000 acres of ponded water and supports the largest number of licensed fishermen in the planning subarea, more than 12,000 in 1966.

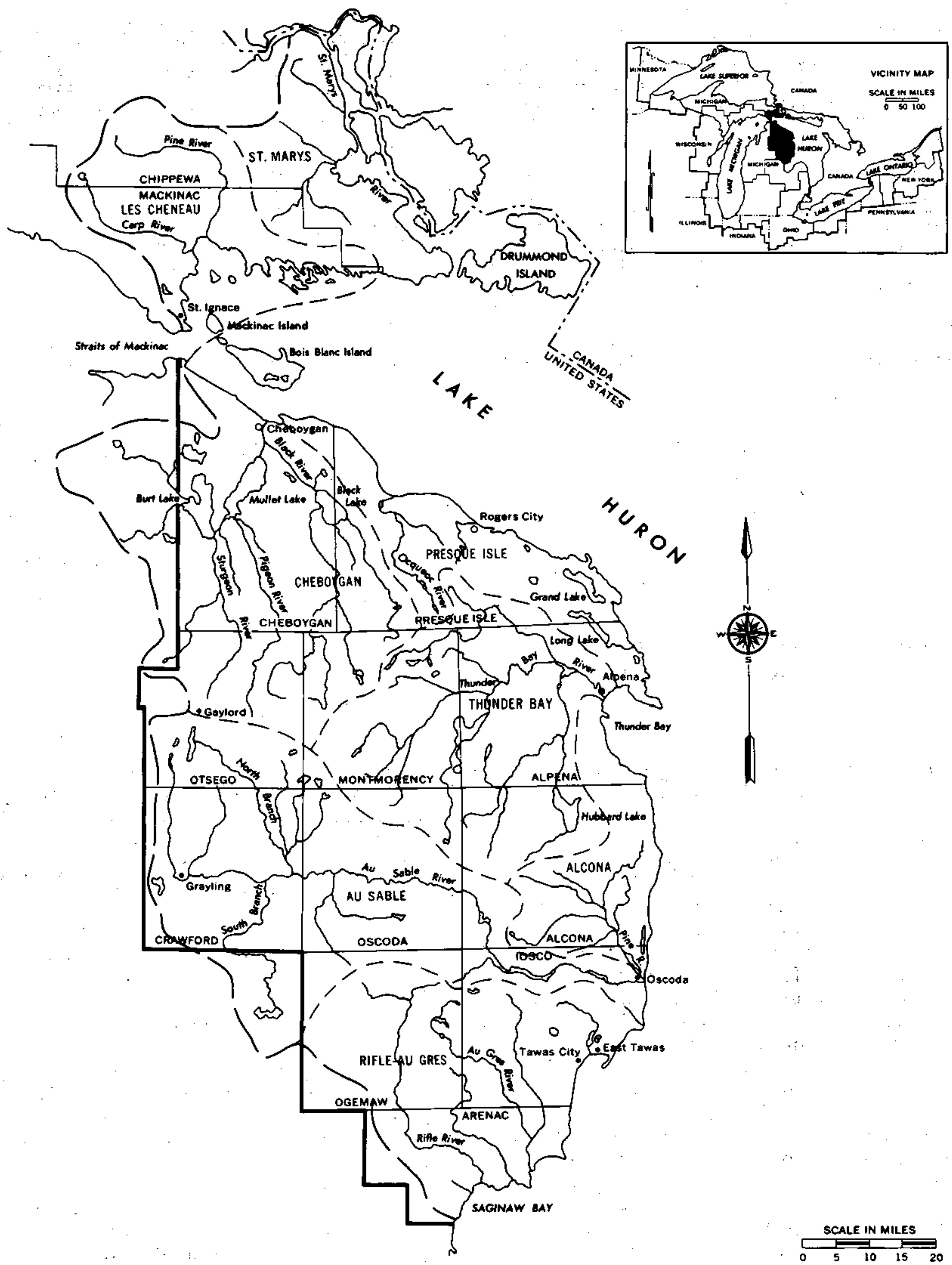


FIGURE 8–49 Planning Subarea 3.1

TABLE 8–31 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 3.1

State and Counties	Land Area (sq.mi.)	Population (1000s)	Population per Sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
Michigan								
Alcona	676	6.3	9.3	12,777	2.0281	490	3,428	.5441
Alpena	564	29.2	51.8	17,251	.5908	1,877	7,187	.2461
Arenac	367	9.6	26.2	190	.0198	893	6,243	.6503
Cheboygan	716	14.9	20.8	51,870	3.4812	4,111	8,047	.5401
Crawford	560	5.9	10.5	2,491	.4222	1,327	4,096	.6942
Iosco	542	23.1	42.6	10,718	.4640	1,570	10,038	.4345
Montmorency	554	4.6	8.3	11,543	2.5093	1,304	4,965	1.0793
Ogemaw	567	10.1	17.8	5,826	.5768	522	4,924	.4875
Oscoda	561	4.1	7.3	5,338	1.3020	442	2,200	.5366
Otsego	524	8.2	15.6	6,737	.8216	1,016	4,005	.4884
Presque Isle	645	12.1	18.8	14,036	1.1600	891	4,607	.3807
Total	6,276	128.1	20.4	138,777	1.0833	14,443	59,740	.4664

State and Years	Land area (sq.mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand: Resident[1]	Projected Angler Day Demand: Total[2]
Michigan					
1980	6,276	164.3	26.2	2,630,998	4,281,000
2000	6,276	208.7	33.3	3,341,992	5,339,000
2020	6,276	267.0	42.5	4,275,572	6,692,000

[1]Demand generated within planning subarea.

[2]Total demand including in- and out-migration.

5.2.3 Habitat Problems Affecting Production and Distribution of Important Fish Species

The rapid development of recreational sites has caused considerable habitat damage to both the lakes and streams of the planning subarea. Dredging and filling have reduced the available spawning areas on inland lakes, and septic runoff from heavy cottage development has accelerated eutrophication. Intense streamside cottage development has destroyed the aesthetic attraction of many streams. The construction of low-head dams on trout feeder streams has elevated stream temperatures beyond the limits for trout.

New Statewide restrictions on dredge and fill have helped control some of the problems on inland lakes and navigable rivers. Some townships and counties have instituted zoning ordinances to preserve the quality of streamside property, but strong legislation is needed to provide State agency support to local communities in planning and implementing necessary zoning laws.

Although there are no major metropolitan areas, domestic waste disposal is a major problem. Small communities that once depended upon streams to dilute and carry away waste now find that these streams are slowly changing because of the nutrients in domestic waste. Many stream areas below these waste outfalls can no longer support good trout populations. The solution may have to be land disposal of the nutrient-rich waste effluent.

5.2.4 History of Sport Fishery

The number of resident fishing licenses sold has been steadily increasing, and in 1968 it reached a new high of 66,462. Nonresident license sales are consistently approximately one-fourth the resident sales.

Planning Subarea 3.1 has not experienced the large increase in fishing license sales recorded in Planning Subarea 2.4 during the last three years because steelhead and salmon fishing has not developed as rapidly in Lake Huron and its tributaries.

Warmwater fishing on large inland lakes and trout stream fishing will probably remain

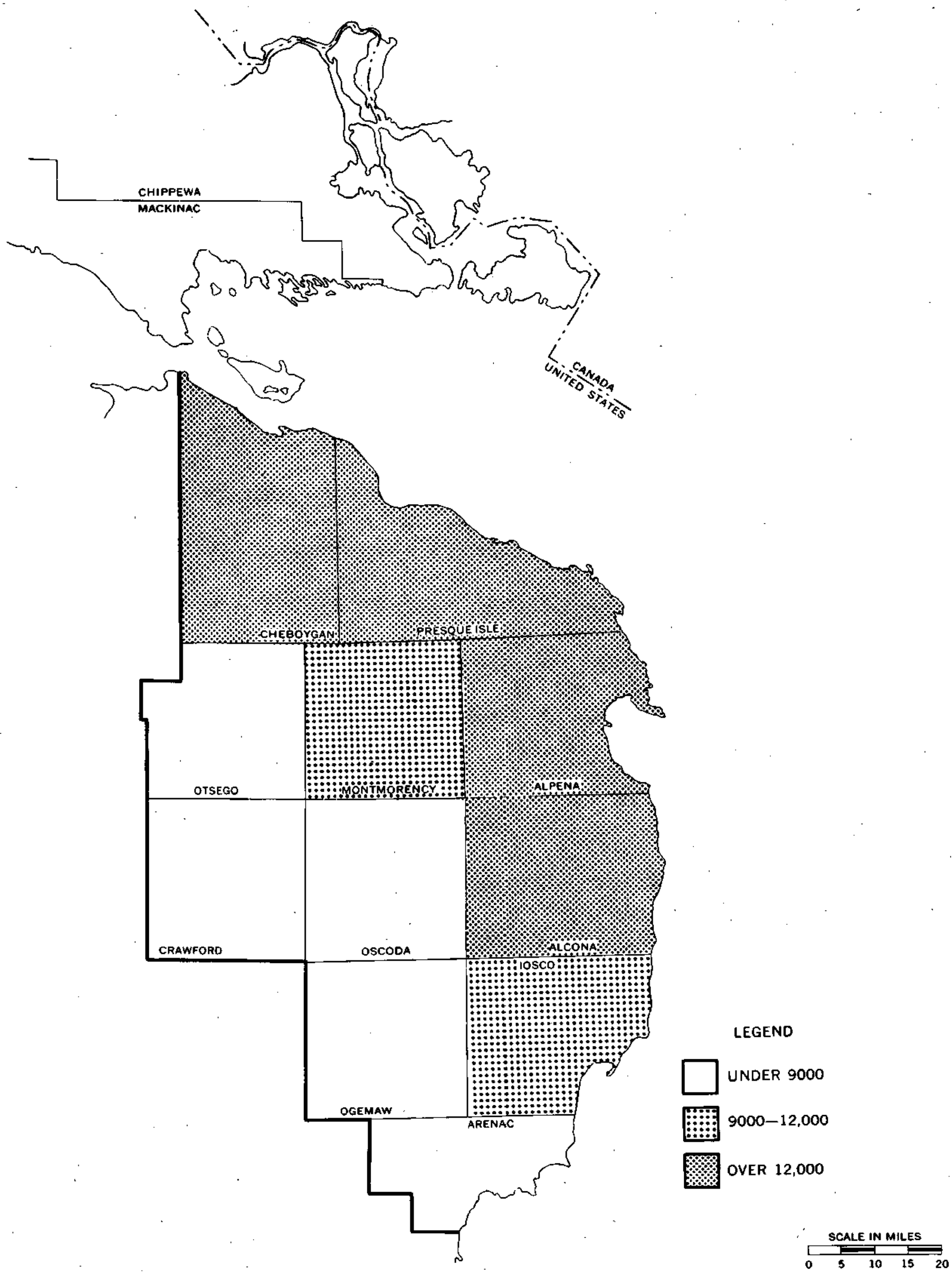


FIGURE 8–50 Acres of Ponded Water, Planning Subarea 3.1

the primary sources of angling opportunities in the planning subarea.

5.2.5 Existing Sport Fishing Demand and Current Needs

The total angler day demand expressed in the inland waters has increased steadily since the early 1950s. An excess of 2,000,000 angler days is currently (1970 base year) provided, not including fishermen who buy their licenses outside the planning subarea and fish in Planning Subarea 3.1. In-migration probably accounts for an additional 1.4 million angler days currently provided.

This entire demand is probably being supplied by the inland waters. Needs reflect the difference between existing supply and demand. Demand determined only through license sales must be satisfied, and therefore, needs cannot be quantitatively determined.

5.2.6 Ongoing Programs

Much of the fish management effort involves protection of fish habitat and maintenance of existing fishery resources. Annual maintenance plantings of hatchery fish and the operation of artificial spawning marshes are important to the current fishery program. Figures 8–51 and 8–52 and Table 8–32 summarize the fishery programs in Planning Subarea 3.1.

In 1969 more than 800,000 rainbow trout, brown trout, splake, and steelhead were planted totaling more than 50,000 pounds. Warmwater fish plants during the same year totaled 316,000 fish, but most were fry and the poundage was quite small in comparison. Warmwater plants included muskellunge, sunfish hybrids, smallmouth bass, and largemouth bass.

Salmon plants were initiated in 1969 when 200,000 chinook were planted in the Ocqueoc River. In 1968 the Au Sable, Tawas, and Thunder Bay Rivers were planted with a total of 352,000 chinook. These same three rivers were planted with 500,000 coho in 1970.

Steelhead stocking was initiated in 1968 in the Au Gres, Au Sable, and Ocqueoc Rivers when 50,000 were planted. Steelhead stocking rates have increased each succeeding year in these rivers.

5.2.7 Future Trends in Habitat and Participation

Future demand based on the current relationship of habitat base to number of licensed fishermen indicates that the number of angler days will increase to 3.1 million by 1980. There will be an increased demand on the fishery resources of Planning Subarea 3.1 from people buying their licenses in other planning subareas (Table 8–31).

New impoundments are not a significant factor in supplying this demand in Planning Subarea 3.1. However, the new warmwater fish hatchery in Planning Subarea 4.1 will raise enough planting stock to manage 30,000 acres of warmwater lakes in Planning Subarea 3.1 and provide 750,000 new angler days in the planning subarea by 1980.

Preservation of the quantity and quality of the present fishery resources of Planning Subarea 3.1 will be a difficult task because of the expected increased use and development

TABLE 8–32 Summary of Base Year Fish Habitat and Management Efforts, Planning Subarea 3.1

County	Total Area (sq.mi.)	Acres Ponded Waters	Number Ponded Waters	Number Intensively Managed	Acres Intensive Warmwater	Acres Intensive Trout	Miles Total Streams	Miles Trout Streams	Miles Anadromous Streams
Michigan									
Alcona	694	12,777	46	4	1,513.1	25.9	362	251.8	7.0
Alpena	590	17,251	31	--	-------	--------	301	16.5	1.1
Arenac	369	190	8	--	-------	--------	156	34.5	29.3
Cheboygan	798	51,870	44	6	3,395	34,596.9	420	118.0	----
Crawford	566	2,491	34	9	1,920	9,725.8	204	87.2	----
Iosco	563	10,718	53	--	493	--------	259	123.1	12.4
Montmorency	567	11,543	89	9	128.5	1,064.2	306	120.0	----
Ogemaw	580	5,826	129	2	-------	126	381	162.0	----
Oscoda	568	5,338	73	3	224	311.6	219	104.2	----
Otsego	538	6,737	115	11	1,972	467.6	198	134.8	----
Presque Isle	678	14,036	77	5	6,560	139	301	103.6	2.0
Total	6,511	138,777	699	50	16,205.6	46,457	3,107	1,255.7	51.8

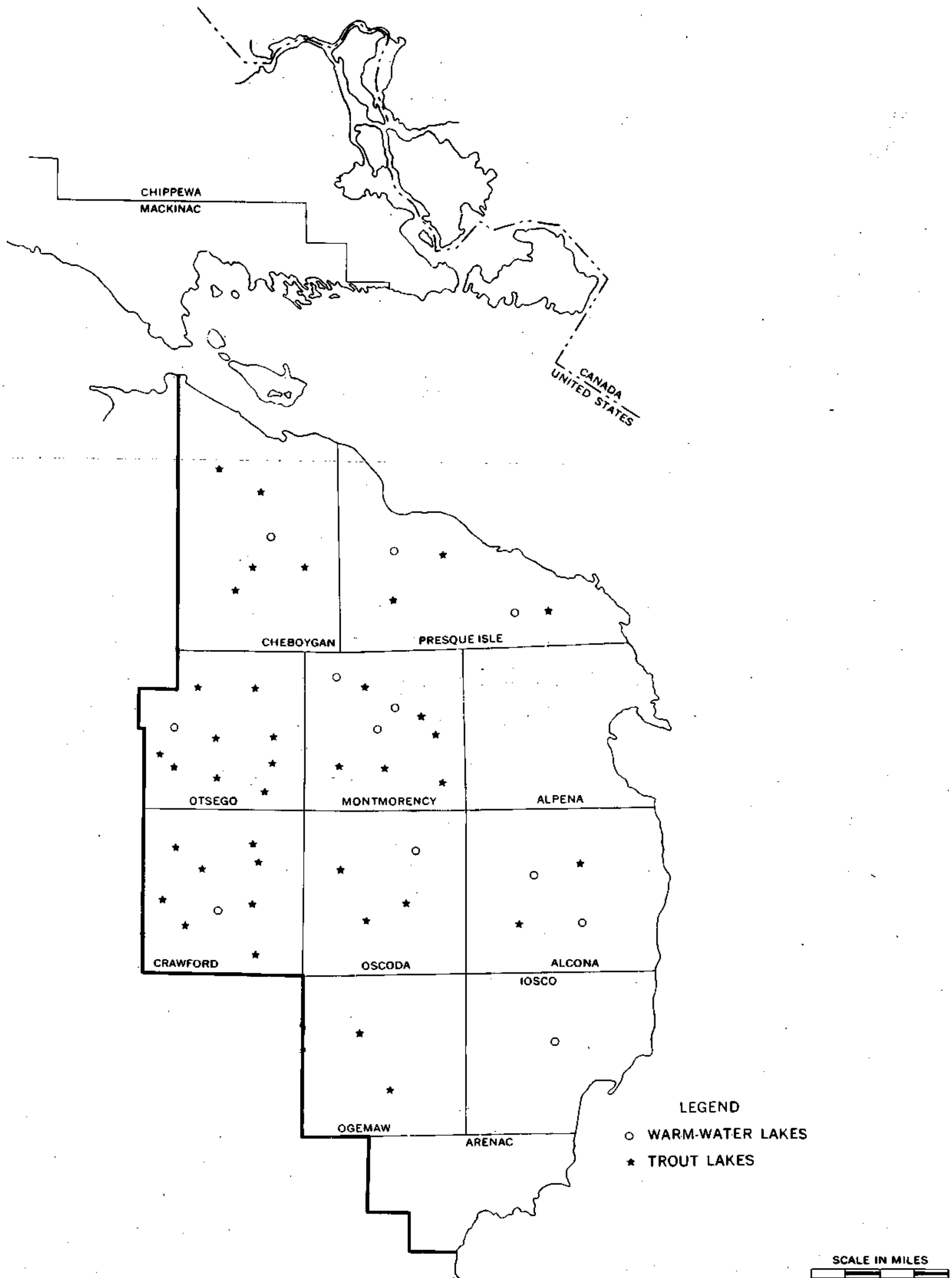


FIGURE 8-51 Current Fish Stocking Program, Planning Subarea 3.1

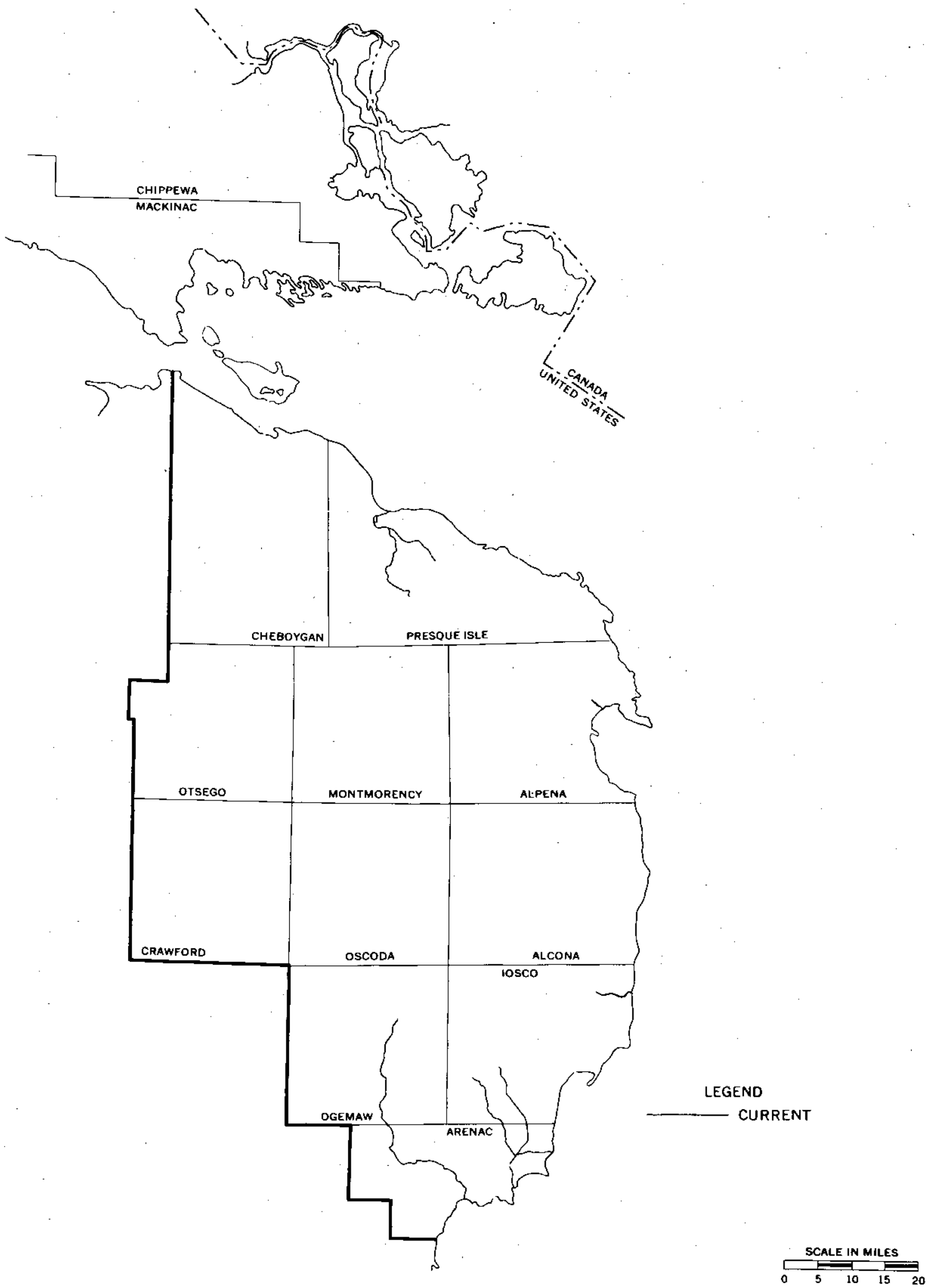


FIGURE 8–52 Anadromous Stream Fishery, Planning Subarea 3.1

in the planning subarea. If the present fishery resource is to be maintained, stream improvement, proper zoning, and wild frontage acquisition must receive a high priority.

5.2.8 Fishery Development Plans

Approximately $400,000 of the capital cost of the warmwater hatchery in Planning Subarea 4.1 will be charged against the fishery programs of Planning Subarea 3.1. An additional $150,000 will be needed each year in new operational monies to pay for the cost of raising and planting the warmwater fish scheduled for Planning Subarea 3.1.

Only three land acquisition projects are scheduled for Planning Subarea 3.1 before 1980, one each in Arenac, Presque Isle, and Cheboygan Counties. Although the capital cost should be less than $250,000, total acreage and sites have not yet been determined.

Planning Subarea 3.1 will share the capital cost of the new trout hatchery with Planning Subarea 2.4. Approximately 1.2 million dollars in capital cost and an annual operating cost of $100,000 will be charged to Planning Subarea 3.1 for this new facility.

No expenditures for fish passage have been planned for Planning Subarea 3.1 before 1980. However, an annual operating expenditure of $100,000 has been planned for new trout stream improvement programs by 1980.

Fish management programs beyond 1980 have not been detailed. However, fish passage and land acquisition will be key programs to insure continued growth and maintenance of existing fishing opportunities in Planning Subarea 3.1.

5.3 Planning Subarea 3.2

5.3.1 Species Composition, Relative Importance, and Status

Planning Subarea 3.2 (Figure 8–53) has the full range of fish species found in Michigan. Brook and brown trout are common in the headwater areas of the Pine, Tobacco, and Cedar Rivers. The mainstream areas of the Tittabawassee, Saginaw, Cass, Flint, and Shiawassee Rivers contain northern pike, smallmouth bass, rock bass, suckers, and carp. Anadromous streams in Planning Subarea 3.2 are shown in Figure 8–54.

Although large lakes are not common, large impoundments and warmwater lakes do support sport fisheries for many species. The most important to the catch are bluegill and perch.

Pollution of the rivers and impoundments in the past has forced many fishermen in the planning subarea to seek recreation either in Saginaw Bay or further north. However, recent improvements in water quality and planned impoundments on the Pine River offer hope for reestablishing valuable fisheries in Planning Subarea 3.2.

5.3.2 Habitat Distribution and Quantity

The inland ponded waters provide only 29,575 acres of water. In Clare and Gladwin Counties nearly 50 percent of the population is licensed to fish. In these two counties the ponded water per capita averages approximately 0.5 acres. In Genesee and Saginaw Counties less than 7 percent of the population is licensed, and the ponded water per capita is less than .01 acres (Figure 8–55 and Table 8–33).

The large rivers and existing impoundments in the planning subarea represent the largest untapped fishery resource. The few remaining trout streams need to be protected or they will disappear.

5.3.3 Habitat Problems Affecting Production and Distribution of Important Fish Species

Water pollution from industrial, municipal, and agricultural development has diminished the fishing quality in many major rivers and impoundments, particularly around Flint, Saginaw, Bay City, and Midland. Improved waste treatment facilities now allow fish management for valuable sport species. However rough species must be removed first. Steady improvement in water quality of the streams is also anticipated under newly established water quality criteria.

Major problems facing the stream fishery resources in this planning subarea are flood control and drainage improvement projects. Channelization has destroyed many stream fisheries. Flood control and improved land drainage need not be done at the expense of public fishery values. Erosion and siltation from agricultural and urban construction are also major problems in this planning subarea.

TABLE 8–33 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 3.2

State and Counties	Land Area (sq.mi.)	Population (1000s)	Population per Sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
Michigan								
Bay	447	112.3	251.2	154	.0014	435	10,325	.0919
Clare	568	12.9	22.7	5,191	.4024	1,092	7,933	.6150
Genesee	641	422.1	658.5	4,301	.0102	550	39,371	.0933
Gladwin	503	11.4	22.7	6,878	.6033	302	5,155	.4522
Gratiot	565	39.1	69.2	1,375	.0352	119	4,095	.1047
Huron	819	33.5	40.9	155	.0046	37	2,593	.0774
Isabella	571	38.6	67.6	1,082	.0280	124	3,297	.0854
Lapeer	651	47.6	73.1	5,095	.1070	98	5,624	.1182
Midland	520	55.6	106.9	2,502	.0450	527	9,696	.1744
Saginaw	813	210.2	258.5	1,442	.0069	149	13,647	.0649
Tuscola	800	48.1	60.1	1,400	.0291	33	4,870	.1012
Total	6,898	1,031.4	149.5	29,575	.0287	3,466	106,606	.1034

State and Years	Land area (sq. mi.)	Population (1000s)	Population (sq. mi.)	Projected Angler Day Demand: Resident[1]	Total[2]
Michigan					
1980	6,898	1,246.8	180.7	3,886,911	2,322,000
2000	6,898	1,600.5	232.0	4,989,575	2,994,000
2020	6,898	2,057.6	298.3	6,414,589	3,849,000

[1] Demand generated within planning subarea.

[2] Total demand including in- and out-migration.

5.3.4 History of Sport Fishery

Resident fishing license sales reached an all-time high in Planning Subarea 3.2 during the mid-1950s when 131,643 resident licenses were sold. License sales declined to 100,284 in 1965 before they began climbing again. The 1970 resident license sales rose to more than 120,000.

Fishing demand in the 1950s was primarily fulfilled within the planning subarea until fishing quality declined. Recent increases in resident demand probably represent growing interest in Great Lakes and anadromous stream fishing.

5.3.5 Existing Sport Fishing Demand and Current Needs

The resident angler day demand expressed on the inland water is more than 3 million angler days. In-migration is only significant in Clare and Gladwin Counties.

5.3.6 Ongoing Programs

In 1969, 50,017 rainbow and brown trout were planted in the planning subarea. Warmwater plants of walleye, muskellunge, northern pike, bass, and assorted panfish in the same year totaled more than 117,256. These planting numbers are deceiving because fingerling trout plants represented 5,770 pounds, and warmwater species, mostly fry, amounted to only 634 pounds. Salmon plants were initiated in 1971 when nearly 500,000 salmon were planted in the Cass River.

Table 8–34 summarizes the current acreage under intensive management. Approximately 20 percent of the surface acres (6,000 acres) is now under intensive management.

5.3.7 Future Trends in Habitat and Participation

Present fishing demand far exceeds the supply within the planning subarea. Resident

TABLE 8–34 Summary of Base Year Fish Habitat and Management Efforts, Planning Subarea 3.2

County	Total Area (sq.mi.)	Acres Ponded Waters	Number Ponded Waters	Number Intensively Managed	Acres Intensive Warmwater	Acres Intensive Trout	Miles Total Streams	Miles Trout Streams	Miles Anadromous Streams
Michigan									
Bay	451	154	4	--	-------	-----	50	----	----
Clare	577	5,191	123	7	526.4	159.4	331	97.3	----
Genesee	649	4,301	75	1	-------	77	355	3.0	----
Gladwin	512	6,878	49	7	2,506	316	473	41.4	----
Gratiot	566	1,375	20	1	117	-----	241	----	----
Huron	824	155	5	--	-------	-----	942	----	----
Isabella	573	1,082	32	2	65	13	330	24.1	----
Lapeer	662	5,095	129	13	750.3	729.3	594	24.4	----
Midland	523	2,502	11	1	1,250	-----	309	----	----
Saginaw	814	1,442	6	--	-------	-----	593	----	----
Tuscola	820	1,400	35	1	209	-----	184	6.6	----
Total	6,971	29,575	479	33	5,423.7	1,294.7	4,402	196.8	----

angler day demand is expected to increase by nearly one million by 1980. Most of this demand will have to be supplied outside the inland area, either in Saginaw Bay or in areas to the north.

The new warmwater hatchery in Planning Subarea 4.1 will expand intensive management on lakes and impoundments in Planning Subarea 3.2 by 10,000 acres. This will supply an additional 250,000 angler days by 1980. Anadromous stream salmon management can be expected to provide an additional 50,000 angler days by 1980 in the Cass River leaving more than 500,000 additional angler days to be supplied in other planning subareas or in the Great Lakes.

5.3.8 Fishery Development Plans

No new capital expenditures are planned by 1980. However, land acquisition may be required on the Cass River to provide adequate public access for the new salmon fishery. The prorated share of the capital cost of the new warmwater hatchery will be $120,000. An additional annual operating cost of $35,000 will be required by 1980 to chemically treat lakes, impoundments, and rivers, and to pay the cost of raising and planting new warmwater hatchery fish.

New impoundments planned for flood control and low flow augmentation will provide fishing benefits. However, it is not yet certain how costs will be divided.

Fishery development plans for the inland waters beyond 1980 will involve additional efforts to expand intensive warmwater management and acquisition of key lands for habitat protection and fishermen access.

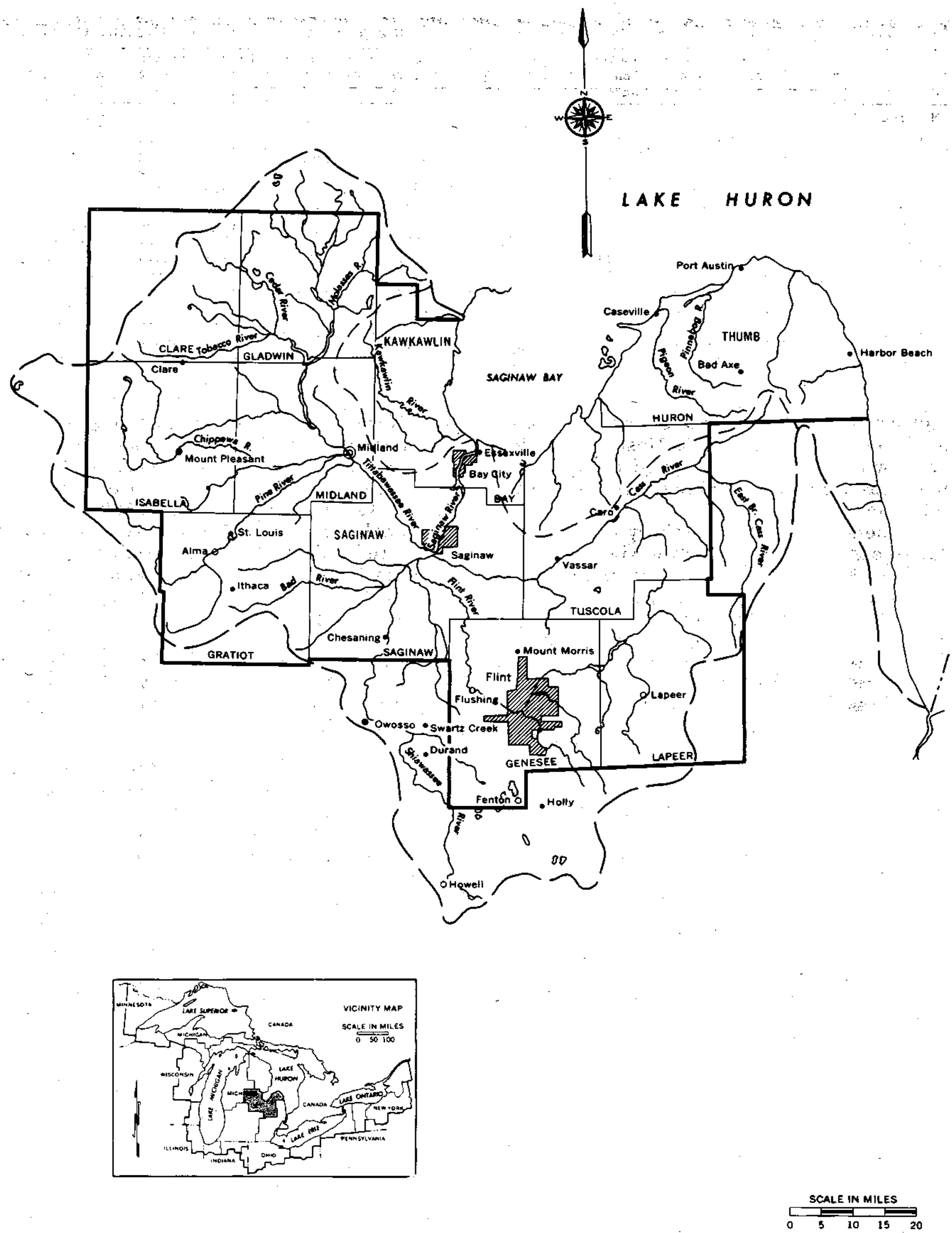


FIGURE 8-53 Planning Subarea 3.2

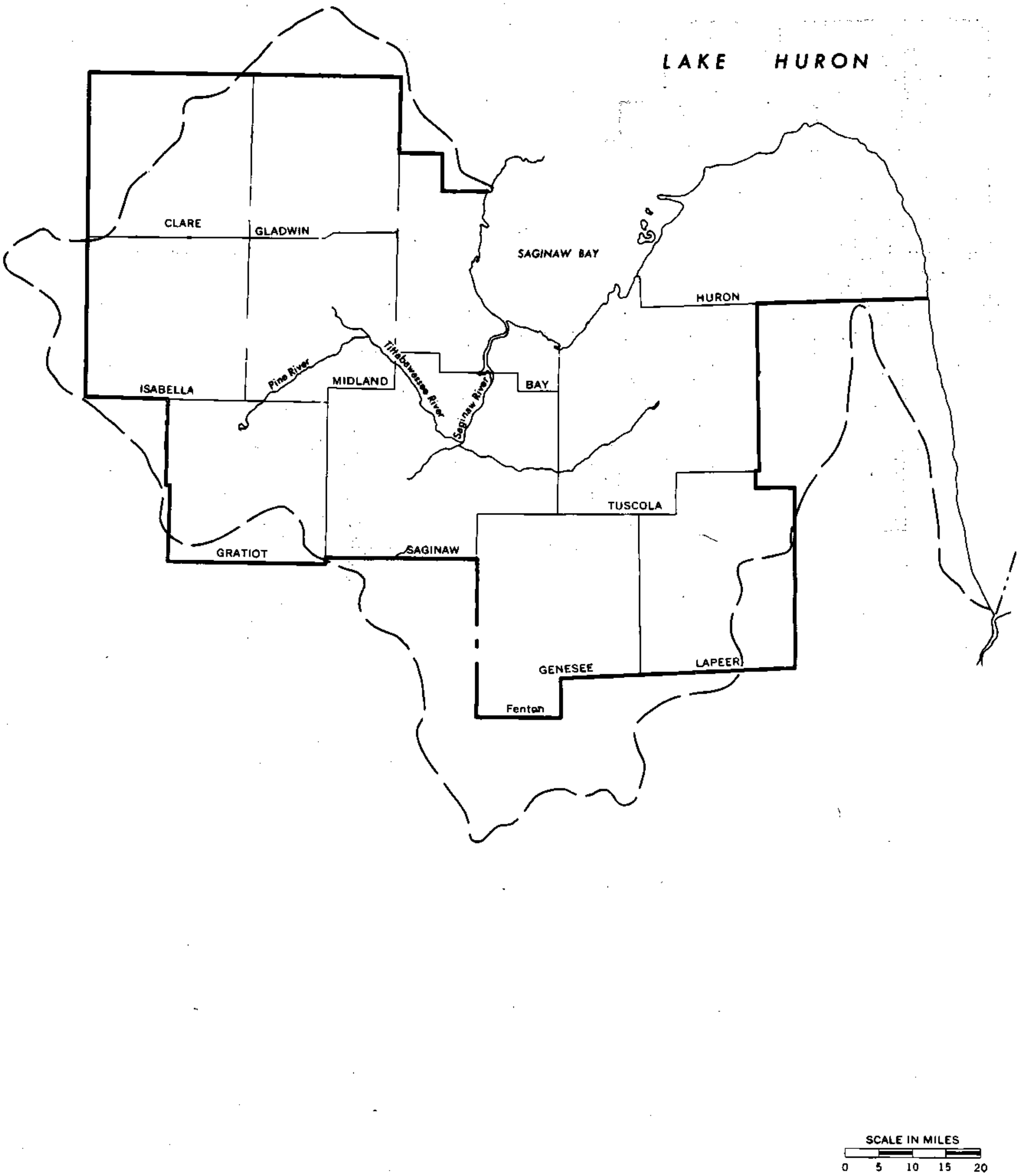


FIGURE 8–54 Anadromous Stream Fishery, Planning Subarea 3.2

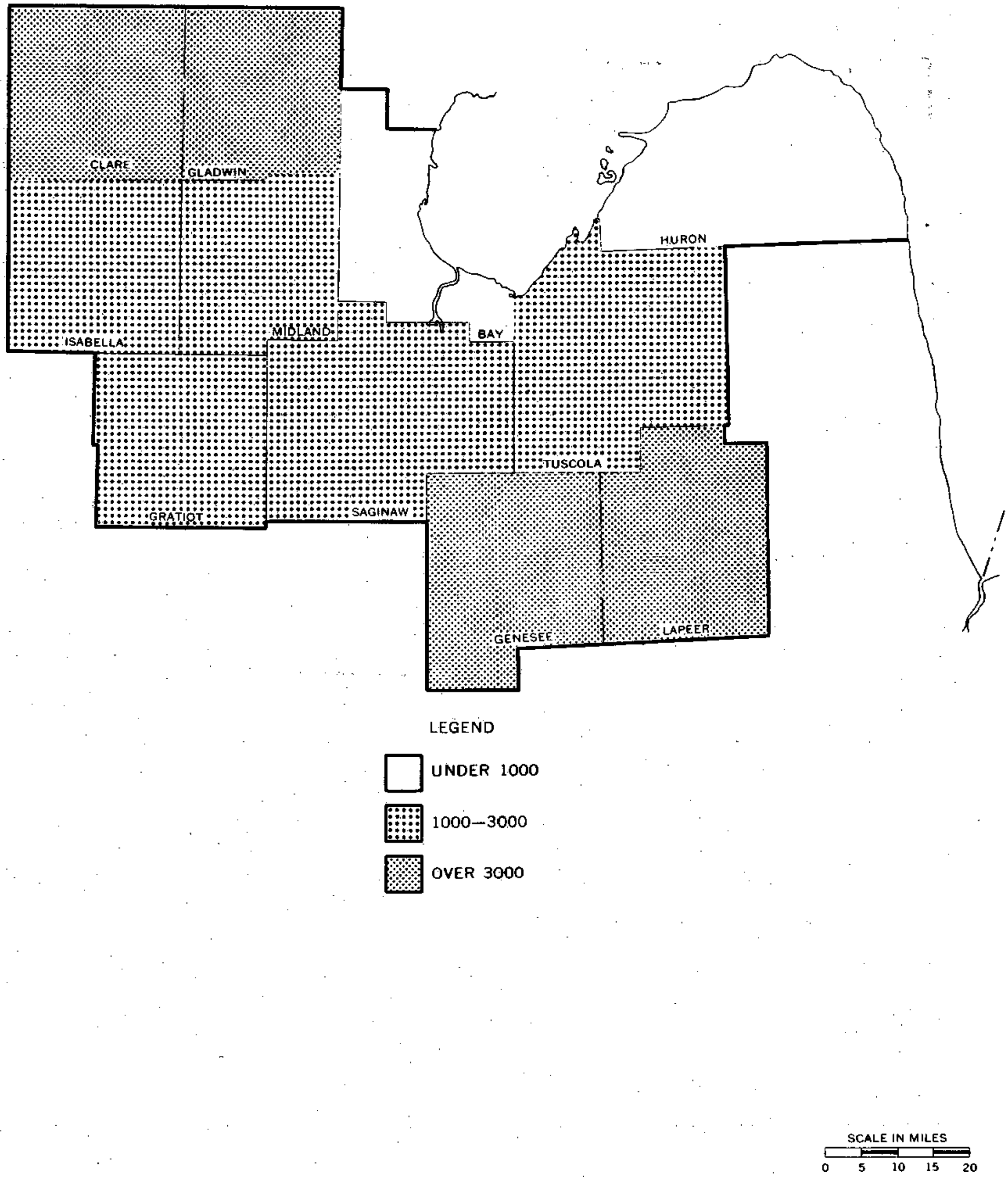


FIGURE 8–55 Acres of Ponded Water, Planning Subarea 3.2

Section 6

LAKE ERIE BASIN, PLAN AREA 4.0

The comments on Plan Area 4.0 (Figure 8–56) are divided into two major parts. The first is limited to Lake Erie, and the second treats the individual planning subareas of the Lake Erie basin.

6.1 Resources, Uses, and Management

6.1.1 Habitat Base

Lake Erie ranks fourth of the five Great Lakes in surface area (9,930 square miles). The U.S. share of Lake Erie is 4,990 square miles. Although Lake Erie stores 125 trillion gallons it amounts to only two percent of the total Great Lakes volume, the smallest of the Great Lakes. The Lake is 240 miles long and more than 55 miles wide near the midpoint of its long axis. The average depth of Lake Erie is 60 feet. The western basin ranges from 25 to 35 feet, the central basin ranges from 60 to 84 feet, and the eastern basin ranges from 85 to 210 feet.

Topographically, the western basin bottom is flat, except for the sharply rising islands and shoals in the central and eastern sections. The central basin is flat except for the rising slopes of a morainic bar extending south-southeastward from Point Pelee, Ontario. The eastern basin is bowl-shaped and uniform. The flat bottom areas of Lake Erie are mud and clay, and the ridges and rising slopes are sand and gravel. Rock is exposed in shoal areas of the western basin and nearshore areas of the central and eastern basins.

Surface currents in western Lake Erie are dependent upon winds. There is a surface and bottom clockwise rotational movement of water in western Lake Erie and a general down-lake surface flow which increases in velocity as it nears the outlet at the eastern end.

Lake Erie waters are normally near saturation with oxygen from October through April, and mixing is prevalent from top to bottom. Temporary thermal stratification occurs in the western basin during prolonged quiescent periods. Stable stratification is established in the central and eastern basin by June. Oxygen content nears zero in the hypolimnion waters of the western and central basins, and it may decline to 60 percent saturation in the eastern basin. Lake Erie is bicarbonate, has an average pH of 8.3, and specific conductance of 242 microohms at 25°C. Dissolved solids have been increasing in Lake Erie in this century. Since 1900 chlorides have increased threefold, and sulfates have increased 90 percent. Lake transparency in the western basin averages 1.5 meters, and 6 meters in the central and eastern basins (Figures 8–61 and 8–62).

Diatoms comprise 75 percent of the phytoplankton in Lake Erie. Copepods make up the bulk of the zooplankton while protozoans and rotifers are more numerous. Major benthic organisms of the western basin are *Oligochaeta*, *Tendipedidae*, *Sphaeriidae*, and *Gastropoda*. In the central basin, macrobenthos is sparse and composed mainly of midgefly larvae and oligochaetes. The eastern basin is composed of deepwater species of *Tendipedidae* and *Lumbriculidae*. The filamentous green algae, *Cladophora*, is an increasing nuisance in western Lake Erie, and *Ulothrix* is an abundant green algae. Blue-green algae are comprised largely of *Aphanizomenon* and *Microcystis* which occur in massive blooms during August in the western basin.

6.1.2 Fish Resources—A Summary of Major Changes

Fish distribution and composition in Lake Erie differ from other Great Lakes primarily because of environmental factors. The Lake Erie fish ecosystem has undergone radical changes due to environmental changes and high utilization.

Sturgeon virtually disappeared from Lake Erie around the turn of the century. Cisco, once a dominant Lake Erie species, experienced a sharp decline in 1926. It recovered slightly, and then declined to insignificance in 1957. Whitefish were abundant in Lake Erie until 1955 when they declined drastically. Wall-

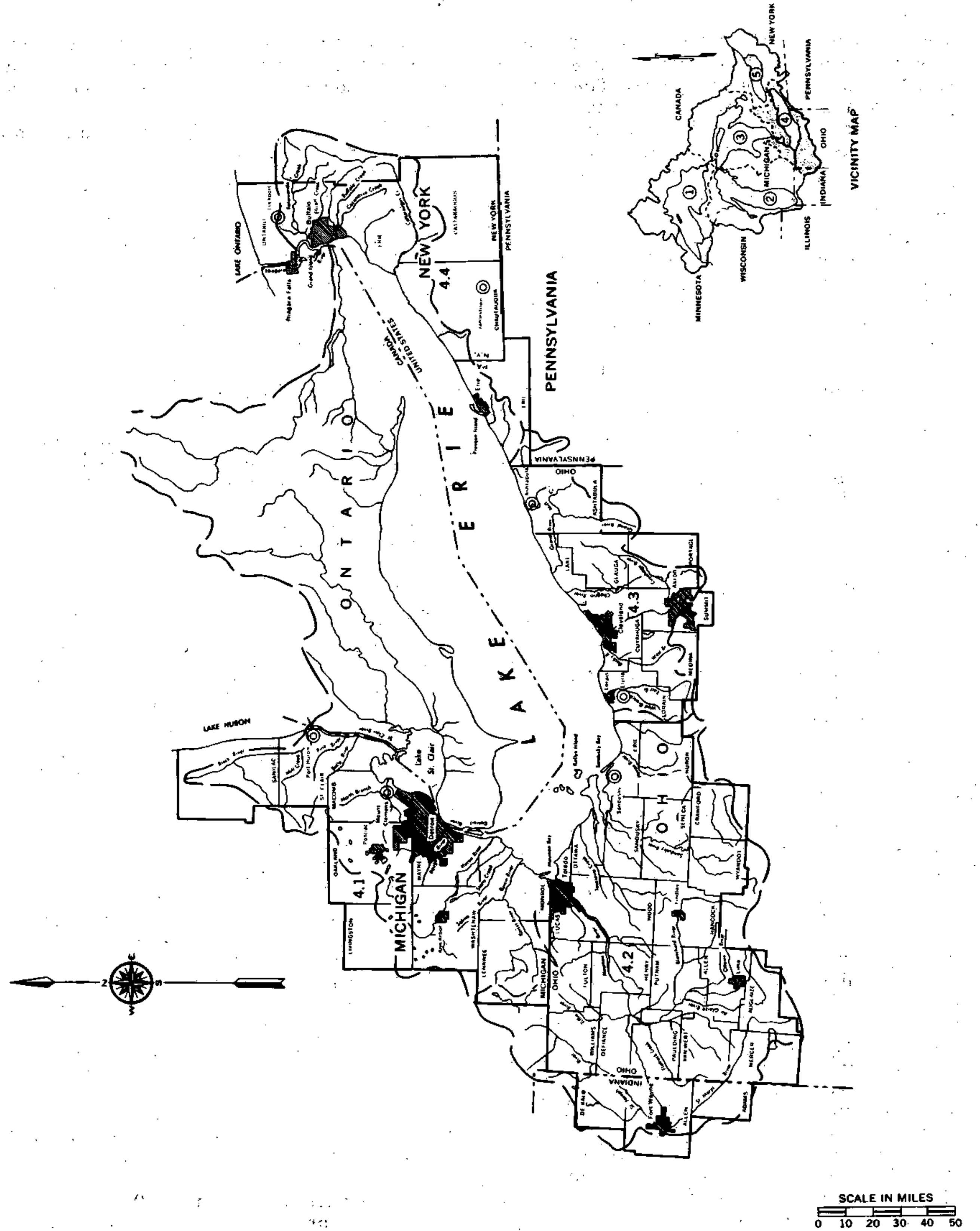


FIGURE 8–56 Plan Area 4.0

eye declined in 1957 and remain in distress. Blue pike was nearly extinct in 1958 and is listed as an endangered species. The yellow perch population is beginning to show signs of weakening, but the smelt population (first noted in Lake Erie in 1932) remains relatively stable. White bass and channel catfish have been abundant in Lake Erie since the turn of the century, and utilization emphasis has shifted to these species in the past 20 years. Alewife entered Lake Erie in 1931 via the St. Lawrence River. Gizzard shad is indigenous to Lake Erie and has experienced massive die-offs. Tables 8–35 and 8–36 show some of the major changes in these species.

The capability of Lake Erie to support fish may be improving. Habitat changes favor such species as sheepshead, alewife, shad, carp, and goldfish. Sheepshead has always been plentiful in Lake Erie. It presently dominates western Lake Erie habitats and is probably the most underexploited Lake Erie species (Figures 8–57 and 8–58).

6.1.2.1 Value of the Individual Species to the Ecosystem

The natural shallowness of Lake Erie has supported a fish ecosystem that has fluctuated considerably over the past 60 years. Many of the dominant species occurred in one geographical basin, while some species occurred in all basins, and discrete populations of the same species occurred in two different basins.

The western basin of Lake Erie accounts for the major portion of Lake Erie commercial and sport fish production. As many as 19 species have occurred in fish landings during the history of the fisheries. Lake trout, *Salvelinus namaycush*, was a dominant and important commercial species a century ago in eastern Lake Erie, but it is now considered extinct. At one time sturgeon, *Acipenser fulvescens*, was plentiful in Lake Erie, but this species virtually disappeared at the turn of the century. Lake herring, *Coregonus artedii albus*, which dominated portions of the central basin, dwindled in commercial production from millions of pounds to hundreds of pounds per year between 1900 and 1970. Whitefish, *Coregonus clupeaformis*, which was once abundant in all basins of Lake Erie, has followed the same pattern as herring. Sauger, *Stizostedion canadense*, and blue pike, *Stizostedion vitreum glaucum*, which once dominated the western and eastern basins of Lake Erie respectively, declined to extremely low numbers in the 1960s. The Lake Erie blue pike and sturgeon are now listed as endangered species.

The 1970s are demonstrating a valuable and unstable walleye population in western Lake Erie and a separate, less valuable but more stable eastern basin population. Since the start of the century, walleye, *Stizostedion vitreum vitreum*, yellow perch, *Perca flavescens*, white bass, *Roccus chrysops*, and channel catfish, *Ictalurus punctatus*, have occurred in Lake Erie commercial landings, and within the past 25 years utilization emphasis has shifted to these species. Because of harvest and habitat stress factors, these populations are depressed and fluctuating. Consequently, carp, *Cyprinus carpio*, freshwater drum, *Aplodinotus grunniens Rafinesque*, and smelt, *Osmerus mordax*, dominate the Lake Erie fish ecosystem. The trends of species dominance is reflected by the order of yield of Lake Erie commercial fish species shown in Table 8–35 and Figure 8–58.

6.1.3 The Fisheries

6.1.3.1 Historical Background and Economic Contribution of the Commercial Fishery

Commercial fishing began as a seine fishery in the Maumee River in Ohio about 1815. Early fishing methods involved the use of brush weirs and drag nets in nearshore areas. The lack of storage facilities caused 95 percent of the landed fish to be released after local demand was met. The fisheries had attained economic importance by 1830. Twine gear replaced brush gear, but until 1850 commercial fishing was nearshore. At this time deepwater fishing was restricted to hook-and-line. Commercial fishing in streams took place in the pools below the mill dams.

Around 1850 pound nets and gill nets were used in the western and eastern basins respectively. The Civil War increased the demand for fish, and by 1870 more than 100 pound nets were in use. Fyke nets, seines, and some trap nets were reported in use in the U.S. section of Lake Erie at this time. The gill net fishery was strengthened in 1899 with the advent of mechanical net lifters. Beginning in 1903, deep meshed gill nets (bull nets) were floated off the bottom of Lake Erie until they were outlawed in 1929. Pound net use began to

TABLE 8–35 Average Pound and Percent Contribution of 13 Major Species in the U.S. Waters of Lake Erie

Species	1935–1939	1940–1944	1945–1949	1950–1954	1955–1959	1960–1964	1965–1969
Blue Pike							
Lbs.	11,652,800	8,123,980	7,381,260	5,879,380	3,818,280	2,180[1]	120[1]
% of Volume	38.7	32.5	26.7	23.3	14.4	---	---
Burbot							
Lbs.	353,760	374,540	378,920	195,700	120,300	7,760[1]	2,700[1]
% of Volume	1.2	1.5	1.4	.8	.5	---	---
Bullhead							
Lbs.	565,500[2]	858,500[2]	226,475[3]	95,080	136,220	100,860	46,620
% of Volume	1.9	3.4	.8	.4	.5	.6	.4
Catfish							
Lbs.	---[2]	---[2]	741,475[3]	1,405,240	1,612,360	1,325,160	778,540
% of Volume	---	---	2.7	5.6	6.1	7.3	6.4
Carp							
Lbs.	2,288,800	2,330,280	1,923,740	2,768,800	3,879,000	4,056,160	3,127,600
% of Volume	7.6	9.3	7.0	11.0	14.7	22.3	25.7
Lake Herring							
Lbs.	345,980	51,900	2,176,340	85,420	28,880	5,180[1]	160[1]
% of Volume	1.1	.2	7.9	.3	.1	---	---
Sauger							
Lbs.	1,414,780	878,080	566,740	271,620	7,380[1]	340[1]	---[1]
% of Volume	4.7	3.5	2.0	1.1	---	---	---[1]
Sheepshead							
Lbs.	3,359,420	3,623,580	3,732,060	2,619,940	2,951,320	4,612,400	2,801,040
% of Volume	11.2	14.5	13.5	10.4	11.2	25.3	23.0
Sucker							
Lbs.	979,920	628,340	505,820	509,640	269,080	260,960	175,000
% of Volume	3.2	2.5	1.8	2.0	.1	1.4	1.4
White Bass							
Lbs.	655,440	552,980	601,520	1,537,740	1,696,400	1,609,640	1,075,480
% of Volume	2.2	2.2	2.2	6.1	6.4	8.8	8.8
Lake Whitefish							
Lbs.	1,161,960	1,698,400	1,947,760	1,069,160	359,320	6,580[1]	2,760[1]
% of Volume	3.9	6.8	7.0	4.2	.1	---	---
Yellow Perch							
Lbs.	3,928,060	2,450,280	2,226,560	3,012,060	6,892,800	4,994,900	3,536,640
% of Volume	13.1	9.8	8.0	12.0	26.1	27.4	29.1
Yellow Pike							
Lbs.	3,076,520	3,294,260	4,957,520	5,535,100	4,507,460	754,760	419,963
% of Volume	10.2	13.2	17.9	22.0	17.0	4.1	3.5
Average Total Volume	30,069,720	25,017,860	27,664,160	25,188,160	26,450,740	18,214,615	12,161,400

[1] Less than 100 pounds or .1%

[2] Includes catfish catch

[3] Based on four-year average

decline in 1920 and was completely discontinued in 1935.

Although the catches of various species have fluctuated considerably, fishing methods in the U.S. waters of Lake Erie have changed little since 1935. Lake Erie has accounted for a third of the total Great Lakes fish production annually.

Early landings (1879–1930) suggest healthy production until 1913 and reflect only the loss of the sturgeon fishery. United States and Canadian fisheries declined steadily until 1929, largely because of the decline in cisco landings that began in 1925, although these recovered briefly in 1945 and 1946. Since 1957, the cisco has become commercially extinct. During the same period, northern pike began to disappear from commercial catches, following an abrupt decline in 1915. Whitefish landings fluctuated between one and seven million pounds annually between 1913 and 1954. In 1955 landings dropped drastically and this downward trend has continued. Less than one thousand pounds were landed in 1963.

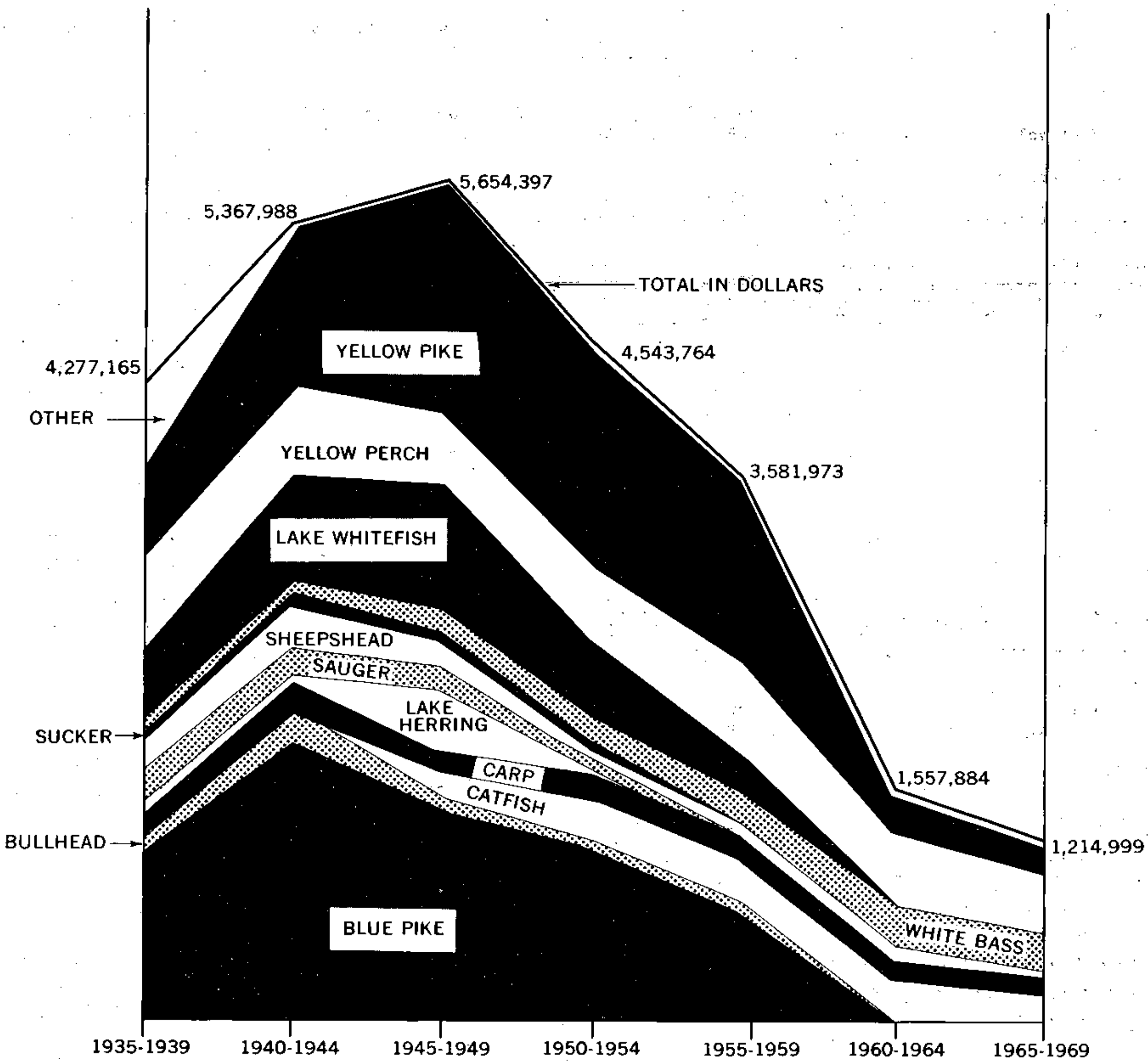


FIGURE 8–57 Average Annual Production (Dollars) of Major Species by the U.S. Lake Erie Commercial Fishery for 5-Year Periods, 1935–1969

TABLE 8–36 Average Value and Percent Contribution of 13 Major Species in the U.S. Waters of Lake Erie

Species	1935–1939	1940–1944	1945–1949	1950–1954	1955–1959	1960–1964	1965–1969
Blue Pike							
Dollars	1,131,315	1,874,382	1,430,237	1,175,053	750,411	823	---[1]
% of Value	26.5	34.9	25.3	25.9	20.9	.1	---[1]
Burbot							
Dollars	10,628	22,085	16,390	14,442	6,364	506[1]	131[1]
% of Value	.2	.4	.3	.3	.2	---	---
Bullhead							
Dollars	94,610[2]	192,072[2]	37,287[3]	15,043	15,687	11,731	6,980
% of Value	2.2	3.6	.7	.3	.4	.8	.6
Catfish							
Dollars	---[2]	---[2]	199,878[3]	321,715	338,106	303,837	213,374
% of Value	---	---	3.5	7.1	9.4	20.0	17.6
Carp							
Dollars	135,259	174,215	124,248	127,492	136,682	138,362	104,372
% of Value	3.2	3.2	2.2	2.8	3.8	8.9	8.6
Lake Herring							
Dollars	98,848	18,535	406,910	35,784	9,865	1,710	---[1]
% of Value	2.3	.3	7.2	.9	.3	.1	---[1]
Sauger							
Dollars	231,746	213,973	132,003	60,636	1,261[1]	---[1]	---[1]
% of Value	5.4	4.0	2.3	1.3	---	---[1]	---[1]
Sheepshead							
Dollars	177,873	315,240	236,308	100,222	86,891	99,889	75,757
% of Value	4.2	5.9	4.2	2.2	2.4	6.4	6.2
Sucker							
Dollars	59,753	55,087	34,792	26,671	9,780	8,257	4,527
% of Value	1.4	1.0	.6	.6	.3	.5	.4
White Bass							
Dollars	81,512	102,213	158,894	179,178	203,127	233,183	221,903
% of Value	1.9	1.9	2.8	3.9	5.7	15.0	---
Lake Whitefish							
Dollars	482,891	694,428	805,740	505,380	209,483	4,100	1,488
% of Value	11.3	12.9	14.2	11.1	5.8	.3	.1
Yellow Perch							
Dollars	614,426	589,988	508,571	499,733	666,621	454,173	392,358
% of Value	14.4	11.0	9.0	11.0	18.6	29.2	32.3
Yellow Pike							
Dollars	627,503	1,098,205	1,529,354	1,448,381	1,134,275	279,384	183,164
% of Value	14.5	20.5	27.0	31.9	31.7	17.9	15.1
Average Total Value	4,277,165	5,367,988	5,654,397	4,543,764	3,581,973	1,557,884	1,214,999

[1]Less than $100 or .1%

[2]Includes catfish catch

[3]Based on four-year average

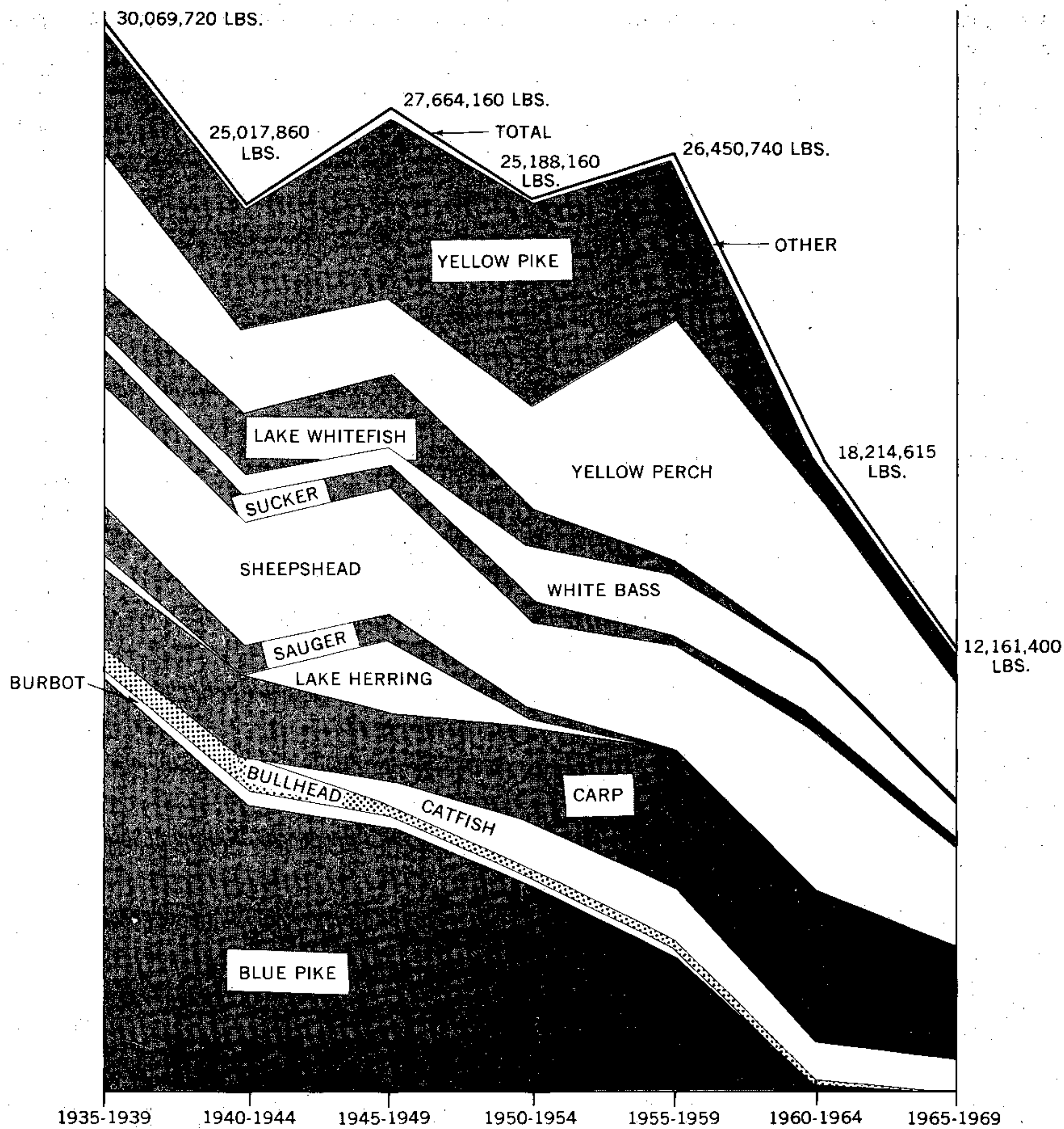


FIGURE 8–58 Average Annual Production (Pounds) of Major Species by the U.S. Lake Erie Commercial Fishery for 5-Year Periods, 1935–1969

Between 1913 and 1957, the blue pike production never fell below several million pounds. Following a drop in landings to 1.4 million pounds in 1958, the fishery collapsed completely. Deterioration of commercial sauger production preceded that of the whitefish and blue pike. Until 1945, annual yields did not depart from the mean, but between 1946 and 1948 commercial production declined steadily and swiftly.

Walleye has always contributed to the commercial fisheries. Until 1930 walleye production was unchanged in long-term landing trends. At that time landings increased from one or two million to more than three million pounds per year. In the ensuing years, walleye production rose until 1956, when an unprecedented catch of 15.5 million pounds was made. Production since that date has dropped to pre-1935 levels (Table 8–38).

Yellow perch, white bass, and channel catfish have also made significant contributions to the commercial landings. Perch landings over a 50-year period averaged 7 million pounds annually, and in 1969 total Lake production was 30 million pounds. White bass landings have ranged between one and nine million pounds annually since 1952. For the past 20 years, channel catfish landings have ranged between .75 and 2 million pounds. Early production figures for these species are not indicative because they were not actively sought by fishermen (Table 8–35).

From 1930 to 1950 lakewide production leveled off. Table 8–37 reflects changes in commercial operating units and productivity. In the decade 1951 to 1960 lakewide production rose, due to gear efficiency (nylon nets) and intensified effort in Canada. Effort was directed at smelt, which appeared in 1953 in large enough numbers to be commercially important. Concurrent with this rise in Canadian production, U.S. production was reduced as sauger, whitefish, and blue pike declined in abundance and producers became dependent upon perch, white bass, channel catfish, and walleye.

6.1.3.2 Historical Background and Economic Contribution of Sport Fishery

Sport fishing has been important in the development of resorts and vacation areas located in the island areas and various points along the south shore of Lake Erie. Writings from the late 1800s refer to excellent catches of black bass by sportsmen at popular locations such as the Bass Islands north of Port Clinton, Ohio, and the Presque Isle area near Erie, Pennsylvania.

Sport harvest records from Lake Erie are poor. Fishing pressure and success on Lake Erie has been dictated by many factors. Each decade experienced various social and economic changes that dictated the status of the sport fishery. Since 1945 sport angling methods and pressures have changed radically. Sportsmen have acquired great numbers of improved boats and fishing tackle.

Throughout the early and mid-1900s, the black (smallmouth) bass, walleye, sauger, blue pike, and perch were the major species sought by sportsmen. Because of commercial exploitation and environmental degradation, species composition has changed in recent years. Currently available species sought by sport anglers arranged in order of abundance are: yellow perch, white bass, channel catfish, smallmouth bass, and walleye. Estimated annual numbers of anglers, angler days, and total harvest within the last decade (1960–1969) are presented in Tables 8–39 and 8–40.

United States sports fishing on Lake Erie during the past decade was directed primarily at the yellow perch, white bass, channel catfish, walleye, and smallmouth bass. Yellow perch is by far the most popular and harvested species sought throughout the Lake. White bass and channel catfish angling is a spring and early summer fishery, confined primarily to the western and central basins. Walleye and smallmouth bass angling is concentrated in the Bass Islands and reef areas of the western basin and along the rocky shorelines of the central and eastern basins. These two species are the mainstay of the New York sport fisheries. Annual walleye and smallmouth bass angler success is strongly dependent on the current population densities of these species.

More than 1.3 million anglers annually spend some 26.7 million angler days sport fishing in the United States waters of Lake Erie and its major drainage basins. Approximately 476,000 of these anglers spend some 8.5 million man-days on Lake Erie proper. The majority of the effort comes from pier fishing and from private boats (Table 8–39). The value of the charter boat industry outlined in Table 8–41 is for Ohio only. Estimated annual sport harvest from Lake Erie is nearly 18 million fish. Yellow perch compose nearly 96 percent (by number) of the total harvest (Table 8–40). Revenue generated by the sports fishery for all agencies bordering Lake Erie is not pre-

TABLE 8–37 Commercial Operating Units and Productivity in the U.S. Waters of Lake Erie

Year	Number of Fishermen[1]	Pounds Landed per Fisherman	Value of Catch per Fisherman[2]	Number of Vessels	Number of Boats
1930	1,507	19,603	$2,327	59	279
1931	1,408	24,696	3,024	63	291
1932	1,479	22,765	2,749	57	305
1934	1,504	21,815	2,324	55	276
1936	1,081	34,021	4,509	48	268
1937	1,313	20,512	2,316	51	288
1938	1,471	18,777	3,132	52	304
1939	1,517	18,895	3,462	60	303
1940	1,083	21,186	3,676	75	237
1950	1,089	22,022	4,626	155	229
1954	1,132	25,035	3,704	175	190
1955	957	27,999	4,433	161	142
1956	883	34,817	4,976	151	117
1957	858	34,622	4,931	142	123
1958	873	25,859	3,514	145	143
1959	855	26,237	2,362	135	156
1960	1,044	20,362	1,826	128	332
1961	1,022	19,141	1,723	110	368
1962	917	21,439	1,551	102	321
1963	644	26,766	2,228	86	261
1964	596	22,406	2,090	84	254
1965	523	25,858	2,639	80	247
1966	503	25,243	2,212	66	258
1967	452	25,696	2,764	62	226
1968	397	30,026	2,700	42	223
1969	381	29,001	3,317	42	199

[1] Refers to all fishermen engaged in harvesting.

[2] Value deflated by wholesale price index (1957–1959=100).

sented. However, the net economic value added by sport fishing in Ohio is presented in Table 8–42.

6.1.4 Effects of Non-Fishery Uses on Fish Resources

6.1.4.1 Effects of Physicochemical Changes

Since 1850, pollutants such as wastes from industrial sites, gas and oil wells, and salt mines as well as municipal sewage have been evident in Lake Erie. Fertilizer runoff and siltation from agriculture enter Lake Erie in increasing amounts. Power plants add vast amounts of fly ash and hot water to the Lake. Steel industries discharge such wastes as chromium, phenols, cutting oils, and acids. Herbicides and pesticides are detectable in Lake Erie, and significant concentrations of mercury have recently been discovered. Nitrogen- and phosphate-bearing nutrients from industrial and commercial wastes continue to be discharged into Lake Erie (Table 8–43 and Figures 8–59 and 8–60).

TABLE 8–38 Economic Value, Lake Erie Commercial Fishery (Dollars)

Year	Species	Net Value Added			Total
		Harvesting	Processing	Marketing	
1969 to 1965 (Avg.)	Walleye	.28	.44	.23	.95
	Perch	.13	.08	.23	.44
	Catfish	.45	.17	.23	.85
	White Bass	.18	.12	.22	.52
	Suckers	.04	.03	.22	.29
	Sheepshead	.05	.04	.19	.28
	Carp	.04	.03	.19	.26
	Buffalo	.10	.06	.19	.35
	Miscellaneous	.03	.04	.20	.27
1965 to 1960 (Avg.)	Walleye	.30	.38	.21	.89
	Perch	.10	.16	.21	.47
	Catfish	.50	.19	.21	.90
	White Bass	.20	.12	.20	.52
	Suckers	.04	.04	.20	.28
	Sheepshead	.04	.04	.17	.25
	Carp	.04	.03	.17	.24
	Buffalo	.05	.05	.17	.27
	Miscellaneous	.03	.03	.18	.24
1960 to 1955 (Avg.)	Walleye	.40	.37	.21	.98
	Perch	.07	.13	.20	.40
	Catfish	.40	.19	.21	.80
	White Bass	.20	.12	.20	.52
	Suckers	.04	.05	.20	.29
	Sheepshead	.03	.05	.17	.25
	Carp	.04	.03	.17	.24
	Buffalo	.04	.03	.17	.24
1955 to 1950 (Avg.)	Walleye	.40	.37	.21	.98
	Perch	.07	.09	.17	.35
	Catfish	.35	.09	.18	.62
	White Bass	.06	.10	.17	.33
	Blue Pike	.20	.13	.17	.50
	Whitefish	.37	.24	.17	.77

Turbidity has increased substantially in Lake Erie. Approximately 32 million tons of sediment wash into the Lake annually. Sixteen million tons come from shore erosion, nine million tons from lake dredging operations, and seven million tons from stream discharges. In western Lake Erie alone, the Maumee, Portage, and Sandusky Rivers add approximately three million tons of suspended solids per year.

Turbidity readings in Lake Erie increased approximately 30 ppm during a period from 1930 to 1950. The greatest turbidity readings were generally found in the western basin (Figure 8–61).

Water temperature records from Erie, Pennsylvania, show an increase in mean annual water temperature of about 2°F since the early 1920s. This follows the general climatic warming trends. However, Ohio Division of

TABLE 8–39 Estimated Anglers and Angler Days, U.S. Waters of Lake Erie

Type Angler	Number Anglers	Angler Days Expended
Pier	309,451	5,757,620
Private Boat	117,824	2,120,832
Charter Boat	25,000	75,000
Shore	23,804	615,974
Total	476,079	8,569,426

TABLE 8–40 Estimated Sport Fish Harvest, U.S. Waters of Lake Erie

Species	Number Caught
Yellow Perch	17,000,000
White Bass	180,000
Catfish	96,000
Walleye	56,000
Smallmouth Bass	90,000
Sheepshead	135,000
Miscellaneous	258,000
Total	17,815,000

Wildlife temperature recorders at Put-In Bay show a slight trend toward lower temperatures during the same period.

Chemical changes in Lake Erie were gradual until about 1910, after which there was a rapid increase. From 1910 to 1960 the total dissolved solids, calcium chloride, sodium, potassium, and sulfate rose almost 50 ppm (Figures 8–62 and 8–63). Only incomplete data is available for nitrogen changes, but data collected by Wright in 1930, Chandler and Weeks in 1942, the Bureau of Commercial Fisheries in 1958, and the Federal Water Quality Administration in 1964 seem to be reliable. These show increasing nitrogen levels in the western basin. Free ammonia (NH_3) had the following concentrations: 1930, 0.13 ppm; 1942, 0.036 ppm; 1958, 0.092 ppm; 1964, 0.190 ppm.

Low oxygen concentrations in bottom waters have occurred annually in the central basin, and the extent of affected areas has increased in recent years. Areas devoid of oxygen in the hypolimnetic waters of the central basin during summer months are not uncommon. Turbulence in the shallower waters of the western basin has restricted depletion of oxygen in the bottom waters to an intermittent occurrence dependent on high air temperatures and low wind velocity. These factors point to increased fertility, greater algal blooms, and increasingly widespread oxygen depletion of the bottom waters. This is due not only to the BOD of decaying algal blooms, but also to the oxygen demands of sediment. Such conditions can result in direct changes not only in fish populations, through the survival of preferred fish species' eggs and larval stages, but also in invertebrate populations.

TABLE 8–41 Charter Boat Industry on Ohio Waters of Lake Erie

Year	Number of Boats	Number of Excursions	Number of Fisherman-Days	Gross Income	Net Income	Average Net Income Per Boat
1969	31	3,720	55,500	$390,600	$279,000	$9,000
1968	36	4,320	65,446	453,600	324,000	9,000
1967	32	3,840	57,600	403,200	288,000	9,000
1966	30	3,600	59,400	378,000	270,000	9,000
1965	29	3,480	52,200	365,400	261,000	9,000
1964	27	3,240	48,600	340,200	243,000	9,000
1963	32	3,840	63,360	364,800	249,600	7,800
1962	34	4,080	73,440	387,600	265,200	7,800
1961	38	4,560	75,240	433,200	296,400	7,800
1960	40	4,800	72,000	456,000	312,000	7,800

TABLE 8–42 Net Economic Value of Sport Fishery in Ohio Waters of Lake Erie in Millions of Dollars

Year	Species	Local	State	Regional	National	Total
1969	Perch	7.15	3.25	1.69	.91	13.00
	White Bass	1.10	.50	.26	.14	2.00
	Catfish	1.10	.50	.26	.14	2.00
	Walleye	.28	.12	.06	.04	.50
	Smallmouth Bass	.28	.12	.06	.04	.50
	Sheepshead	.28	.12	.06	.04	.50
	Miscellaneous	.28	.12	.06	.04	.50
	Total	10.47	4.73	2.45	1.35	19.01
1968	Perch	8.25	3.75	1.95	1.05	15.00
	White Bass	.83	.38	.19	.10	1.50
	Catfish	1.10	.50	.26	.14	2.00
	Walleye	.55	.25	.13	.07	1.00
	Smallmouth Bass	.28	.12	.06	.04	.50
	Sheepshead	.28	.12	.06	.04	.50
	Miscellaneous	.28	.12	.06	.04	.50
	Total	11.57	5.24	2.71	1.48	21.00
1967	Perch	8.25	3.75	1.95	1.05	15.00
	White Bass	.83	.38	.19	.10	1.50
	Catfish	1.10	.50	.26	.14	2.00
	Walleye	.83	.38	.19	.10	1.50
	Smallmouth Bass	.28	.12	.06	.04	.50
	Sheepshead	.28	.12	.06	.04	.50
	Miscellaneous	.28	.12	.06	.04	.50
	Total	11.85	5.37	2.77	1.51	21.50
1966	Perch	7.15	3.25	1.69	.91	13.00
	White Bass	1.10	.50	.26	.14	2.00
	Catfish	.83	.38	.19	.10	1.50
	Walleye	1.10	.50	.26	.14	2.00
	Smallmouth Bass	.28	.12	.06	.04	.50
	Sheepshead	.28	.12	.06	.04	.50
	Miscellaneous	.28	.12	.06	.04	.50
	Total	11.02	4.99	2.58	1.41	20.00
1965	Perch	6.60	3.00	1.56	.84	12.00
	White Bass	.83	.38	.19	.10	1.50
	Catfish	.83	.38	.19	.10	1.50
	Walleye	1.10	.50	.26	.14	2.00
	Smallmouth Bass	.28	.12	.06	.04	.50
	Sheepshead	.28	.12	.06	.04	.50
	Miscellaneous	.28	.12	.06	.04	.50
	Total	10.20	4.62	2.38	1.30	18.50

TABLE 8–42(continued) Net Economic Value of Sport Fishery in Ohio Waters of Lake Erie in Millions of Dollars

Year	Species	Local	State	Regional	National	Total
1964	Perch	6.60	3.00	1.56	.84	12.00
	White Bass	1.10	.50	.26	.14	2.00
	Catfish	1.10	.50	.26	.14	2.00
	Walleye	1.38	.62	.33	.17	2.50
	Smallmouth Bass	.28	.12	.06	.04	.50
	Sheepshead	.28	.12	.06	.04	.50
	Miscellaneous	.28	.12	.06	.04	.50
	Total	11.02	4.98	2.59	1.41	20.00
1963	Perch	5.50	2.50	1.30	.70	10.00
	White Bass	.55	.25	.13	.07	1.00
	Catfish	1.10	.50	.26	.14	2.00
	Walleye	1.38	.62	.33	.17	2.50
	Smallmouth Bass	.28	.12	.06	.04	.50
	Sheepshead	.28	.12	.06	.04	.50
	Miscellaneous	.28	.12	.06	.04	.50
	Total	9.37	4.23	2.20	1.20	17.00
1962	Perch	4.95	2.25	1.17	.63	9.00
	White Bass	.55	.25	.13	.07	1.00
	Catfish	.83	.38	.19	.10	1.50
	Walleye	1.65	.75	.39	.21	3.00
	Smallmouth Bass	.28	.12	.06	.04	.50
	Sheepshead	.28	.12	.06	.04	.50
	Miscellaneous	.28	.12	.06	.04	.50
	Total	8.82	3.99	2.06	1.13	16.00
1961	Perch	4.95	2.25	1.17	.63	9.00
	White Bass	.83	.38	.19	.10	1.50
	Catfish	.83	.38	.19	.10	1.50
	Walleye	1.65	.75	.39	.21	3.00
	Smallmouth Bass	.28	.12	.06	.04	.50
	Sheepshead	.28	.12	.06	.04	.50
	Miscellaneous	.28	.12	.06	.04	.50
	Total	9.10	4.12	2.12	1.16	16.50
1960	Perch	4.40	2.00	1.04	.56	8.00
	White Bass	.83	.38	.19	.10	1.50
	Catfish	1.10	.50	.26	.14	2.00
	Walleye	1.65	.75	.39	.21	3.00
	Smallmouth Bass	.28	.12	.06	.04	.50
	Sheepshead	.28	.12	.06	.04	.50
	Miscellaneous	.28	.12	.06	.04	.50
	Total	8.82	3.99	2.06	1.13	16.00

TABLE 8-43 Near Shore and Harbor Water Quality in Mg/l

Parameter	Michigan Waters of Lake Erie		Maumee Bay		Sandusky Bay		Lorain Harbor		Cleveland Harbor		Feirport Harbor		Astabula Harbor		Erie Harbor	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Cond (25°C)	---	---	280	460	256	800	300	340	---	---	330	5920	---	---	330	360
DS	---	---	200	290	190	680	160	230	180	370	180	6000	170	230	180	290
TS	---	---	200	350	210	760	170	270	180	680	190	6100	180	250	200	290
Chlor.	27	82	20	32	16	32	19	25	14	88	---	---	24	42	26	38
Sol PO_4	.05	.20	.02	.19	.02	.17	.02	.11	---	---	---	---	.02	.06	.01	.03
SO_4	---	---	---	---	25	256	27	37	---	---	---	---	---	---	26	44
SiO_2	---	---	0.6	1.7	0.3	5.9	.40	1.10	---	---	---	---	---	---	.3	.5
K	---	---	1.4	2.6	1.2	4.0	1.3	2.2	---	---	---	---	---	---	1.4	1.9
Mg	---	---	12	18	10	38	9	11	---	---	---	---	---	---	9	9
Ca	---	---	35	42	38	114	34	38	---	---	---	---	---	---	42	47
Na	---	---	12	20	10	16	10	13	---	---	---	---	---	---	17	21
ABS	<.025		.05	.15	.05	.20	.05	.15	---	---	---	---	---	---	.07	.14
Alk	78	157	86	120	87	120	88	99	81	130	90	110	94	100	90	96
pH	8.4	9.2	7.4	9.7	7.5	9.1	7.5	8.7	6.7	9.5	7.1	8.7	8.2	8.5	7.3	8.1
Temp	---	---	21	25	23	26	24	25	16	21	23	29	15	17	16	19
DO%S	---	---	60	95	65	115	80	95	70	95	80	130	95	110	Avg.60%	
BOD	---	1	1.5	4.0	2.1	6.3	1.0	2.3	---	---	---	---	2.0	5.6	Avg.3.3	
COD	---	---	12	53	13	42	10	28	8	22	8	12	7	11	Avg.24	
Phenol	0.0	0.058	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Total N	---	---	.82	3.45	.82	3.50	.50	4.20	---	---	---	---	---	---	.66	.80
Org N	0.20	0.30	.07	1.33	.53	2.30	.01	1.10	---	---	---	---	.29	.49	.30	.59
Amn N	0.20	0.30	.30	1.80	---	---	.12	.90	---	---	---	---	.03	1.55	.12	.23
Nit N	0.11	0.91	.00	.80	.01	1.80	.00	2.90	---	---	---	---	---	---	.07	.14

The most harmful effects of pollution entering western Lake Erie from the Maumee, Portage, and Raisin Rivers are the depletion of dissolved oxygen and siltation. Bottom conditions in western Lake Erie have deteriorated. Large die-offs of mayflies have resulted from the lack of oxygen in the bottom muds. Whitefish in the Detroit River and Maumee Bay decreased drastically around 1900. Biologists believe that the heavy silt load entering the Lake from the Maumee River smothered their spawning beds and hastened the decline of the fisheries.

Agricultural fertilizers and phosphorus from detergents in municipal wastes enrich Lake Erie waters, contributing to the heavy algal growths that commonly collect in many Lake Erie coves and beaches. Decomposition of dead algae does not always result in fish kills, but it creates numerous nuisances, such as bad odors, bad-tasting water, and fouled beaches.

Nitrogen- and phosphate-bearing nutrients from domestic sewage and industrial wastes cause pollution and aesthetic problems at many points along the lakeshore. Highly-tolerant tubificid worms have increased markedly in areas adjacent to sewage outfalls. Other effects of industrial pollution include increased turbidity, sludge deposits, grease and oil mats, suspended solids, and chemical dyes, all of which either directly or indirectly impair fish propagation.

Modern technology is beginning to discover critical levels of herbicides, pesticides, polychlorides, and heavy metals such as mercury, lead, and cadmium in Lake Erie fish species. This has significantly depressed the commercial and sports industry. The effect of these pollutants on fish reproduction and physiology is not fully known. State and Federal agencies are currently involved in measuring the levels of pollutants found in all age groups of Lake Erie fish.

The heavy siltation rate and increased water temperatures, plus the continued enrichment from agricultural, municipal, and industrial pollution will increase phytoplankton production and result in higher biochemical oxygen demands. This will increase the incidence of oxygen depletion in the bottom waters of all basins and result in vastly altered or reduced populations of both fish and benthic organisms.

6.1.4.2 Biological Changes

Besides the major changes in fish species enumerated in the preceding sections, in western Lake Erie there has been a reduction of *Hexagenia* to a mere fraction of its former abundance. *Sphaeriidae* has increased twofold, *Chironomidae* fourfold, *Gastropoda* sixfold, and *Ologochaeta* ninefold. These changes can be attributed to:

(1) siltation from erosion and dredging
(2) industrial and municipal wastes
(3) intensive agricultural practices
(4) stream and river rehabilitation projects

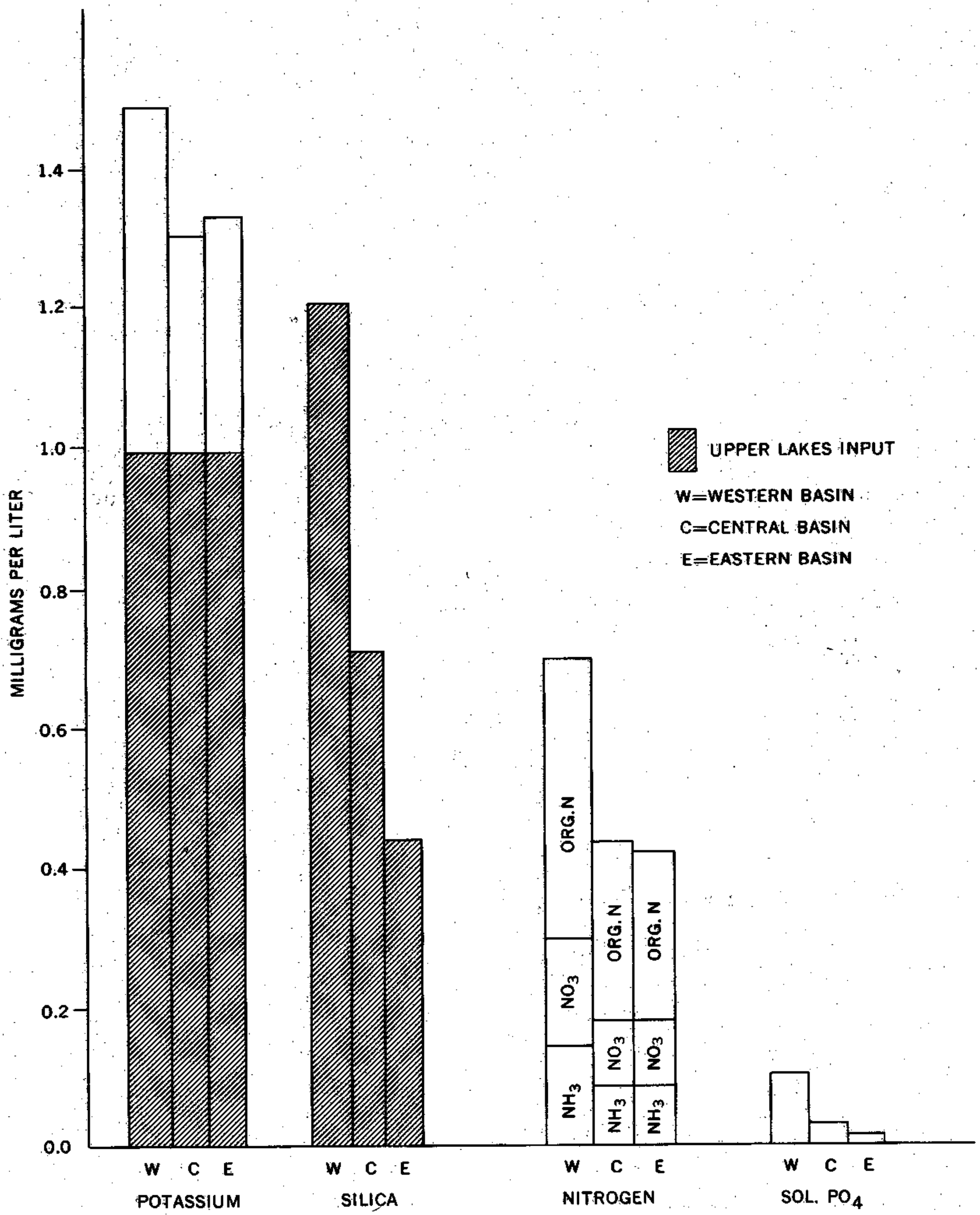


FIGURE 8–59 Chemistry of Lake Erie Water in Western, Central, and Eastern Basins, Nutrients

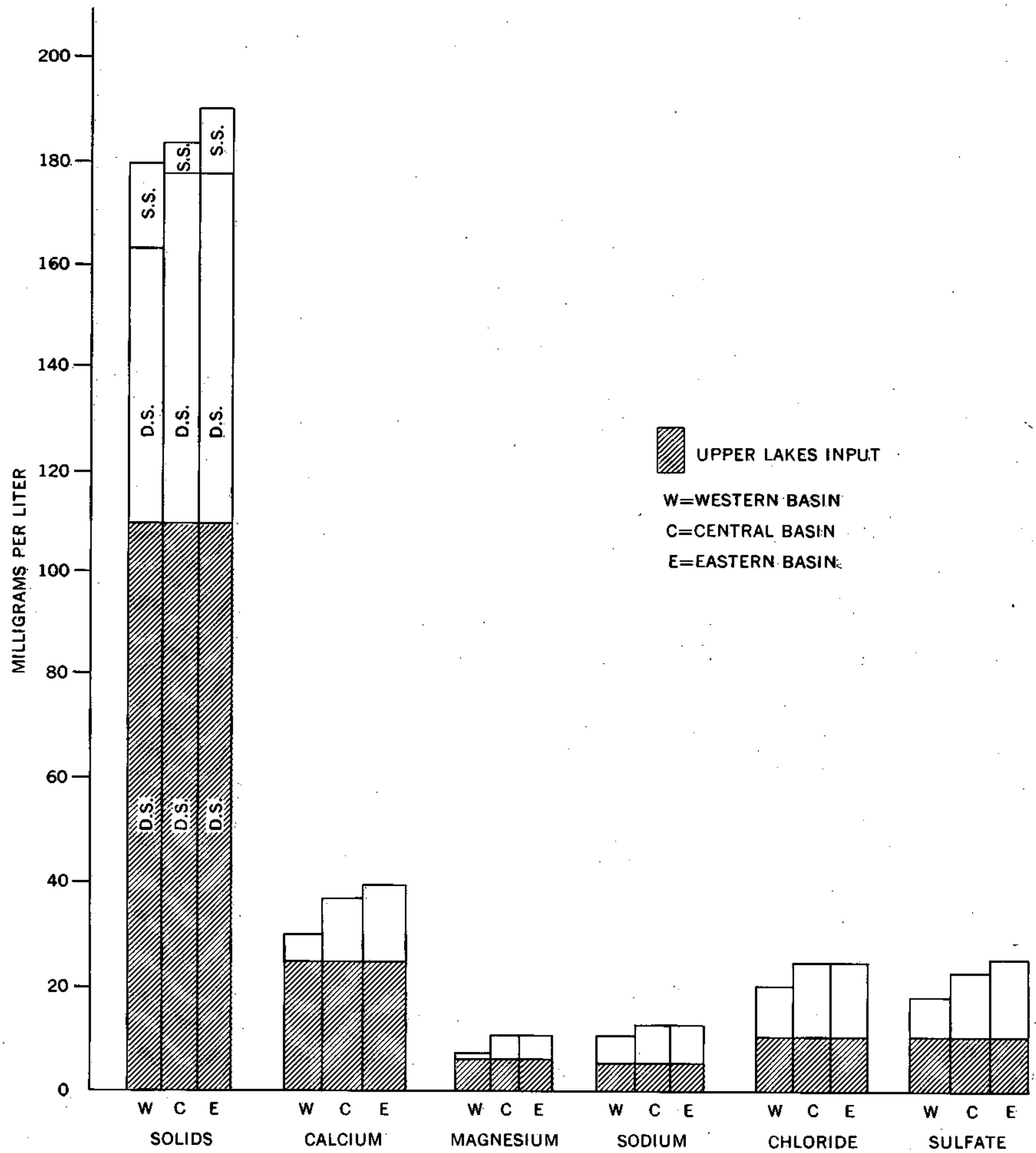


FIGURE 8–60 Chemistry of Lake Erie Water in Western, Central, and Eastern Basins, Major Constituents

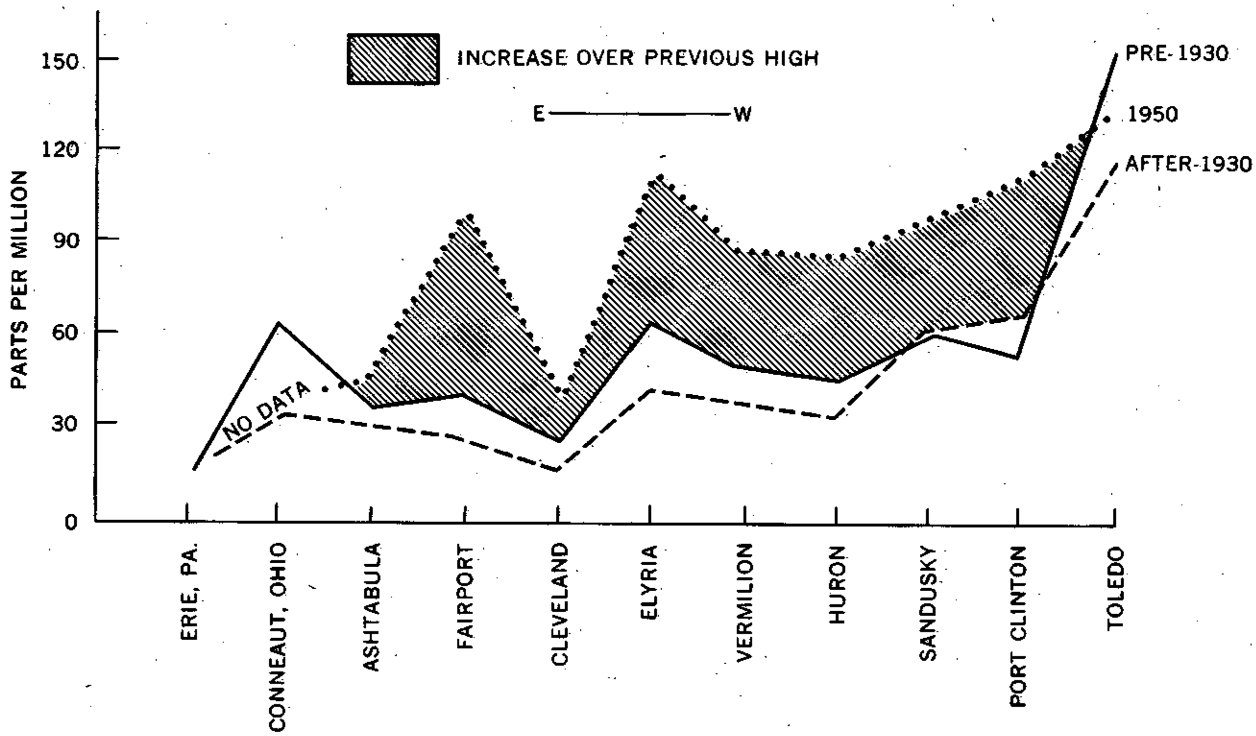


FIGURE 8–61 Lake Erie Turbidity Readings

(5) misuse of persistent chemicals (DDT, TFM, PVC, PCB)

(6) exploratory drilling for petroleum distillates

(7) waste materials from mining operations

The ever-increasing human population and resultant intensified land development within the Lake Erie watershed are evidenced by the filling of marshes and embayments for building and highway construction. The City of Cleveland is now considering construction of a huge island in the central basin of Lake Erie for an ultramodern jetport. Public utility companies are presently constructing a nuclear power plant in a Federal wildlife refuge area. Projects such as these will definitely have adverse effects on wildlife habitats.

6.1.4.3 Effects of Physical Changes

Since the 1900s western Lake Erie has been used as a firing area by the U.S. government and armament manufacturers. During earlier periods, discarded shells and canisters may have enhanced channel catfish spawning by artificially simulating spawning habitat. This benefit was short-lived at best. Presently 12 percent of western Lake Erie is covered by steel, copper, and lead armament, and controlled firing continues.

Offshore waters of Lake Erie are habitually used as dump areas for refuse and channel dredgings. Unnavigable and uninhabitable muck areas such as Maumee Bay negate the existence of fish life and the passage of fish. Power plants traditionally have used Lake Erie waters for their operations. This type of use will increase with the advent of nuclear power plants. In the eastern basin of the Lake there is a tributary stream that has a nuclear fuel service plant (one of two in the United States) releasing radioactive wastes into Lake Erie via the tributary.

The effects of these misuses are damaging to the lake Erie fishery. Total effects are incalculable except to say that chemical and physical stress has been exerted upon the fishery by these operations.

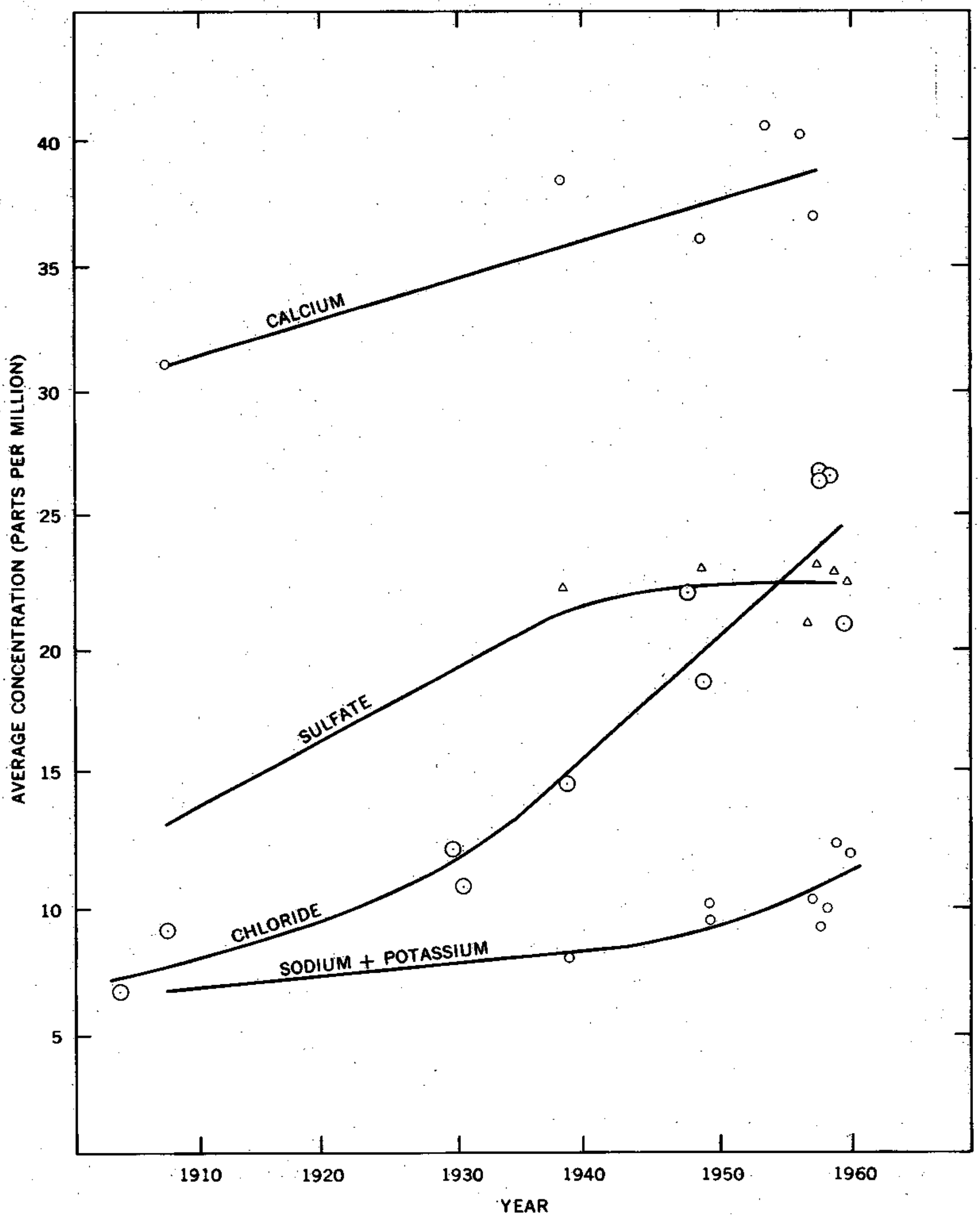


FIGURE 8-62 Changes in the Chemical Characteristics of Lake Erie Waters

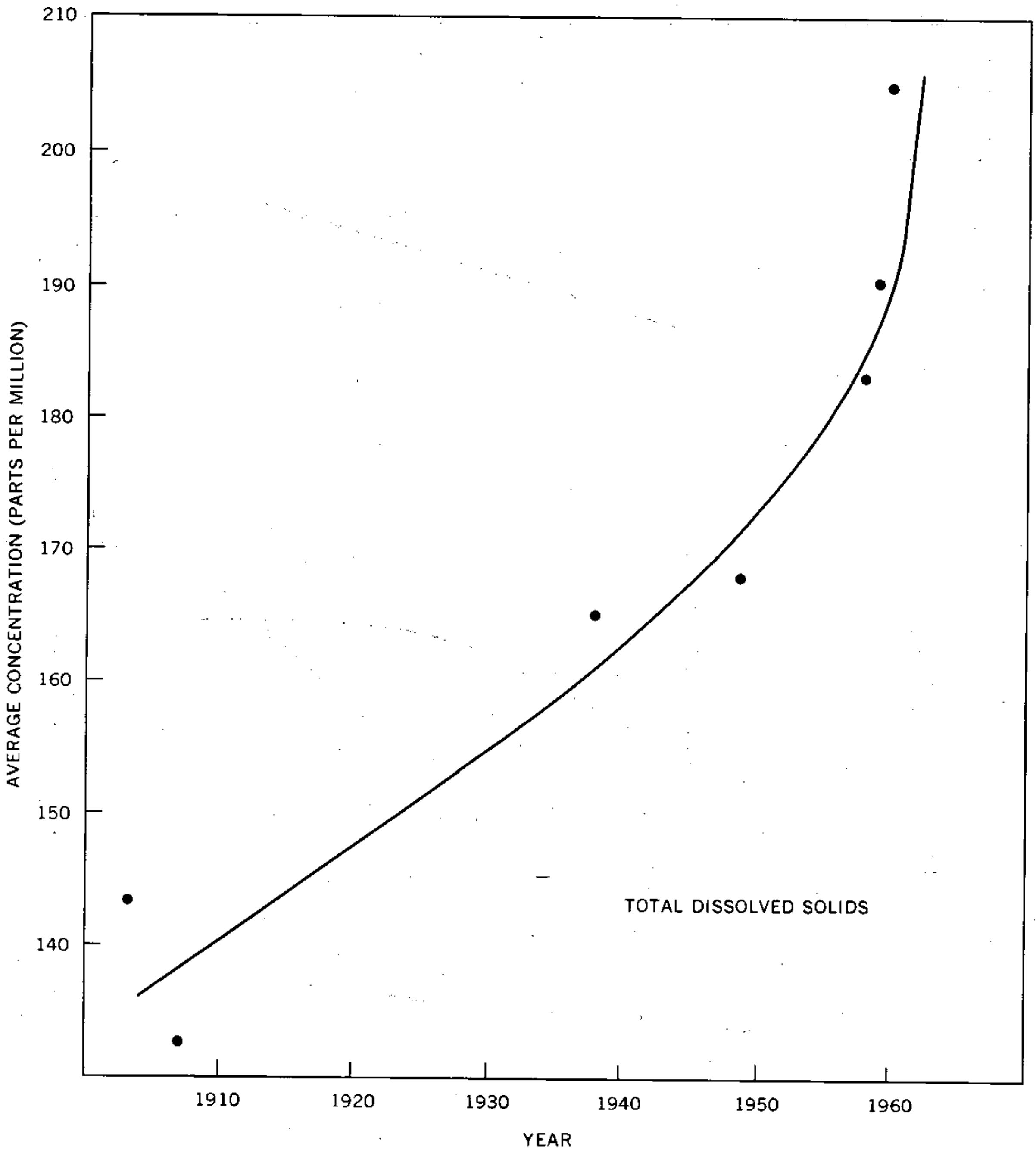


FIGURE 8–63 Changes in the Concentration of Total Dissolved Solids in Lake Erie

6.1.5 Fisheries Management

6.1.5.1 Past and Present Management

Fishery operations in Lake Erie are under the jurisdiction of four States and the Province of Ontario. Management has used the following priorities as guidelines: restoration of desirable species by stocking programs; ensuring abundant levels of high-value species by imposing restrictions on or prohibiting gear and regulating fish sizes; and use of abundance predictions that allow for adjustments of harvest rates by concerned agencies.

Inconsistency in the approach and philosophies of governmental agencies compounds the problem. Most of the assessed data have had little value because of lack of cooperation between agencies. Exotics introduced without proper preinventory studies have been unsuccessful. With minor exceptions, there has never been an attempt to manage the Lake Erie fisheries by restricting fishing effort. Sport fishing has had only minor limitations imposed upon it throughout its history.

The broad goal of the State fishery programs is to restore an optimum balance between prey and high-value predator species, and to manage these populations for the maximum benefit of society on a lakewide basis. Management policies place high priorities on a multiple-use concept of the fish populations for both sport and commercial harvest. The United States commercial fishery uses high-value species only during periods of limited supply. The States of Ohio and Michigan are attempting to improve the economic viability of the commercial fishery through limited entry control.

Management measures under way on Lake Erie include stocking of hatchery-reared fish, regulation of fishing, and habitat improvement and maintenance. In addition to coho and chinook plants, the Lake Erie stocking program includes plantings of rainbow trout fingerlings by Pennsylvania and New York, and walleye fry by Ohio. The desirability and practicability of stocking blue pike, sauger, and striped bass are being investigated by various State agencies.

Recent changes in commercial fishing regulations have been limited to Ohio waters, where considerable effort has been made to provide greater protection for depressed walleye stock. Ohio changes include an increase in the minimum legal length of walleye from 13 to 15½ inches; complete closure of gill net fishery in the western basin; and closure of commercial fishing within ¼ mile of reefs from March 1 to May 9.

Sport fishing regulations have undergone few changes in recent years, but uniform regulations on sport fishing for trout and salmon are being developed.

Thermal pollution from nuclear and fossil fuel plants is a major concern. State and Federal agencies are aware of the seriousness of prevailing conditions and have undertaken studies to provide solutions that will decelerate the unnatural rates in the aging processes of the Lake. State agencies cooperate with the Environmental Protection Agency in a pollution abatement program on Lake Erie. Water quality standards have been designated for most waters and time schedules for pollution abatement have been established for communities and industries. The States of Ohio and Michigan have passed bond issues involving millions of dollars earmarked for pollution abatement activities.

State, interstate, Federal, and international agencies cooperate in matters pertaining to dredging and filling, establishment of harbors of refuge, and development of fishing piers, marinas, and public access sites.

In New York a Memorandum of Understanding between the Departments of Transportation and Conservation provides coordinated planning of all public works projects to protect fish and and wildlife resources. The Stream Protection Law of 1966 requires private individuals and industry to obtain permits before the beds or banks of most waters can be altered. Counties, towns, and municipalities must obtain permits or Memoranda of Understanding before highway construction affecting watersheds can be undertaken.

Ohio has a research unit on Lake Erie that carries out a monitoring program, collecting information on the abundance of various fish species, their sizes and ages, distribution and existence of discrete populations, year class strength, interrelations, and the extent to which they are utilized by recreational and commercial fishermen. The Commonwealth of Pennsylvania has begun development of a modest but similar program in its waters. In Michigan waters investigations are limited to sampling of commercial landings by the Bureau of Commercial Fisheries and periodic observations by Michigan's Lake St. Clair research unit. Investigations in New York waters have been limited to periodic observations in cooperation with the Bureau of Commercial Fisheries.

Biological investigations carried out by the Bureau of Commercial Fisheries involve several long-range research projects to provide information on the following areas: life histories of fish with emphasis on walleye, yellow perch, and sheepshead; relationship between physical, chemical, and biological properties of the environment and fish survival, growth, and reproduction; population dynamics of walleye, yellow perch, and sheepshead; and the effect of changes in environment and species composition.

Ohio is conducting a study to assess the sport fishing pressure, success, and harvest for perch, walleye, white bass, and channel catfish in the Ohio waters of Lake Erie. The first year of study will incorporate a 25 percent sampling of fishing days and development of a statistical model to be incorporated in the following years of the study. Data assessed will include: area, number of fishermen, total fishing hours, type of fisherman (pier, boat by type, shore), residency, and catch. Plans will be incorporated to determine pressure, volunteer questionnaires will be distributed to appropriate concessions, and completed trip data will be assessed at various points. Data will be tabulated on computer systems. The later years of study will be directed to those areas deemed most relevant to desired data.

Studies of thermal effluents and their anticipated effect upon Lake Erie fish, benthos, and zooplankton are continuing. Surveys of hatch and survival of young-of-the-year walleye and related species in western Lake Erie will be conducted. Gill net and trawl investigations in western and central Lake Erie will determine survival, abundance, and distribution of fish species.

Monitoring of commercial recaptures and periodic samplings of coho will take place in Ohio's portion of Lake Erie. Data pertaining to growth, forage, distribution, and angler harvest will be assessed. Similar data will be assessed in tributaries.

Major fish species will be collected from Lake Erie by age group and area. These fish will be analyzed for mercury and pesticide concentrations. Differences in concentration will be recorded by species, size, and season, and relative changes noted.

Survey samples of important commercial species will be interpreted for age composition, and these data related to periodic commercial samples, designed to sample the age composition of commercial landings by gear and area. Both net run and landed run of fish are recorded so that the data can be compared to survey net sampling.

A final report pertaining to major walleye spawning reefs in western Lake Erie will be drafted, covering a ten-year period and dealing with egg deposition and viability, benthic organisms, and water parameters. Data from this study have been incorporated into a joint U.S. Bureau of Sport Fisheries and Wildlife and Ohio Division of Wildlife paper dealing with the environmental factors affecting year class success of walleye in western Lake Erie, 1959–1971.

Pennsylvania cooperated with the Food and Drug Administration by monitoring mercury residues in fish in 1971. Pennsylvania State University conducted sampling for DDT residues. Limited fish inventory sampling by means of trawl and gill nets was conducted in the fall of 1971.

New York reported that field work on both sport and commercial fisheries will be conducted by Regional Fish Management personnel as part of the overall regional program. No special research units are available for detailed fish studies in New York waters of Lake Erie.

Investigations associated with the coho program will continue, and New York will continue to cooperate with the FDA and universities in monitoring mercury and DDT residues in fish.

Projects treating the following areas have been completed by the Bureau of Sport Fisheries and Wildlife:

(1) commercial catch sampling in Lake Erie during spring and fall fisheries

(2) effects of different water temperatures on the incubation of walleye eggs

(3) mercury levels in small forage, sport, and commercial fishes in Lake Erie

(4) effects of different water temperatures on the incubation of coho salmon eggs

(5) effects of different mercury levels on hatchability of eggs and viability of fry for Lake Erie walleyes

(6) effects of exploitation, eutrophication, and introductions on Lake Erie's fishery and aquatic resources

(7) indices of abundance of important juvenile fishes in western Lake Erie, 1959–1971

(8) unharvested fishes in the U.S. commercial catch from western Lake Erie, 1969

(10) age and growth of walleyes in Lake Erie

(11) movements of adult walleye tagged in eastern Lake Erie in 1968

(12) predation on walleye eggs at a spawning reef in western Lake Erie

(13) overwinter mortality of white bass and freshwater drum in Lake Erie, 1969–1970, and 1970–71

(14) effects of different water temperatures on the incubation of chinook salmon eggs

(15) overwinter growth of freshwater drum in western Lake Erie

(16) environmental factors affecting year class success of walleye in western Lake Erie, 1969–1971

In addition to these United States studies and programs, Ontario has conducted similar studies with analogous objectives.

6.1.5.2 Cost of Fish Management and Development Programs

Table 8–44 enumerates the costs of various fish management programs in Lake Erie.

6.1.6 Projected Demands

6.1.6.1 Demand for Fishery Products

Projected demands for Lake Erie commercial fish species are expected to be identical to those discussed in Subsection 2.5.

6.1.6.2 Demand for Sport Fishery

Future demands on Lake Erie sport fishery will increase tremendously if present population trends, incomes, and available leisure time continue to increase at their present rate. Future United States sport angler demands on Lake Erie are projected to 2020 in Table 8–45.

Present socio-economic trends have prevented sportsmen's interest in and utilization of the more abundant, but less desirable species such as carp and sheepshead. Future demand will increase for the more popular and desirable native species such as yellow perch, walleye, smallmouth bass, catfish, and white bass. Greater demand for large exotic game species such as coho and chinook salmon and striped bass can be anticipated.

As sport fishing and other water sport activities on Lake Erie increase, demand for related services such as access areas and launching facilities will increase proportionately. If increased funds are obtained by the industries serving sport fishermen in an area, these associated industries will be able to exercise greater political influence over fish management and research programs.

6.1.7 Problems and Needs

6.1.7.1 Resource Base Problems and Needs

The large amounts of pollutants entering Lake Erie have drastically changed its ecosystem and will continue to do so. It is imperative that inputs of phosphates and nitrates be reduced if fish resources are to be maintained and species quality improved. Most pollutants result from inadequate sewage treatment by municipalities adjacent to Lake Erie and from excessive fertilizer applications to the agricultural areas of the Lake basin. Although improvement of sewage treatment facilities will reduce oxygen demands, high levels of nutrients, which increase phytoplankton production, will eventually increase them. Heavy loads of nutrients are the result of farming practices attempting to achieve high yields from a limited amount of land, a practice encouraged in part by the soil bank programs of the Federal government.

The effects of pesticides in Lake Erie should be investigated, especially the effects of heavy concentrations of these chemicals in bottom sediments on benthic communities. The effects of industrial pollutants such as hydrocarbon compounds and heavy metals should be investigated also.

The heavy rate of sedimentation is resulting in relatively rapid and dramatic changes in the Lake Erie ecosystem. In addition, there is the threat of thermal stress induced by the operation of proposed nuclear power plants. The effects of sedimentation on the spawning success of fish and benthic organisms should be determined, and preliminary research on the probable and anticipated effects of thermal pollution should be conducted to determine possible results of the operation of nuclear plants.

There is only limited knowledge of the distribution and abundance of benthic organisms and plankton, and what changes have occurred within these groups over the years. Additional knowledge must be gained regarding the various parameters of these organisms and their role in the ecosystem.

6.1.7.2 Total Fishery Problems and Needs

The decline of high-value species and increase in low-value species is the major problem of the Lake Erie fisheries. Reliable population estimates of the species important to the commercial and sports fisheries in Lake Erie are a necessity. Methods of increasing populations of high-value predator species while concurrently reducing populations of low-value species are necessary.

Fisheries research may be divided into five general categories: life histories; distribution and migration; population dynamics; the direct impact of man; and influence of physiochemical changes. Most Lake Erie work has been done in individual categories, and very little effort expended in reviewing applicable literature. Consequently, information that is applicable to Lake Erie may exist but not be centrally organized.

Life history studies should include such information as predation and forage at various ages, parasitosis, growth, diurnal and nocturnal movements, fecundity and spawning

TABLE 8-44 Lake Erie Fish Management Costs, 1960-1970 Average

	Agencies Conducting Research Programs					
Program	Ohio	New York	Pa.	BCF[1]	FWQA[2]	Total
Management	$51,000	$15,000	$15,000	--------	--------	$81,000
Enforcement	86,726	40,000	42,000	--------	--------	168,726
Research	186,400	5,000	60,000	$112,000	$400,000	763,400
Total	$324,126	$60,000	$117,000	$112,000	$400,000	$1,013,125

[1]U.S. Bureau of Commercial Fisheries

[2]U.S. Federal Water Quality Administration

TABLE 8-45 Actual and Projected Sport Fishery Demand, U.S. Waters of Lake Erie

Year	Number Anglers	Angler Days Expended
1960	476,079	8,569,426
1980	580,816	12,655,000
2000	708,596	17,915,000
2020	892,831	18,290,000

habits, and behavior. Many important Lake Erie commercial and sport species are migrant, and little is known about their movements. If fish stocks are to be managed intelligently, information regarding population, reproductive potential at various population levels, natural mortality, and inter- and intraspecies relationships must be gathered.

Present knowledge of populations permits only the use of adjectives such as good and poor. It is often assumed that there are only single populations of a species in Lake Erie. However, evidence that discrete geographical and breeding subpopulations may occur has been found for many species.

Landings by commercial fisheries are good general indicators of the existence of geographical and breeding subpopulations. However, these data have been considered as harvest. Little attention has been directed to the interaction of commercial fishing and dynamics of fish population as yet. Similarly, sport fishing in Lake Erie may also be important in determining fish subpopulations, but again, limited attempts have been made to research this.

There has been much conjecture regarding the effects of physicochemical factors on fish populations. Little effort has been made to investigate this area empirically. To solve the fish resource problems of Lake Erie, several changes must take place in administrative philosophies, budget tenures, research objectives, and agency cooperation. Researchers and their agencies must realize that the portion of the Lake within their boundaries is a study area and not private fish stock. When this fact is accepted, perhaps agencies will coordinate projects.

6.1.7.3 Problems and Needs of Commercial Fishery

In the U.S. waters of Lake Erie, the commercial fisheries are characterized by generally obsolete and inflexible harvesting systems. Because of the decline of high-value species, the number of commercial fishermen has declined, and limited capital makes the remaining fishermen unable to modernize their techniques.

Fish processing has not made technological advances like those in other food processing industries. Because of changes in species composition, a major portion of the fish captured are discarded as being of low value. With proper emphasis, a market for human and non-human consumption for these species could be developed. If facilities were available on Lake Erie, large quantities of these species could be channeled into production of fish meal, oil, cakes, fish protein concentrate, and similar products.

A major problem is the lack of coordination of research and management policies of the agencies bordering Lake Erie. There are five governmental units subdividing Lake Erie, and each of these conducts research and management under the assumption that the fish existing in the portion of Lake Erie fronted by their governmental boundaries are separate and distinct from other areas. Although humans may be fiercely aware of these boundaries, fish tend to adopt a more cosmopolitan attitude. As a result, research is conducted piecemeal with little coordination of programs to gather more comprehensive data.

Even more aggravating is the lack of coordination of regulatory practices, and the unwillingness of the agencies to establish uniform regulations. While there are admittedly bureaucratic difficulties in establishing such uniform policies, these agencies create even greater problems by protecting only their own immediate interests.

6.1.8 Probable Nature of Solutions

6.1.8.1 Natural Resource Base

The population explosion, consequent larger demands on the resources, and man's apparent lack of concern for his environment make solutions to the present and future problems of Lake Erie multiple and complex. Existing and future physical problems of Lake Erie and the fishery resources are listed below:

(1) Lake Erie is being used as a dumping ground and physical and chemical wastes are flowing into Lake Erie from improper agricultural practices and municipal and industrial wastes. A possible solution would be to educate the population concerning misuse of the environment and devise equitable methods for proper farming practices and disposal of municipal and industrial wastes.

(2) There is an unstable fish population because of environmental degradation and overexploitation. A possible solution would be to devise new methods of harvesting and marketing less desirable and more abundant species until a proper environment and uniform regulations will permit relative stabilization.

(3) Knowledge of relative species numbers, seasonal distribution, and annual recruitments is lacking in magnitude and accuracy. The demands and harvests (commercial and sport) are not known accurately. Future harvest and facility needs cannot be anticipated until these parameters are accurately determined. For this, a universal method of tabulating all sport and commercial effort and harvest on each governmental subdivision of Lake Erie must be developed, if the present and future needs and demands of Lake Erie fishermen are to be met.

6.1.8.2 Habitat Base

For many decades the Lake Erie basin has been a prime recreational and industrial area. Active utilization of natural resources (water, fish, game, and minerals) within the basin plus low transportation and handling costs of Lake shipping have generated an ever-increasing economy within the region. The desirable physical characteristics of the remaining undeveloped areas (marsh sites) have intensified demand and elevated values for prospective developers. Because of these factors, future land acquisition and proposed utilization need to be monitored and regulated by the State and Federal governments to insure minimum degradation of the ecosystem. Such control will insure that sufficient land is developed for public use, and will maintain a balance between recreational and commercial use.

Lake Erie has the worst water quality in the Great Lakes. Hypolimnetic waters of the central basin are usually devoid of oxygen during the summer months. The western basin often reaches critical levels of dissolved oxygen when a combination of high air temperatures and low wind velocities occurs. Annual die-offs of algal blooms, oxidizing organic sediments, and increased turbidity and water temperatures are placing greater demands on oxygen levels. Phytoplankton in Lake Erie also is increasing and further depleting available oxygen.

In order to correct and enhance oxygen levels in Lake Erie, the following programs are necessary: primary treatment of all sewage, and curtailment of excessive nutrient and sediment entrance from industrial and farming practices.

The use of herbicides and pesticides in the Lake Erie basin and upper Lakes has necessitated Federal control to insure that application rates are uniform. Existing concentration levels of toxic heavy metals must be determined. All sources of heavy metal pollution must be located, and further discharge of such material prohibited. Although Lake Erie has a rapid flushing rate (less than three years), it cannot rehabilitate itself unless grossly polluted tributaries are corrected, and the water quality of the upper Great Lakes improved.

Water quality necessary for fish life will generally support the needs of related uses. However, many of the subtle effects of toxicants are unknown and can only be expressed in terms of changes attributed to them: survival of eggs and larvae of certain fish species has altered; tubifex worms occur in greater numbers; and mayflies have practically disappeared from Lake Erie. These changes are indicators and should not be construed as factual aquatic life criteria.

Restrictions are being imposed on commercial fisheries (minimum legal fish size, net size, prohibited areas, seasons), to create optimum yield and minimum depredation of present dominant species such as the perch, white bass, walleye, channel catfish, smelt, and freshwater drum. Ohio, Pennsylvania, and New York have introduced salmon fingerlings and are considering striped bass and blue pike to augment the predator population and create desirable sport fisheries. Walleye fry are still being released into Lake Erie by Ohio to supplement the natural hatch.

The Lake Erie commercial fishery is experiencing competition from the sport fishery, reducing the number of commercial harvesters and thus enhancing the fishing success of remaining businesses. If fish management can provide equitable commercial harvest without depletion of species, neither industry should be impaired, and abrasive confrontations between the two fisheries can be minimized. Defining and regulating the effects of fishing pressure on Lake Erie fish species and improving fishing success are major goals of State agencies within the Lake Erie basin.

6.1.9 Fish Resources and Their Uses

If present conditions in the commercial fisheries continue, the end of this industry on the U.S. waters of Lake Erie is within sight. Solutions to these problems must be concentrated within a relatively short period of time. Research must be directed to the re-establishment of high-value species with stabilized yield and the concurrent reduction or economic utilization of low-value populations. If the industry is to modernize harvest technology, governmental assistance is necessary. New processing and marketing techniques must also be developed.

Projected sport fishing demands will require expansion of facilities of both public and private nature. Reliable data on the sport fishing harvest must be gathered and included in harvest estimates. This will also help insure stable populations of important species.

Management of fish resources faces biological, social, and economic problems. Additional biological data are needed on each species, including intra- and interspecies relationships. The seasonal physical and chemical environment of Lake Erie needs to be better defined. Demands for better quality fishing can be evaluated on biological-environmental and socio-economic grounds. Once these are determined, fish populations can be managed to meet realistic objectives. However, objectives must first be placed in their proper perspective, and then met by uniform regulations and enforcement.

6.2 Planning Subarea 4.1

This planning subarea encompasses parts of Michigan along the northwestern portion of Lake Erie (Figure 8–64).

6.2.1 Species Composition, Relative Importance, and Status

Warmwater species dominate the stream fishery of this planning subarea. Only 40 miles of stream are currently managed for trout, and nearly all the trout streams require maintenance hatchery stocking. Smallmouth bass, northern pike, suckers, panfish, and rock bass are the most important game fish taken by stream anglers in the area. Many of the streams of the planning subarea are dominated by rough fish.

Inland fishing opportunities in Planning Subarea 4.1 are found predominantly in natural lakes. Although crappie, perch, bluegill, rock bass, and other panfish dominate the sport catch, large- and smallmouth bass, northern pike, muskellunge, and walleye are also common in the lakes here. A surprising number of lakes in the area can support trout as well as warmwater fish, and two-story trout management has been very successful in the area.

Planning Subarea 4.1 has a number of reservoirs that offer potential for fishery development, but are not dominated by rough species. The area does not have a stream with a significant run of anadromous salmonids. The potential for anadromous fishery development is extremely limited by both water temperature and water quality. Fishing opportunities of the planning subarea can be enhanced through chemical rehabilitation and maintenance stocking of warmwater species.

6.2.2 Habitat Distribution and Quantity

The range of ponded water varies from a low

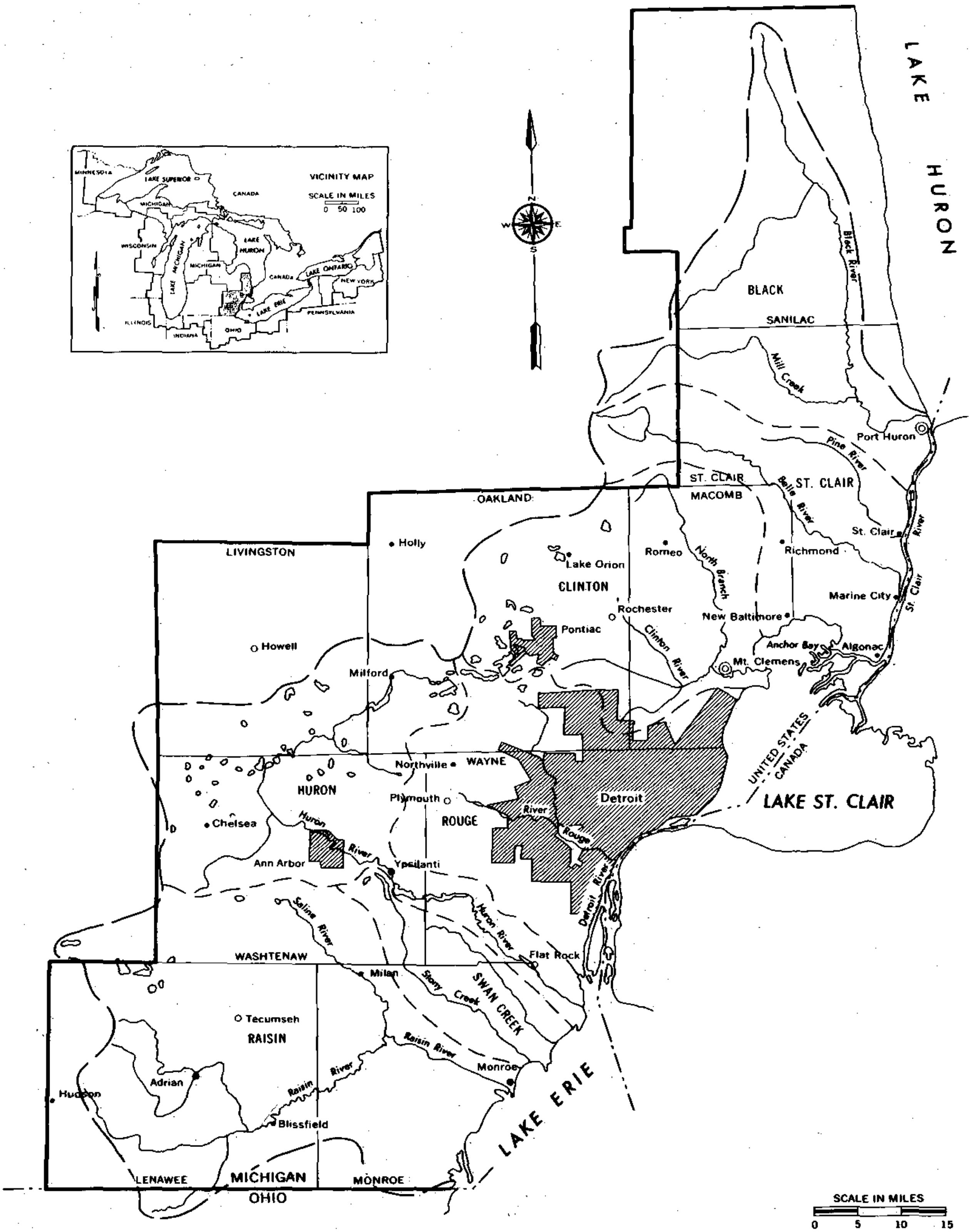


FIGURE 8–64 Planning Subarea 4.1

of 74 acres in Sanilac County to a high of 22,896 acres in Oakland County (Figure 8–65). Fortunately, available habitat is located within reasonable proximity of the population. The ponded water per capita ranges from a high of .216 in Livingston County to a low of .001 in Wayne County. Distribution of available fishing opportunities has an effect on fishing license sales. For example, nearly 25 percent of the residents of Livingston County were licensed fishermen in 1967, and only 2.7 percent of the residents of Wayne County bought fishing licenses (Table 8–46).

Many unlicensed fisherman of Wayne, Oakland, Macomb, and St. Clair counties fish on Lake St. Clair. Their demand is recorded separately in the Lake Erie-Lake St. Clair section of this report.

6.2.3 Habitat Problems Affecting Production and Distribution of Important Fish Species

Poor water quality because of industrial and municipal pollution has degraded many of the rivers and impoundments to the point that only rough fish such as carp remain. Water quality in many stream systems is being significantly improved, but carp will continue to dominate unless chemical removal and restocking occurs. Portions of the Raisin and Rouge Rivers, and Willow Creek (Ypsilanti) have such poor water quality that enhancement of fisheries will not be possible for a long time. Most river systems, however, have standards designed to protect valuable game species.

Most of the inland lakes of the area are intensively developed. Nutrients added from septic disposal systems have accelerated eutrophication and have limited available habitat for the more desirable game species. Filling of shore marshes to create building sites has significantly reduced spawning areas, particularly for northern pike.

The 60 existing reservoirs in Planning Subarea 4.1 offer the best potential for intensive fish management. Many of these are owned and operated by local governments with whom cooperative management plans must be developed. Total chemical rehabilitation and maintenance stocking in these impoundments would provide a significant new fishing opportunity in areas close to population centers.

TABLE 8–46 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 4.1

State and Counties	Land Area (sq.mi.)	Population (1000s)	Population per sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
Michigan								
Lenawee	751	80.0	106.5	4,851	.0606	3,218	9,438	.1180
Livingston	568	44.2	77.8	9,559	.2163	554	10,392	.2351
Macomb	479	553.1	1,154.7	1,308	.0024	107	13,582	.0255
Monroe	556	112.0	201.4	339	.0030	1,910	8,561	.0764
Oakland	858	803.0	935.9	22,896	.0285	942	58,968	.0734
St. Clair	734	114.9	156.5	578	.0050	248	4,462	.0388
Sanilac	961	34.3	35.7	74	.0022	18	2,726	.0795
Washtenaw	708	203.8	287.9	7,298	.0358	883	18,817	.0923
Wayne	604	2,704.6	4,477.8	2,591	.0010	510	72,920	.0270
Total	6,219	4,649.9	747.7	49,494	.0106	8,390	199,866	.0430

State and Years	Land area (sq.mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand: Resident[1]	Projected Angler Day Demand: Total[2]
Michigan					
1980	6,219	5,801.7	932.9	7,568,515	2,523,000
2000	6,219	7,425.2	1,194.0	9,686,426	3,228,000
2020	6,219	9,567.6	1,538.4	12,481,259	4,160,000

[1]Demand generated within planning subarea.

[2]Total demand including in- and out-migration.

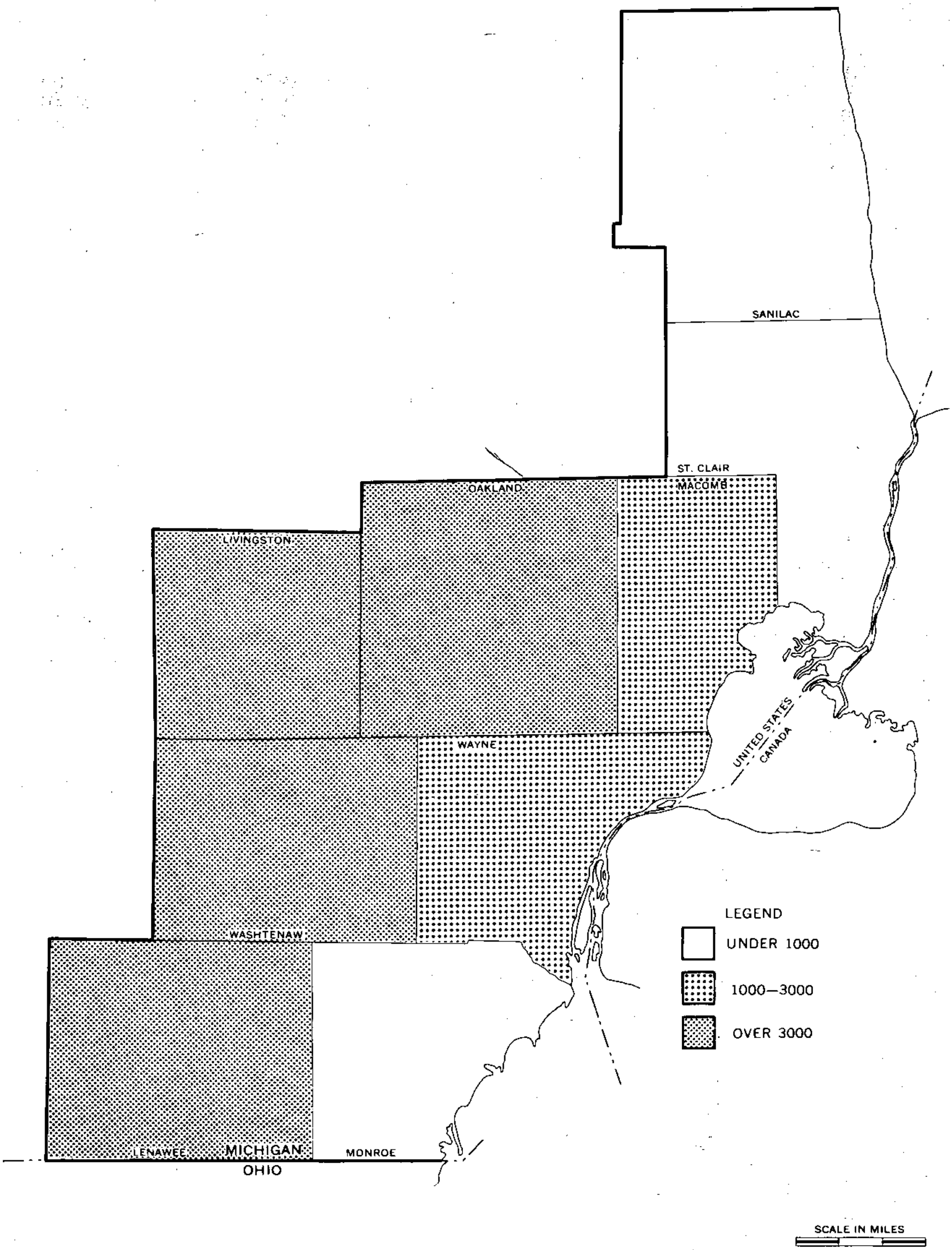


FIGURE 8-65 Acres of Ponded Water, Planning Subarea 4.1

6.2.4 History of Sport Fishery

Fishing activity and license sales in this planning subarea grew annually until the mid-1950s. In 1954 resident license sales reached an all-time high, 278,468. Because of a decline in fishing quality and an increase in competing lake uses, fishing license sales declined for a period of ten years. From 1964 to the present, license sales have increased every year.

Originally the licensed sport fishery was limited to the inland lakes of the area. However, Lake St. Clair fishermen are now also licensed, and therefore, many anglers travel outside the area to fish.

6.2.5 Existing Sport Fishing Demand and Current Needs

The total angler day demand on inland water of this planning subarea has decreased since the mid-1950s. The number of licensed sport fishermen in this area has remained the same due to new licensing requirements on Lake St. Clair in 1968 and new fishing interest for trout and salmon in other Great Lakes areas. No surveys related to the percentage of resident angler days on inland lakes were made. Perhaps 30 percent of the current 6,000,000 angler days is supplied in other planning subareas primarily in northern Michigan.

Non-resident license sales and in-migration from other areas into Planning Subarea 4.1 are negligible. However, many residents of Planning Subarea 4.1 purchase their licenses in other areas. This out-migration is recorded as license sales in other counties and will be considered as demand in these other planning subareas.

6.2.6 Ongoing Programs

Fish habitat protection and maintenance of the resource base consumes the greatest part of fish management effort in Planning Subarea 4.1. Figure 8–66 summarizes the manipulation of fish populations through a combination of rough fish removal and maintenance stocking. The number of lakes and acreage involved varies from year to year, but Figure 8–66 and Table 8–47 clearly represent the magnitude and general location of current programs.

In 1968, 379 pounds of warmwater species and 18,941 pounds of trout were planted in lakes and streams. The plantings included 305,800 trout (rainbow trout, brown trout, and splake) and 4,390 warmwater fish (muskellunge, largemouth and smallmouth bass).

6.2.7 Future Trends in Habitat and Participation

Current fishing demand (1966 base year) of just over 6,000,000 angler days is projected to increase to 8,500,000 angler days by 1980. The new warmwater fish hatchery is expected to provide substantial fishing improvement in 25,000 acres of inland water. Some fish will be stocked in new impoundments, but a major portion will be used in renovation projects on existing lakes and impoundments (Table 8–48).

Each new acre of water under intensive warmwater species management will provide 25 angler days. On that basis, an additional 625,000 angler days will be provided as a result of the warmwater hatchery and related renovation projects.

Latent demand is extremely important for planning future fishing opportunities for resi-

TABLE 8–47 Summary of Base Year Fish Habitat and Management Efforts, Planning Subarea 4.1

County	Total Area (sq.mi.)	Acres Ponded Waters	Number Ponded Waters	Number Intensively Managed	Acres Intensive Warmwater	Acres Intensive Trout	Miles Total Streams	Miles Trout Streams	Miles Anadromous Streams
Michigan									
Lenawee	760	4,851	74	1	-------	63	622	----	----
Livingston	583	9,559	172	7	292.8	421.4	469	----	----
Macomb	481	1,308	29	--	-------	-------	296	2.0	----
Monroe	564	339	7	--	-------	-------	459	----	----
Oakland	899	22,896	394	37	1,639	4,831.2	469	27.9	----
St. Clair	751	578	19	--	-------	-------	959	----	----
Sanilac	961	74	9	--	-------	-------	1,007	----	----
Washtenaw	723	7,298	99	9	19.7	1,003.2	372	8.2	----
Wayne	625	2,591	56	1	-------	35	391	1.2	----
Total	6,347	49,494	859	55	1,951.5	6,353.8	5,044	39.3	----

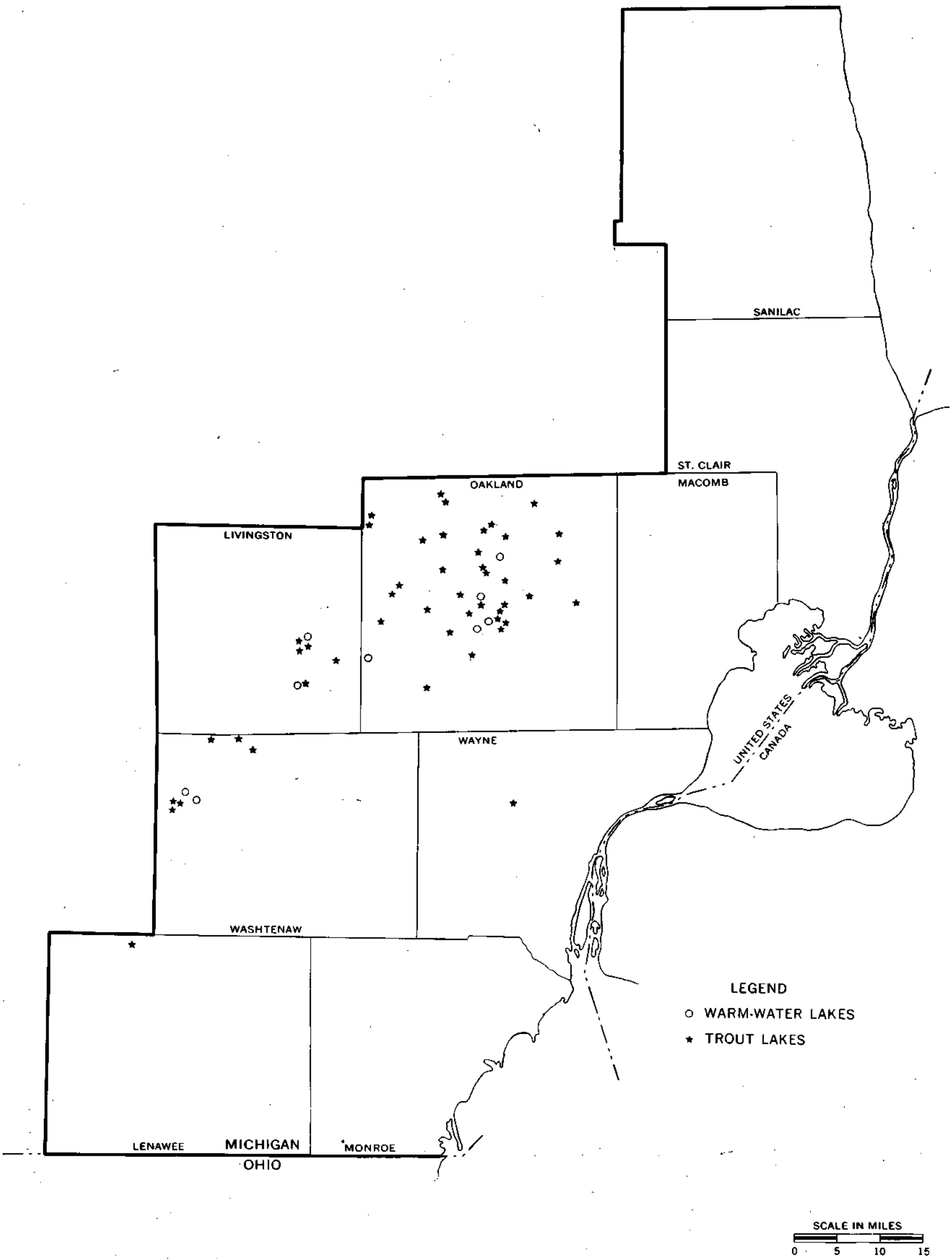


FIGURE 8–66 Current Fish Stocking Program, Planning Subarea 4.1

TABLE 8–48 Priority Land Acquisition Areas, Planning Subarea 4.1

County	River	Acres
Livingston	Huron	540
Livingston	Portage	520
St. Clair	Belle	---
Lenawee	Bean Creek	---
Lenawee	Black Creek	---
Washtenaw	Raisin	---
Washtenaw	Saline	---
Washtenaw	Paint	---
Monroe	Saline	---
Total		1,060

dents of Planning Subarea 4.1. New fishing opportunities will undoubtedly attract people who were not considered in the projected demand. Latent demand could more than double the projected fishing demand figures for 1980 through 2020.

Anadromous fish management was initiated in 1970 when a total of 50,000 coho salmon were stocked at Lakeport (Lakeport Creek) and at Port Sanilac (Elk Creek). These plants were designed to provide a surf or nearshore fishery in Lake Huron. No stream fishery was intended. Additional rivers have been selected for anadromous species management in the future. However, these streams will be suited only for anadromous warmwater species such as striped bass.

6.2.8 Fishery Development Plans

The warmwater hatchery being designed for southeastern Michigan will serve many areas of the State. About one-third of the total $3 million capital cost of this facility will be charged to Planning Subarea 4.1. The operational cost of raising fish and treating the lakes before stocking will require $150,000 to $200,000 annually from Planning Subarea 4.1.

Land acquisition for fisherman access and habitat protection will be very costly. Potential sites have been surveyed, but little work has been done to estimate acreages involved, or more importantly, the cost. The cost of land acquisition prior to 1980 will exceed $500,000. The summary of sites being considered is included in Figure 8–67 and Table 8–48.

Numerous potential impoundment sites offer potential fishery enhancement. The Pine River in St. Clair County would have good fishery potential if developed. However, renovation of existing impoundments would probably have a better cost-benefit ratio for fishing.

Fishery development plans beyond 1980 will concentrate on land acquisition to prevent encroachment. Expansion of the warmwater stocking program beyond the 25,000 acres planned will depend upon maintenance of existing habitat and access either through zoning or land acquisition. Land acquisition costs between 1980 and 2000 could exceed $2,000,000.

The cost of providing additional inland fishing opportunities must be weighed against the cost of providing the same opportunities in Lake St. Clair, other Great Lakes areas, or in the northern part of Michigan. Additional fishing opportunities should be provided for the relatively immobile portion of the population. However, the large, mobile, and relatively affluent portion of the population may be satisfied by fishing opportunities outside the planning subarea.

In summary, costs to preserve existing fisheries and add 25,000 acres of intensively managed water will exceed $3 million by 1980. This figure excludes the cost of new impoundments.

6.3 Planning Subarea 4.2

6.3.1 Species Composition, Relative Importance, and Status

Planning Subarea 4.2 contains a diversified fishery environment (Figure 8–68). The sport fishery predominates, and the commercial fishery is limited to tributaries immediately adjacent to Lake Erie in Erie, Lucas, Ottawa, and Sandusky Counties. Crappies, yellow perch, white bass, bluegill and other sunfish, bullhead, and channel catfish compose the majority of the sport catch in this subarea. Largemouth and smallmouth bass, rock bass, walleye, and northern pike are the most sought-after game fish. Rainbow and brown

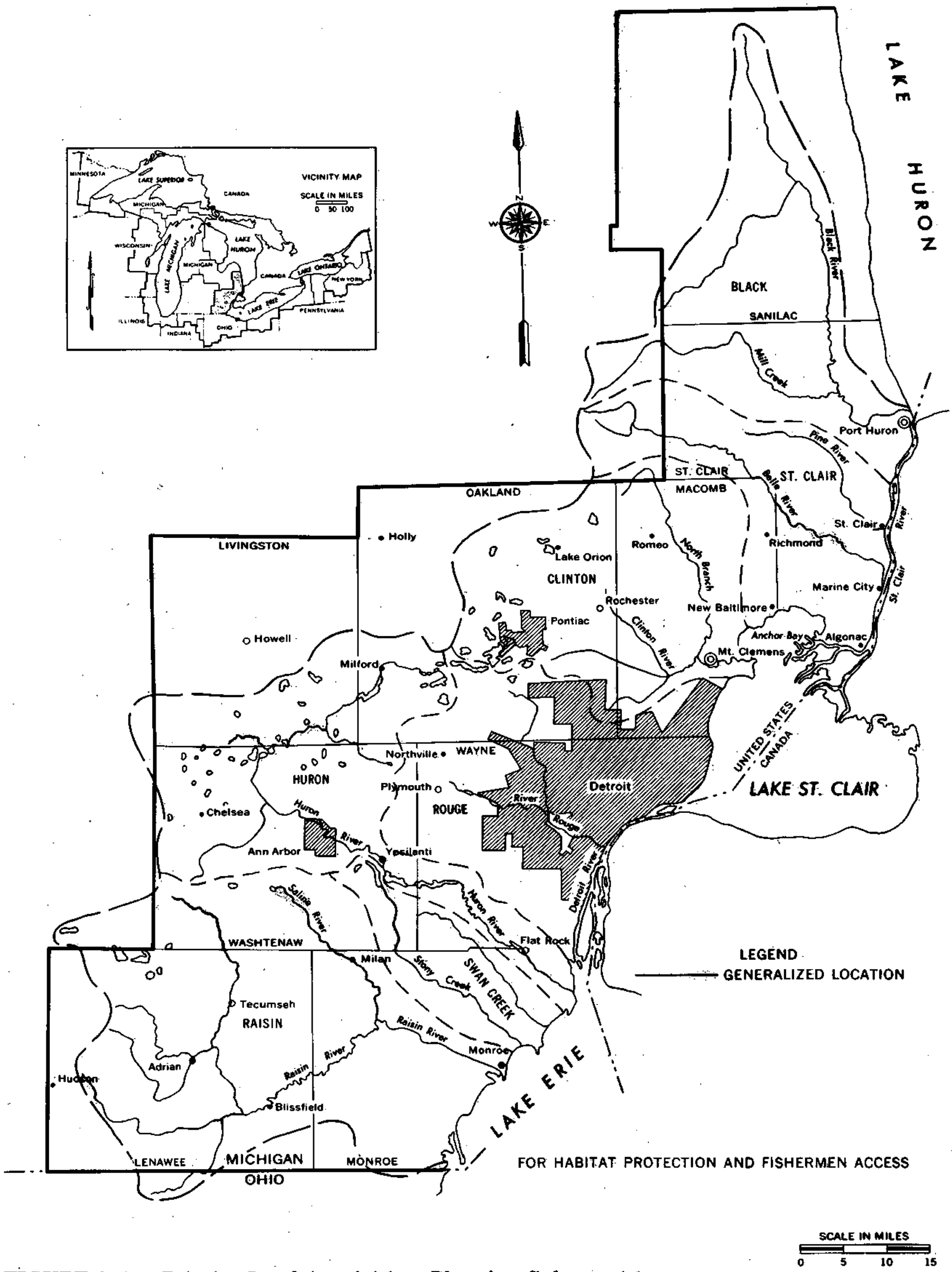


FIGURE 8–67 Priority Land Acquisition, Planning Subarea 4.1

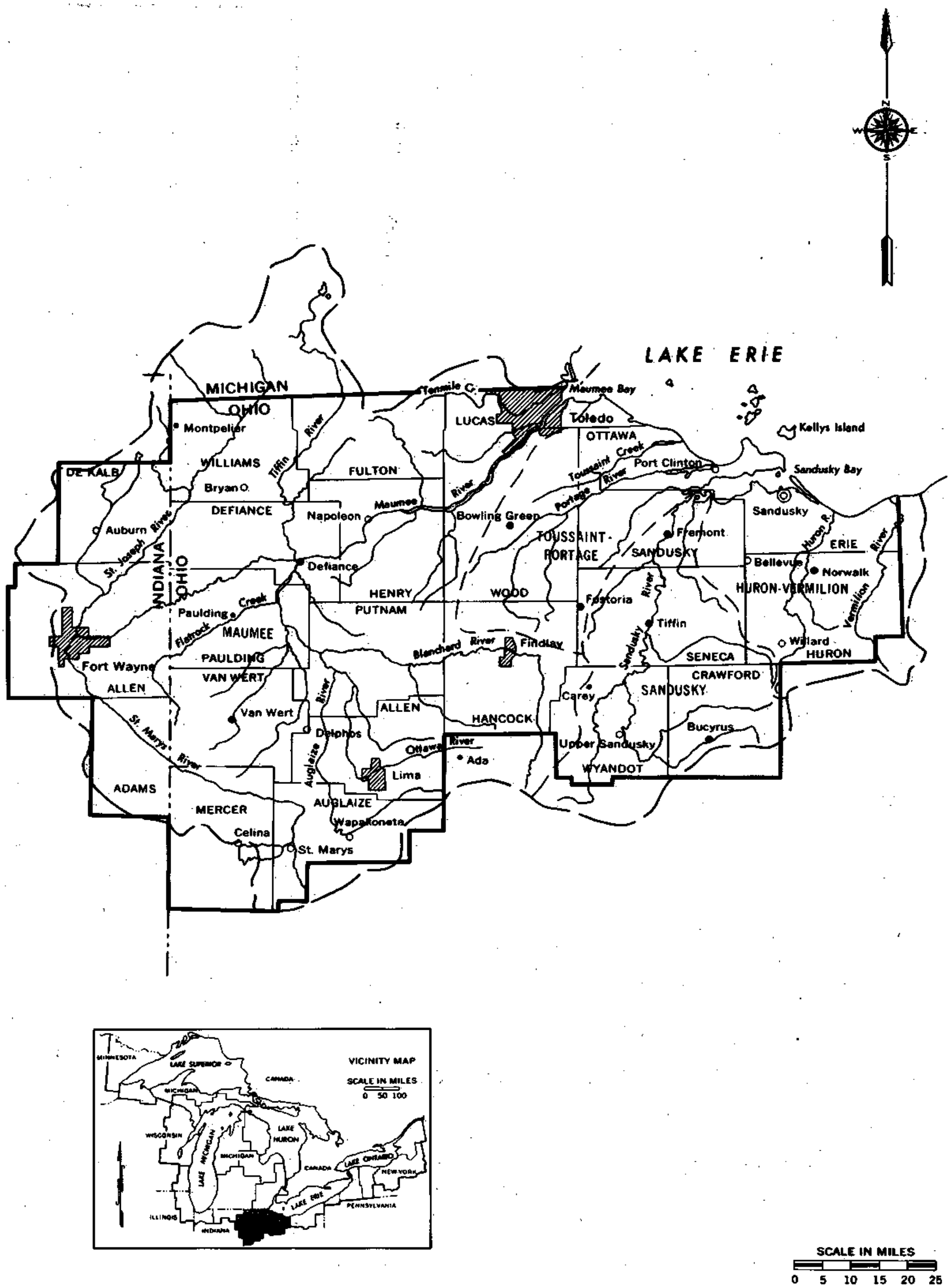


FIGURE 8–68 Planning Subarea 4.2

trout are present but extremely limited. Coho salmon have been recently introduced into the area. Other sport fish include suckers, gar, bowfin, carp, and stonecat.

Inland ponds, lakes, and reservoirs are generally small in size (except for Grand Lake St. Marys, which is the largest inland lake in Ohio), but provide a significant amount of angling opportunity. Many of these water areas, particularly the drainage impoundments, are dominated by stunted panfish and rough fish populations. The inland lake fisheries have varied throughout the years depending on water quality demands placed upon them. Lake productivity and angler expectations are seldom compatible. Natural fish population balance, especially in small water areas, seldom approximates desirable angling populations without management.

The development of upground reservoirs since 1950 has been important to the fishery of the area. These unique water areas have provided highly desirable pelagic habitat for such species as walleye, yellow perch, white bass, largemouth and smallmouth bass, bullhead, and channel catfish. The Northwest Ohio Water Management Plan includes the development of 37 more upground reservoirs over the next few decades (Figure 8–70).

The stream fishery is composed almost entirely of warmwater species such as smallmouth bass, rock bass, northern pike, crappies, sunfish, bullhead, and channel catfish. Quality fisheries for walleye and white bass exist during spawning and migration runs in the lower portions of larger tributaries near Lake Erie. Dams on these larger tributaries block migration and confine this quality fishing to limited areas. A very limited trout fishery is available in a few streams.

Streams have been important to anglers of this area in the past because of the limited impounded waters. Water quality problems have seriously affected the stream habitat and reduced angler utilization. The continued development of ponded waters for water supply, low-flow stream augmentation, agricultural uses, and recreation has transferred much angling pressure previously applied to streams to the ponds, lakes, and reservoirs.

Recent stockings of coho and chinook salmon in the Huron River are expected to stimulate angler interest in the fishery of this stream. The first adult coho returned to this stream in the fall of 1970 and resulted in 6,965 additional anglers, 18,736 hours, and a catch of 2,283 coho salmon. Future returns are expected to be much larger.

Fish habitat areas and fishing opportunities in the area can be improved by management. Warmwater management, including population control, selectively bred species, stocking of predatory species, and development of feeding and spawning areas can be expected to improve the fish populations of existing areas. The development of new impoundments with special features is expected to improve the fishery potential. Stream water quality problems are principally related to organic or oxygen consuming wastes created by municipalities and industries, but agricultural wastes, including sediments, pesticides, and fertilizers, also contribute to the water quality problem. Improvement of water quality will enhance the stream fishery.

6.3.2 Habitat Distribution and Quantity

The 1,614 inland ponds, lakes, and reservoirs of the Ohio portion of Planning Subarea 4.2 provide more than 40,700 surface acres of fishable waters. There is fair water distribution within the area except for certain large population centers (Figure 8–69). The impounded waters per capita vary from a high of 0.370 in Mercer County to a low of .003 in Lucas County. Because Lucas County has the largest population and the second-smallest area in the planning subarea, this figure is expected to be low.

The distribution of inland fishable water has only a limited effect on fishing license sales. While license sales are related to water acreage available, it should be remembered that today's populations are mobile. As a result, fishermen often purchase their licenses in places of principal use rather than their counties of residence. Lucas, Ottawa, and Erie County license sales are influenced by angler interest in Lake Erie. This causes an influx of non-county residents purchasing resident fishing licenses.

Streams, especially the larger ones such as the Maumee, Auglaize, Sandusky, Huron, and Vermilion, are well distributed throughout the planning subarea and are important to the total fishery of the area.

6.3.3 Habitat Problems Affecting Production and Distribution of Important Fish Species

Many factors peculiar to Planning Subarea 4.2 influence the production and distribution

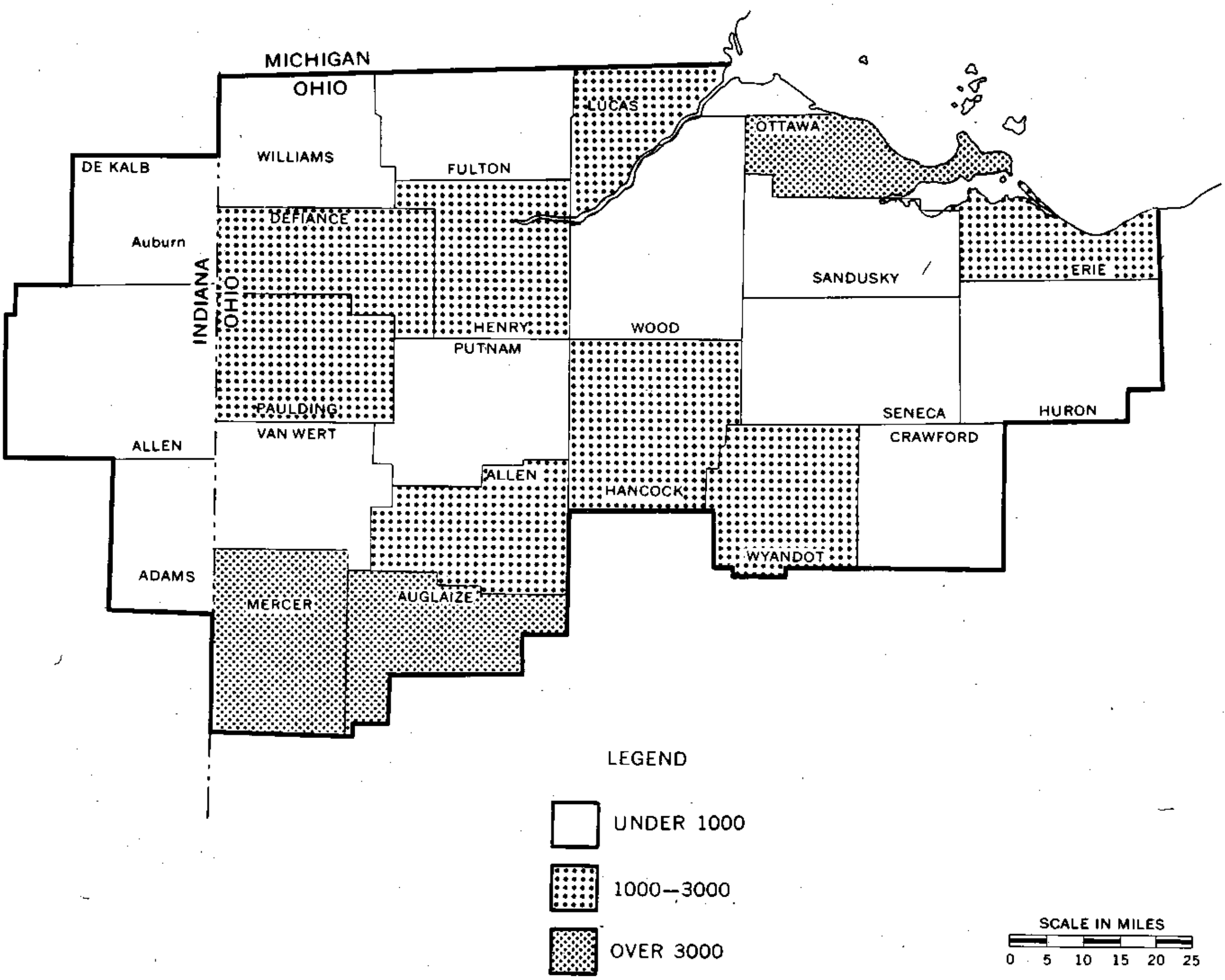


FIGURE 8–69 Acres of Ponded Water, Planning Subarea 4.2

of game and panfish species. The quantity and distribution of inland waters are important factors. The low relief of the lake plain area of northwestern Ohio and the further leveling of this land by glaciers permitted few natural lakes to develop. Less than 200 acres of inland impoundment water in this planning subarea is natural. The monotonous, flat land prevents the development of significant artificial drainage impoundments. However, because of industrial and domestic water supply needs, numerous upground reservoirs have been developed. Numerous small drainage impoundments have been constructed by public and private agencies. These unusual water areas have been managed for fishery utilization since the 1940s.

The recent adoption of the Northwest Ohio Water Management Plan by the State of Ohio has encouraged additional development of these upground reservoirs. In addition to water supplies, upground reservoirs now being constructed are designed to provide recreational activities (primarily water-oriented outdoor activities), low-flow stream augmentation, and water for agricultural needs. As a result, recently developed upgrounds are larger in size, up to 640 acres, and offer greater potential as fisheries. Special fishery enhancement facilities have been included in these reservoir developments (Figure 8–69). Research projects are presently being conducted on the upground reservoirs to evaluate their environments, their fishery potential, and the special facilities designed into the recently constructed upgrounds.

Drainage impoundments are generally eutrophic. Eutrophication is caused primarily by intensive agricultural land management activities, but human wastes also contribute. Eutrophic water areas are extremely fertile. Many are considered overfertile, and although they support large fish populations, these are composed largely of undesirable angling species, such as carp, shad, quillback, and stunted panfish. Lake and pond rehabilitation projects have indicated that eutrophic waters generally support from 400 to 900 pounds of fish per surface acre.

There are many abandoned limestone quarries in this planning subarea, and they are often used as commercial or private fishing lakes. These water areas are generally infertile and incapable of maintaining desirable fish population levels without maintenance stocking programs. Their fish population productivity generally ranges from 60 to 90 pounds per surface acre. Maintenance stocking programs in quarries are the stock-catch type, where quarries serve only as a holding area for fish until they are harvested by anglers. Current research on quarries is attempting to determine carrying capacities. Destratification research may indicate potential for coldwater management in these water areas.

As a result of interstate highway development, many barrow pit ponds have come into existence. Because the majority of these ponds are privately owned, management efforts have been limited. These waters appear to have good potential as public fishing areas. Studies are being conducted to determine their fishery potential and the feasibility of incorporating similar areas into the State public fisheries program.

The upground reservoirs characteristic of this planning subarea offer an entirely different fishery habitat because they are pelagic, and usually not eutrophic. Desirable sport fisheries, including such species as smallmouth bass, walleye, white bass, yellow perch, and channel catfish, have been established in many upground reservoirs. Figure 8–70 diagrams the characteristics of a typical upground reservoir.

Multiple outdoor recreational demands compete with the sport fishery for the use of many inland impoundments. Water skiing and speedboating often make fishing impossible during the summer.

Water level fluctuations during spawning periods have reduced species productivity in certain lakes. Excessive sedimentation in many drainage impoundments has reduced their productive capacities.

Stream systems in northwestern Ohio have had water quality problems for many years. Although nearly all the streams of this area manifest some water quality degradation, most of them support some desirable angling opportunity. Only a few, such as the Ottawa River from Lima to the Auglaize River, a distance of approximately 45 miles, have been sufficiently polluted to preclude the presence of any significant fish populations. The larger streams such as the Auglaize, Maumee, and the Sandusky reflect the effect of stream eutrophication, and their greatly enriched waters support massive populations of undesirable fish species.

In addition to water quality problems, the streams of this area will continue to be affected by certain physical alterations caused by stream habitat destruction for flood control and drainage. Because there are no natural drainage basins for flood control impoundments, flooding and drainage problems are

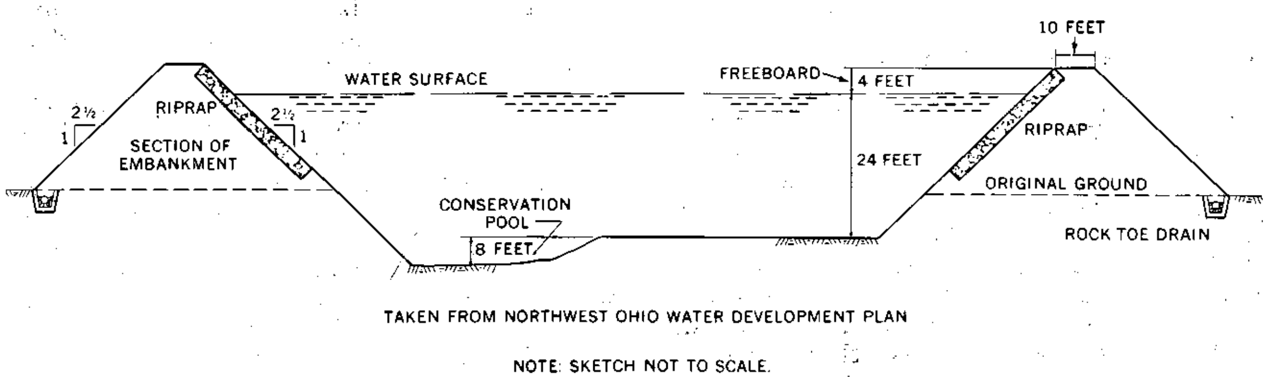


FIGURE 8–70 Typical Upground Storage Reservoir

most easily corrected by stream channelization. Conservancy districts and Federal agencies become involved in larger drainage systems when local property owners cannot handle the necessary developments. After completion of stream channelization projects, continuous maintenance prevents them from returning to natural stream conditions. These projects create a lack of necessary stream fishery habitat. If recommended fishery enhancements were incorporated into the projects, losses to the aquatic habitat could be decreased.

These drainage projects also compound water quality problems by accentuating low-flow characteristics of streams. Because they accelerate runoff during periods of heavy precipitation, flood damage to fish habitat also occurs, especially in stream areas below such projects. Increased water temperatures, which significantly affect the range and distribution of such species as smallmouth bass and northern pike, result from municipal industrial waste discharges, and stream channelization projects. Raised stream temperatures also limit the range of anadromous salmonids.

Soil erosion, primarily sheet erosion, has deposited large quantities of silt in the rivers and drainage impoundments. These silt deposits interfere with fish populations and contribute to excessive water fertility. Rough species with short food chains and greater tolerances to unfavorable conditions respond favorably to these conditions, while the more desirable game and panfish species do not.

Fisheries problems affecting stream systems have caused a reduction of the fishery potential. With improved stream water quality, stream fishery productivity will increase in those streams not affected by channelization projects.

6.3.4 History of Sport Fishery

The sport fishery of this planning subarea concentrated largely on the major streams of the area until the 1950s when human water needs caused development of upground reservoirs. The stream fisheries were more valuable to past generations not only because of good water quality that permitted the development and maintenance of desirable fish populations, but also because those anglers were willing to exert greater effort in their sport fishing activities. Today, impoundment fisheries are more convenient, and the fisherman is not apt to physically exert himself in search of a good fishing stream.

Fishing license sales reached their peak in 1951, stabilized during the late 1950s, and declined in the early 1960s. The decline in this area was due to the deterioration of stream water quality and the stream fishery. Since 1964, fishing license sales have indicated annual increases. These are related to improved stream conditions and to the expanded development of upground reservoirs.

The Federal government has developed private ponds in this area during the last two decades. Fishing licenses are not required on private water areas in Ohio, so the development of significant numbers of private ponds may have contributed to the stabilization and decline of license sales in the area during the late 1950s and early 1960s. During this period angler use may have been transferred from deteriorated public waters to the new private water areas where no licenses were required.

The sport fishery on the streams and impounded waters of this planning subarea concentrated on warmwater species until 1970, when coho and chinook salmon became available. The anadromous stream fishery for coho and chinook is now expected to provide additional fishing activity. However, it will be quite limited because only the Huron River and Cold Creek can be utilized for these species. In order to offer more sport opportunity, largemouth and smallmouth bass, northern pike, rock bass, walleye, white bass, channel catfish, and panfish will continue to be utilized in fisheries management programs.

6.3.5 Existing Sport Fishing Demands and Current Needs

The total angler day demand for the inland waters of this planning subarea peaked in 1951, stabilized during the late 1950s, and declined in the early 1960s. Since 1964, the angler day demand has increased annually. In Planning Subarea 4.2, annual angler demand is currently estimated at nine million angler days. It is estimated that approximately 65 percent of the current demand is supplied within this planning subarea, while nearly 3.1 million angler days are supplied elsewhere, primarily on Lake Erie and in nearby portions of north central Ohio.

Anglers from other planning subareas, both residents and non-residents of Ohio, make up only a small percentage of the total number of angler days recorded in this planning subarea. The purchase of licenses by residents of Planning Subarea 4.2 in other parts of the State is not considered to be significant. Angling outside the area occurs primarily in the portions of Lake Erie belonging to adjacent planning subareas. The nonresident license sales of Planning Subarea 4.2 were used to compute the number of angler days by out-of-State fishermen, which totaled 56,000 days per year.

6.3.6 Ongoing Programs

The current fisheries programs in Planning Subarea 4.2 involve protection, maintenance, and development of the fishery resource. Because inland waters are relatively scarce, intensive management of fish populations is required. All available water areas, including many municipal fishing waters, are utilized for fisheries management programs in order to meet the demands of the Ohio angler. Table 8–49 summarizes the intensive fish management efforts. While the number of lakes and the total acreage vary from year to year, Figure 8–71 and Table 8–49 generally represent the magnitude and the distribution of the current ponded water fisheries programs. Figure 8–72 indicates the stream fisheries management program areas. These streams are occasionally altered for water quality, drainage, and flood control practices.

Intensive warmwater management of impounded water includes the development of new water areas, partial or total chemical rehabilitation, water level fluctuations, aquatic vegetation control, fishing facility development, development and utilization of selectively bred strains of fish, and warmwater fish stockings of both native and exotic species. Coldwater impounded water management is not intensive because few coldwater lakes exist in this area.

Coldwater species, primarily rainbow trout, are used for seasonal fishing in selected lakes where angler population density will permit a high harvest prior to the advent of the undesirable summer environment.

Intensive warmwater stream management includes stream habitat improvement programs, water quality and fish kill evaluations, angler facility development and maintenance, fish planting to reestablish exterminated populations, and evaluations of stream habitat destruction programs. Coldwater stream management is limited to stocking trout in a few selected streams and the anadromous fishery of the Huron River (Figure 8–72).

In 1970, 2,540,099 warmwater fish and 168,130 trout and salmon were stocked in lakes

TABLE 8–49 Summary of Base Year Habitat and Management Efforts, Planning Subarea 4.2

County	Total Area (sq. mi.)	Acres Ponded Waters	Number Ponded Waters	Number Intensively Managed	Acres Intensive Warmwater	Miles Total Streams	Miles Trout Streams	Miles Anadromous Streams
Ohio								
Allen	409	1,668	160	6	1,314	193.22	-----	----
Auglaize	400	4,181	121	2	4,040	266.19	-----	----
Crawford	404	353	96	6	153	213.5	-----	----
Defiance	410	1,057	31	2	45	307.45	-----	----
Erie	263	1,273	143	7	322	106.3	6.0	18.0
Fulton	405	656	57	10	303	223.7	-----	----
Hancock	530	1,438	54	5	1,038	259.0	-----	----
Henry	415	2,085	23	3	24	246.25	-----	----
Huron	469	749	98	11	355	335.0	-----	9.0
Lucas	343	1,263	81	3	62	264.90	-----	----
Mercer	454	12,384	56	1	12,000	182.0	-----	----
Ottawa	261	8,498	179	4	1,410	219.0	-----	----
Paulding	415	1,127	25	4	83	251.25	-----	----
Putnam	484	120	28	3	33	397.80	-----	----
Sandusky	409	936	117	2	97	286.7	9.2	----
Seneca	551	189	63	2	134	404.7	3.3	----
Van Wert	409	456	52	2	135	235.9	-----	----
Williams	418	596	90	2	98	310.8	-----	----
Wood	618	455	73	1	29	374.5	-----	----
Wyandot	402	1,250	67	10	565	324.5	-----	----
Total	8,469	40,734	1,614	86	23,150	5,402.66	18.50	27.0

and streams. The warmwater stock included northern pike, muskellunge, smallmouth and largemouth bass, walleye, bluegill, white bass, yellow perch, striped bass, brown bullhead, channel catfish, and chain pickerel. Coldwater species included only rainbow trout for the inland fishery. Anadromous fish stocking began in 1969 when 28,000 coho salmon were planted in the Huron River in Erie County. A total of 160,000 coho and chinook salmon were stocked in the Huron River in 1970. Figure 8–72 indicates the anadromous stream fishery.

6.3.7 Future Trends in Habitat and Participation

Future demand based on the current relationship of habitat base to the number of fishermen indicates that the number of angler days generated from the Ohio inland portion will increase to nearly 11 million by 1980. This increase should be well distributed throughout the planning subarea, especially near population centers where eight additional multipurpose upground reservoir developments will total approximately 3,000 acres by 1980. By 2006, an additional 29 upground reservoirs totaling approximately 8,000 surface acres are programmed for development. The anadromous salmon fishery is expected to provide additional angling opportunity on the Huron River and some of the smaller nearby tributaries. Pollution abatement procedures will increase the quality of certain stream fisheries. Continued enhancement of the fishery will occur as a result of the continued and intensified management programs outlined in Subsection 6.3.6.

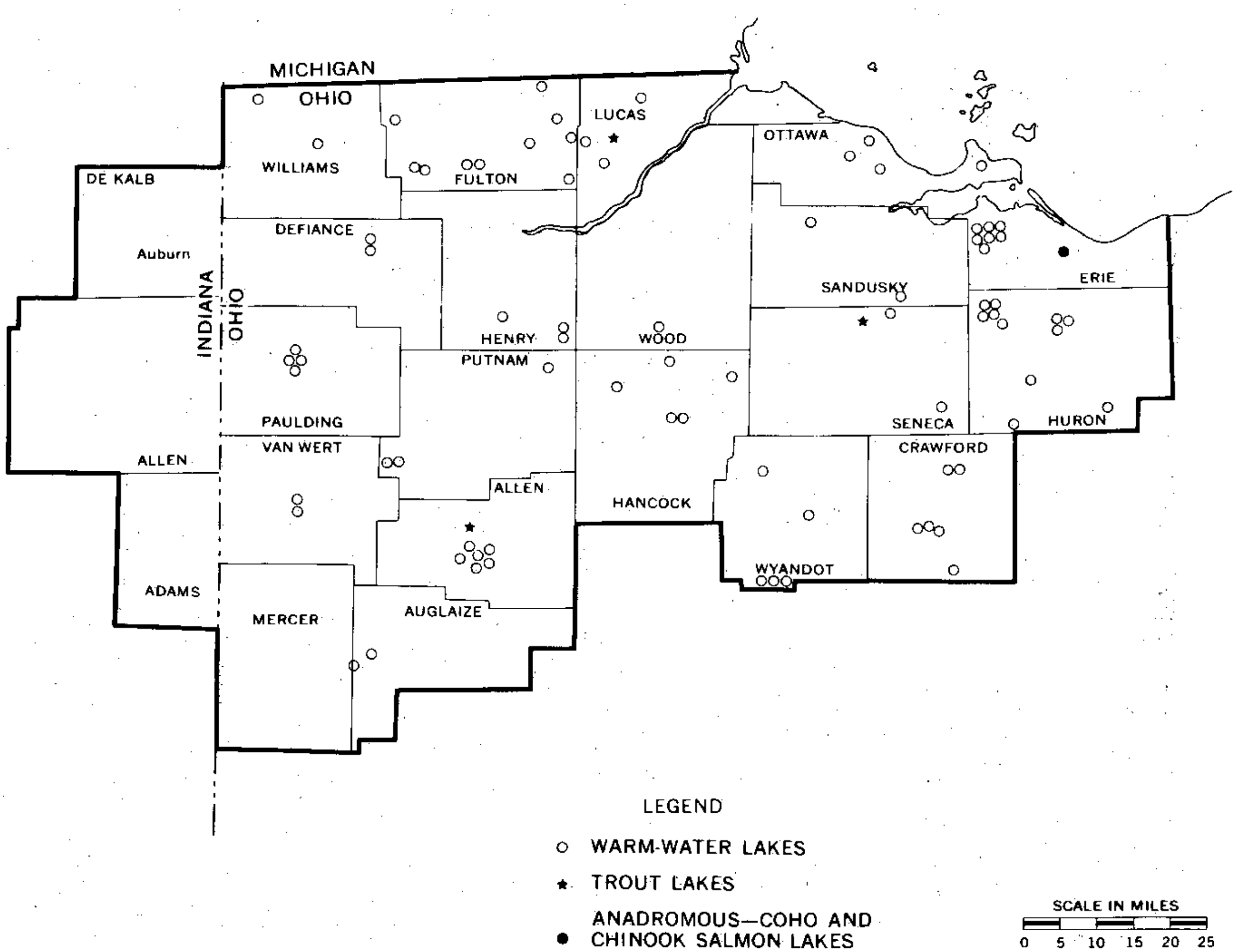


FIGURE 8–71 Current Fish Stocking Program, Planning Subarea 4.2

In order to calculate the future supply of fishing opportunities in the area, additional trout fishing area developments, new impoundments, acres of water improved by management techniques, and improved access to existing waters were estimated.

It is estimated that the projected demand for 1980 in the Ohio inland portion (approximately 11 million angler use days) will be 70 percent supplied by current programs including those recommended in the Northwest Water Development Plan. Combined with improved waste treatment procedures and stream low-flow augmentation provided by many of the new upground reservoirs, improved stream water quality and increased fishing opportunity are expected.

Latent fishing demand was not computed into these angler day estimates because it is related to general population projections. It is not anticipated that a special or excessively important new fishery will be added to this planning subarea to create more intense angling interest. People may have more leisure time in the future, but we can only speculate that they will spend a proportionate amount of this time in angling activities. The increased fishing demand on the inland waters of this planning subarea is expressed in Table 8–50.

6.3.8 Fishery Development Plans

Funds necessary to implement the previously mentioned programs are assured because they are provided by fishing license revenues in Ohio. However, capital outlay funds required for these new developments are not necessarily assured.

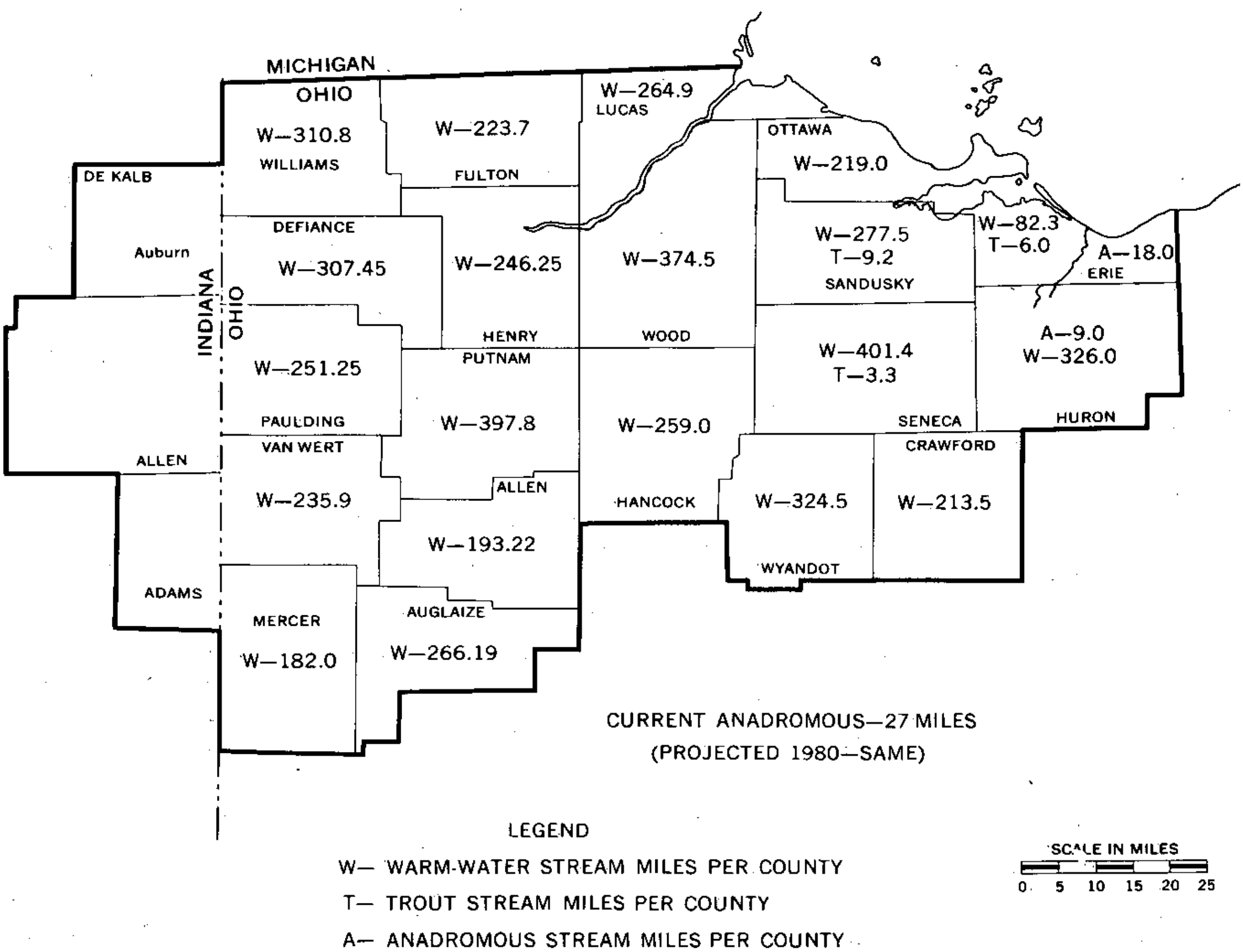


FIGURE 8–72 Stream Fishery Including Warmwater, Trout, and Anadromous, PSA 4.2

TABLE 8–50 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 4.2

State and Counties	Land Area (sq.mi.)	Population (1000s)	Population per sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
Ohio								
Allen	409	111.9	273.6	1,668	.0149	45	1,768	.0158
Auglaize	400	36.0	90.0	4,181	.1161	195	9,450	.2625
Crawford	404	48.0	118.8	353	.0073	66	5,902	.1229
Defiance	410	33.9	82.7	1,057	.0312	99	2,755	.0813
Erie	263	75.7	287.8	1,273	.0168	1,522	22,424	.2962
Fulton	405	30.3	74.8	656	.0216	49	2,259	.0746
Hancock	530	54.9	103.6	1,438	.0261	38	4,433	.0807
Henry	415	25.8	62.2	2,085	.0808	49	2,135	.0827
Huron	496	50.5	101.8	749	.0148	51	5,155	.1020
Lucas	343	474.5	1,383.4	1,263	.0026	787	34,998	.0738
Mercer	454	33.5	73.8	12,384	.3696	783	8,492	.2535
Ottawa	261	34.3	131.4	8,498	.2478	3,566	25,869	.7542
Paulding	415	18.9	45.5	1,127	.0596	71	1,783	.0943
Putnam	484	31.2	64.5	120	.0038	15	2,596	.0832
Sandusky	409	58.0	141.8	936	.0161	180	7,921	.1365
Seneca	551	59.4	107.8	189	.0032	48	5,913	.0995
Van Wert	409	26.4	64.5	456	.0173	35	1,791	.0678
Williams	418	31.3	74.9	596	.0190	55	2,406	.0768
Wood	618	79.3	128.3	455	.0057	50	4,234	.0534
Wyandot	402	21.7	54.0	1,250	.0576	15	2,404	.1108
Total	8,496	1,335.7	157.2	40,734	.0304	7,719	154,688	.1158
Indiana								
Adams	344	25.4	73.8	69	.0027	149	3,120	.1228
Allen	669	262.9	393.0	320	.0012	333	24,171	.0919
DeKalb	363	30.3	83.5	307	.0101	599	7,534	.2486
Total	1,376	318.6	231.5	696	.0022	1,081	34,825	.1093

States and Years	Land area (sq.mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand: Resident[1]	Projected Angler Day Demand: Total[2]
Ohio					
1980	8,496	1,617.4	190.4	10,751,327	7,048,000
2000	8,496	2,185.2	257.2	13,368,309	8,763,000
2020	8,496	2,977.8	350.5	16,607,211	10,887,000
Indiana					
1980	1,376	403.6	293.3	1,328,698	871,000
2000	1,376	561.3	407.9	1,847,865	1,212,000
2020	1,376	775.9	563.9	2,554,353	1,674,000
Total PSA 4.2	9,472	1,654.3	174.6		
1980	9,472	2,021.0	213.4	12,080,025	7,919,000
2000	9,472	2,746.5	290.0	15,216,174	9,975,000
2020	9,472	3,753.7	396.3	19,161,564	12,561,000

[1] Demand generated within planning subarea.

[2] Total demand including in- and out-migration.

These funds are limited and are only utilized on a Statewide priority basis. Capital developments will involve fund sources other than license revenues, especially where general recreation, water supply, and other water uses are involved. Although preliminary planning for these projects has been completed, land acquisition, trout fishing area developments, and new reservoir construction at present are only partially funded, or not funded at all.

Current estimated operational costs for the fisheries management programs in the Ohio portion total $175,000. These program costs include all management activities and the operation of Ohio's largest fish hatchery. Increased annual fisheries management operational costs are expected to approach $325,000 by 1980. Capital expenditures are difficult to estimate because numerous public agencies will be involved, but it is estimated that costs associated with fisheries programs will involve $34,000,000 by 1980. Capital costs associated with only fisheries management projects are estimated at $2,500,000 by 1980.

Land acquisition to provide fisherman access to existing waters, develop trout fishing areas, and construct new water areas will be necessary to satisfy the angler demands of the area (Figure 8–73 and Table 8–51). Although new fishing waters will be developed, even more intensive management will be needed to satisfy these demands. Fishery management including the production and stocking of fish, fishing facility and device development, partial and total lake rehabilitation, and other warmwater and coldwater management programs will enhance the impounded and stream waters.

The combination of the ongoing programs and the capital projects, including the reservoir developments proposed in the Northwest Ohio Water Development Plan, is expected to supply approximately 65 percent of the demand projected for 1980. The Great Lakes fishery program will supply a significant portion of the need. In addition, comprehensive fisheries programs in adjacent north central Ohio will help satisfy angler demands. However, all of the fishing demand generated in Planning Subarea 4.2 cannot be satisfied on its inland waters. Total angler demands generated within the planning subarea will be considered in planning for angler demand in other planning subareas and on Lake Erie.

Nearly all new programs concerned with water and land-related resources can potentially damage the fishery habitat. Competition from other water-associated recreational demands is expected to affect fisherman utilization of these inland waters. Drainage and flood control programs are expected to create deteriorated fishery habitat in selected areas by warming the waters, accentuating siltation during high stream flows, and creating critical low flows. Costs, damages, and benefits to streams and rivers from such projects should be carefully evaluated.

Plans for fishery development beyond 1980 are somewhat speculative except for the upground reservoirs which have been programmed for development through the year 2006. However, they will probably involve the development of new water areas, angler access and facility developments, and intensified fisheries management (including stocking) programs. Current and future fisheries research programs will provide new manage-

TABLE 8–51 Land Acquisition and Capital Developments, Planning Subarea 4.2

County	Multi-Purpose Reservoir Planned	Est. Costs	Number Trout Fishing Develop.	Est. Costs	Angler Access Develop.	Est. Costs	Number Angler Facility Develop.	Est. Costs	Number Recreational Reservoir Develop.	Est. Costs.
Allen	2	$6,500,000	-	-------	-	-------	-	-------	-	---------
Auglaize	-	---------	-	-------	-	-------	1	$200,000	-	---------
Crawford	1	2,500,000	-	-------	-	-------	-	-------	-	---------
Defiance	-	---------	-	-------	-	-------	-	-------	1	$200,000
Erie	1	2,000,000	-	-------	-	-------	-	-------	-	---------
Fulton	3	6,300,000	-	-------	-	-------	-	-------	-	---------
Hancock	1	1,000,000	-	-------	-	-------	-	-------	-	---------
Huron	1	3,500,000	-	-------	-	-------	-	-------	-	---------
Lucas	-	---------	-	-------	1	$300,000	-	-------	-	---------
Ottawa	-	---------	-	-------	1	200,000	3	400,000	-	---------
Paulding	-	---------	-	-------	-	-------	-	-------	2	250,000
Putnam	1	1,500,000	-	-------	-	-------	-	-------	-	---------
Sandusky	-	---------	1	$150,000	-	-------	-	-------	-	---------
Seneca	2	5,000,000	1	100,000	2	150,000	-	-------	-	---------
Williams	-	---------	-	-------	-	-------	-	-------	2	1,700,000
Wood	2	2,000,000	-	-------	-	-------	-	-------	-	---------
Wyandot	-	---------	-	-------	-	-------	-	-------	1	100,000
Total	14	$30,300,000	2	$250,000	4	$650,000	4	$600,000	6	$2,250,000

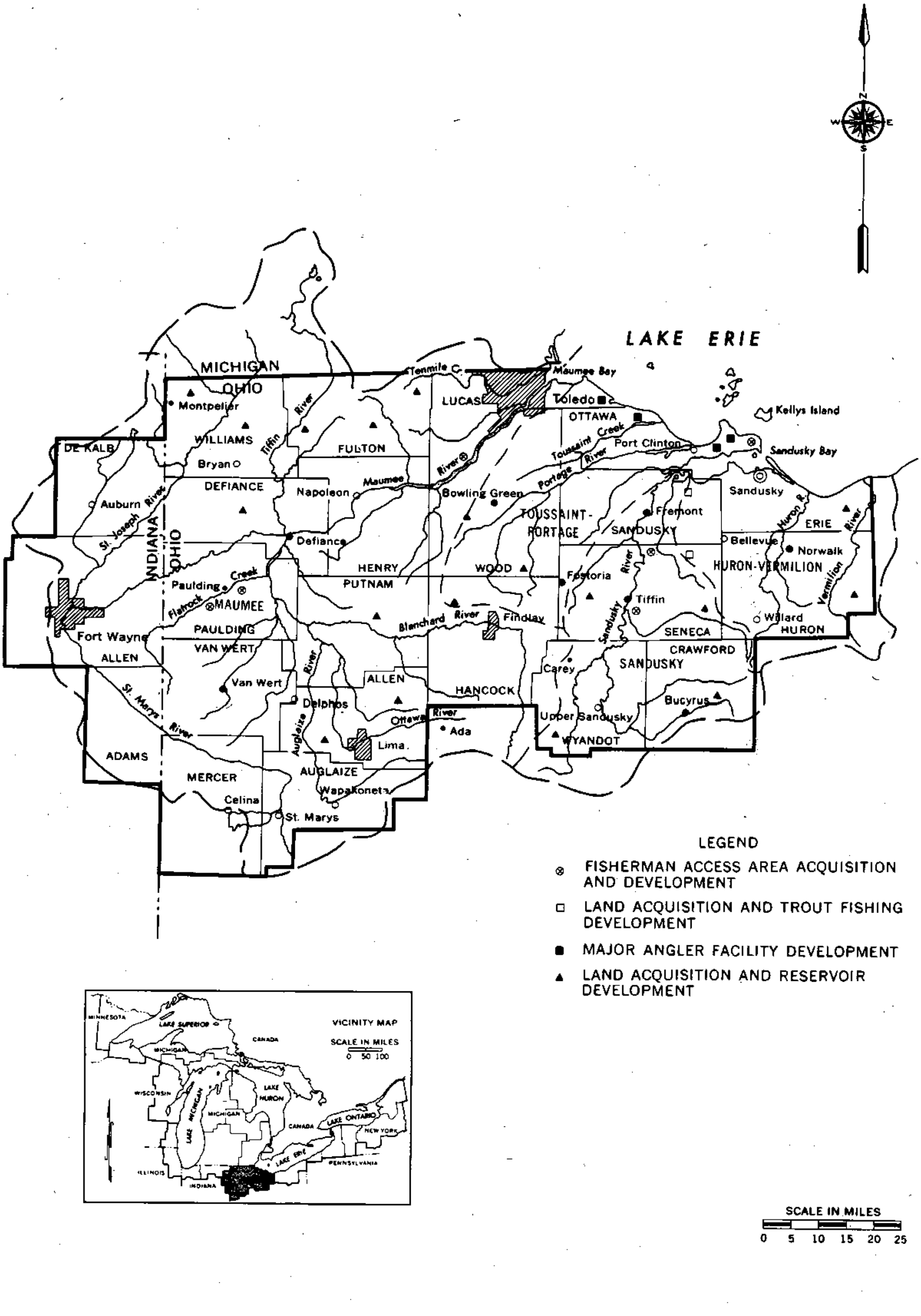


FIGURE 8–73 Land Acquisition and Capital Developments, Planning Subarea 4.2

ment techniques. Operational costs will also increase as a result of these intensified management efforts. Capital funding during the period from 1980 to 2000 is expected to increase to more than $5,000,000 for fishery management projects. Capital expenditures by other agencies, especially for upground reservoir development, are projected to be in excess of $65,000,000 for the same period.

6.4 Planning Subarea 4.3

This planning subarea encompasses eight counties in northeast Ohio (Figure 8–74).

6.4.1 Species Composition, Relative Importance, and Status

The water areas of northeastern Ohio are generally small (less than 450 surface acres), shallow, eutrophic impoundments of artificial origin. They support a complex of warmwater species with little variability in species distribution among the impoundments.

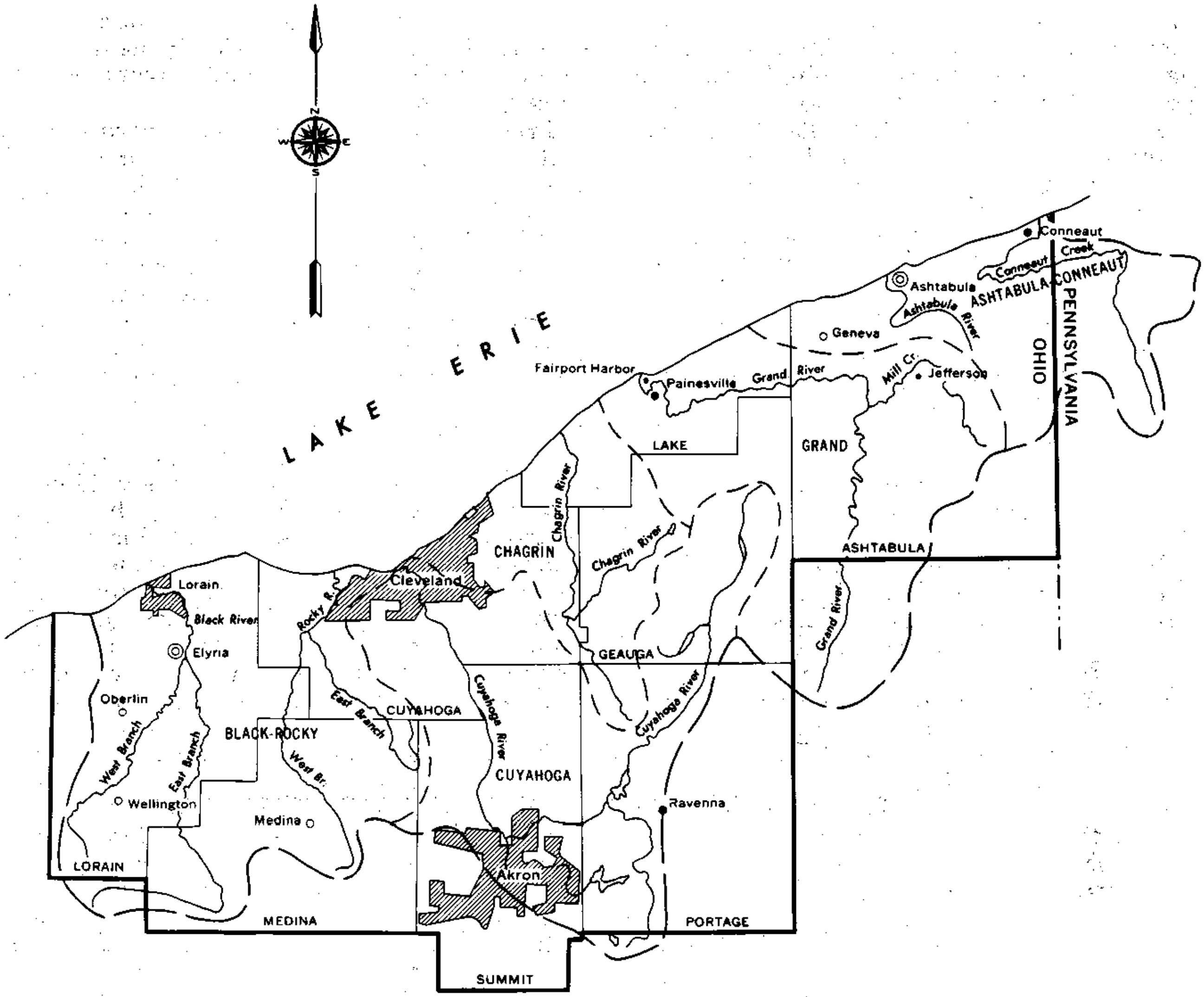
Climax predators are the species of major interest to the sport fishery in the inland impoundments. Included are largemouth bass, northern pike, chain pickerel, muskellunge and channel catfish. Walleye, one of the more successful and desirable of the game species in Ohio, has not readily adapted to the smaller ponded waters. Failure of natural spawning and recruitment of stocked fry are suggested reasons for this poor response to management. Management biologists prefer to work with largemouth bass and the esocid species because they offer an attractive sport fishery, readily adapt to the area's lakes and reservoirs, exhibit good growth, natural recruitment, and survival, and are compatible with the demands of artificial propagation.

Panfish populations in impoundments include white and black crappies, bluegill, common sunfish, yellow perch, brown and black bullhead, and other ictalurids and centrarchids. Although their numbers often fluctuate in cyclic fashion, white crappies frequently dominate the population of a given area. Bluegill does not successfully coexist with the white crappie, and bluegill and other sunfish dominate where crappie year classes are suppressed. Overpopulation of a certain species in a given area intensifies competition for what soon becomes an inadequate food supply. This causes the individuals of the species to be stunted. Severely stunted centrarchids may be observed in impoundments when many species of this family coexist in near-equal frequency of year class strength over a period of several years.

Present data indicate that centrarchids, either a single dominant species or several species, compose 70 percent of the overall adult fish population in most of the impoundments. Rough and forage species including several species of catostomids, carp and other cyprinids, and the eastern gizzard shad make up approximately 17 percent of the lakes' population. Predators and other species make up the remaining percentage. In a few areas, the gizzard shad may constitute as much as 15 to 20 percent of all fish sampled. It is suspected that strong year classes of shad, particularly as young-of-the-year, may severely deplete available planktonic food sought by the young of game species. Competition of this nature can reduce growth or survival of some desirable game species. However, recent investigations have revealed that adult and juvenile walleye are often strongly selective for young shad as food. Therefore, weak or slow-growth walleye populations may benefit from successive, strong year classes of the species.

Coldwater species, principally the rainbow trout, are limited to a few deepwater impoundments where exceptional water quality prevails throughout the hypolimnion during periods of thermal stratification. Seasonal releases of juvenile and small adult trout are made on a put-and-take basis in several other water areas. Natural reproduction of trout does not exist in these ponded waters.

River and stream fish populations are predominantly warmwater species. The larger rivers support minor populations of smallmouth and largemouth bass where suitable habitat has been stablized, but growth is generally retarded. The numbers of bass will often fluctuate from year to year, depending upon spawning success. For any given year, those streams with stable spring discharges and moderate-to-little siltation generally are most productive. The upper Cuyahoga River, Conneaut Creek, the Grand River, and the headwaters of the Black River often produce notable smallmouth bass year classes. Walleye and muskellunge prevail in the Grand River. The two species are thought to be remnants of historical spawning runs of the Lake Erie muskellunge and walleye before a dam was constructed near the mouth of the river. This unique sport fish population must be sustained by occasional releases of young muskellunge and walleye. With the exception



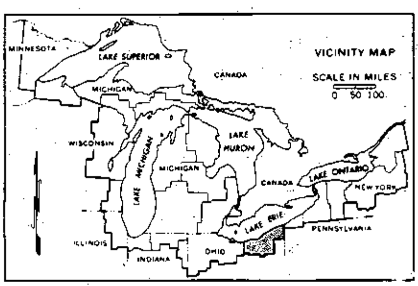


FIGURE 8–74 Planning Subarea 4.3

of the Cuyahoga River, all tributaries of Lake Erie support substantial spawning runs of several species of suckers, encouraging local sport fishing in the spring. Yellow perch, freshwater drum, carp, and members of the catfish family often migrate into streams and rivers from Lake Erie when increased stream discharge improves the water quality.

Anadromous salmonids (rainbow trout, chinook, and coho salmon) are maintained from annual plants of parr on the Chagrin River and Conneaut Creek. Notable fall spawning runs of coho salmon have been realized since 1968. Minor spawning runs of American smelt (*Osmerus mordax*) persist in three or four small tributaries of Lake Erie. However, the number of brood fish seems to have been reduced in recent years.

6.4.2 Limitations of Habitat Affecting Fish Production and Distribution

Acres of ponded waters in this planning subarea are shown in Figure 8–75. Eutrophication is an influential factor in fish production in northeastern Ohio impoundments. All ponded waters are considered eutrophic to some degree, even at their conception. Accelerating rates of eutrophication are generally the result of intensive agricultural development, because many reservoirs, being municipal watersheds with little or no residential development, are not exposed to domestically-oriented nutrients. In some of the older impoundments, sedimentation and siltation have been responsible for altering the habitat required for stable game fish production. In those impoundments the species composition of the fish has shifted towards dominance by rough species such as carp, suckers, gizzard shad, or stunted centrarchids. A few water areas exist as the result of elevating original water levels of bogs, marshes, or wetlands. These areas are considered the most productive waters for game and panfishes. A larger variety of centrarchids, including the redear sunfish (*Lepomis microlophus*) and esocids are found in these habitats. In such areas, game and panfish species achieve stable year classes with better than average growth rates. Such phenomena may be related to the established optimum biological productivity of eutrophic marshlands, accompanied by increased depth and water area after impoundment. Five areas have this type of habitat.

Other impoundments may lack habitat development. This originates partially from reservoir clearing plans which prescribe that stumps and trees be completely removed prior to pooling. The barren, shallow basins provide inadequate refuge for fish. The exceptions are those irregular basins where standing trees, stumps, bedrock ledges, and high ground and gravel deposits are eventually submerged.

Expansive growths of submerged aquatic vegetation may offer too much protection for the prolific centrarchids during their larval and juvenile stages, and the consequence is overpopulation and stunting. Approximately one-third of the impoundments have this problem.

Water level fluctuation in northeastern Ohio's ponded waters may be a factor in overall fish production, but the effect of this factor on reservoir fish populations has not been firmly established. Although prolonged stratification, which critically limits fish production, does not often occur, some thermal stratification of impoundments is always present. In some instances, ferrous iron, carbon dioxide, hydrogen sulfide, or other elements have been known to reach toxic concentrations in firmly established hypolimnions. Such elements generally exist under anaërobic conditions and dissolved oxygen depressions are also critical to fish.

Of the seven major rivers, only two flow to Lake Erie without any servere pollution along their courses. The remaining carry municipal and domestic wastes, storm sewer drainage, and industrial waste for one-third to one-half of their lengths. Only carp, goldfish, and some ictalurids frequent these segments. Other more desirable species such as yellow perch, white bass, freshwater drum, most ictalurids, and occasionally coho salmon and smallmouth bass will enter these areas of the river during heavy spring runoff when more suitable conditions exist. Fish kills are often observed during the summer. In the Cuyahoga River, bottom sediments of the lower reaches of the river cannot support even the most pollution-tolerant of benthic organisms, and fish life is almost nonexistent.

All the major rivers are dammed at one or several points either near the mouth or a short distance from it. The single high dam on the Grand River prevents migration of species into the river from Lake Erie beyond the City of Painesville. Other low-head dams along the Chagrin River, Conneaut Creek, Rocky River, and the Black River prevent or stall fish migrations except during periods of high stream discharge. Smaller tributaries do not attract game fish except for minimal numbers of bass, trout, catfish, and seasonally, smelt and salmon. During periods of low flow, barrier beaches effectively discourage migration.

Water pollution is generally not a limiting factor in headwater productivity. Cities of approximately 1,000 people release treated wastes into some of the headwaters, but reductions of fish production are caused by agricultural and flood control practices. These waters are considered nursery areas for smallmouth and largemouth bass, northern pike, and various forage species found in downstream habitats. The productivity of these areas has been unfavorably influenced by increased silt deposition in areas of intensively cultivated land. Some sections of the Rocky River, Black River, and upper Cuyahoga River are affected, and their fish populations have been reduced to production of cyprinids and catostomids. However, an overall reduction of cultivated farmland acreage has permitted some rejuvenation of streams where silt loads have been reduced.

Flood control projects promoting channelization and stream bed and bank alterations are beginning to find more support from agriculturalists in northeastern Ohio. Two of the

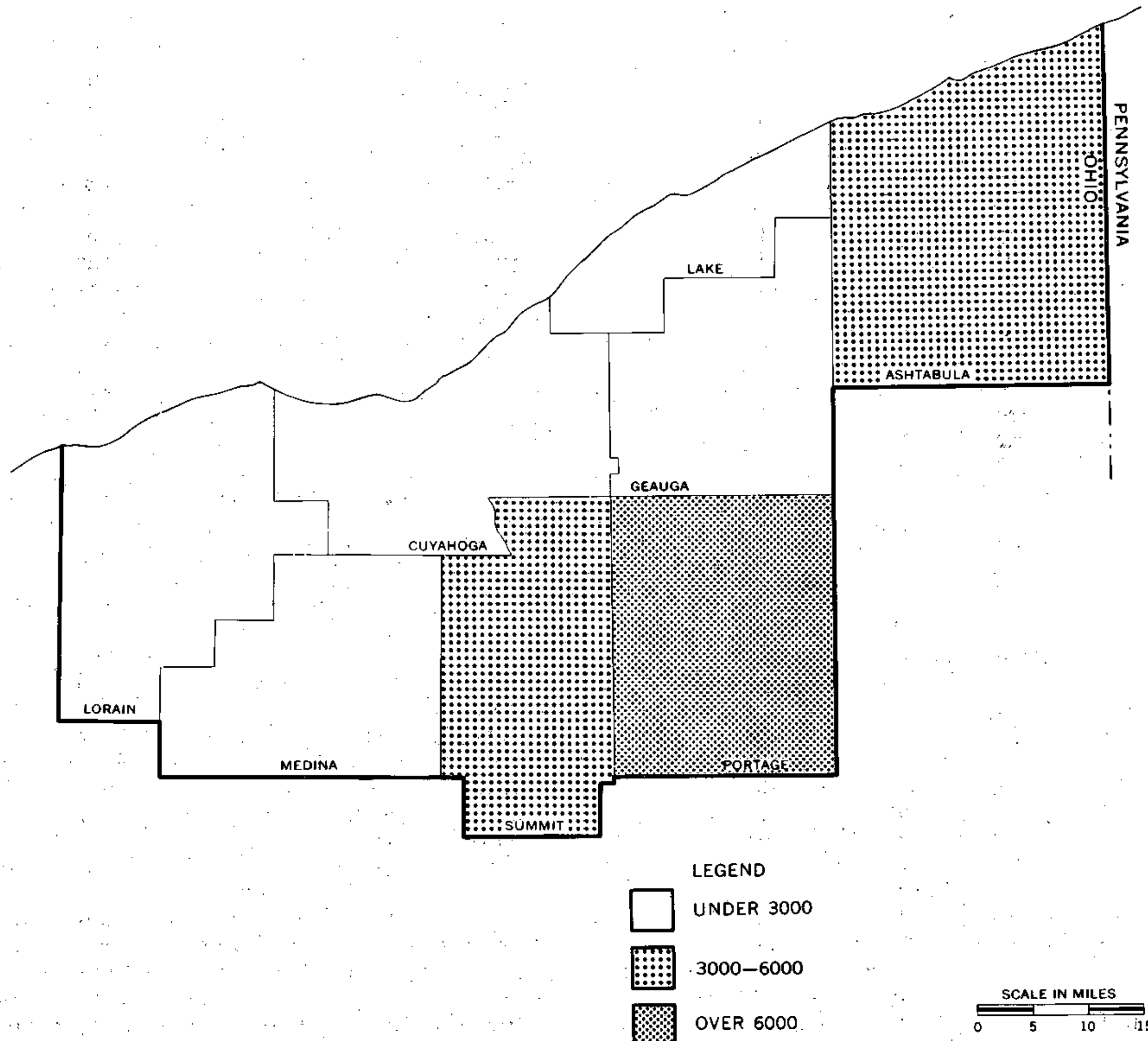


FIGURE 8–75 Acres of Ponded Water, Planning Subarea 4.3

planned projects are expected to have detrimental effects on the overall fish population. Impoundments built on the headwaters of the Cuyahoga River and some of its lateral tributaries serve newly developed housing tracts and recreational areas. Such developments are eliminating upstream and lateral nursery areas which supplied the sport fishery along the main stem of the river. Recent reductions in smallmouth bass populations along the upper Cuyahoga River are thought to be, in part, caused by these eliminations of nursery habitat.

The role of pesticides in limiting fish production in lotic and lentic environments is just being documented. Undoubtedly, their presence in the water is not beneficial. Trace amounts of methyl mercury have also been detected in tissue of a few game and forage fish species in some northeastern Ohio impoundments. Mercury was noted in one species tested in one major river.

6.4.3 History of Sport Fishery

The sport fishery historically has been located around Lake Erie. The Lake's immediate proximity to northeastern Ohio's urban areas and the scarcity of inland water were partially responsible for the concentrated sport fishing effort in the Lake. However, the abundance and availability of desirable game species were more important. The deterioration of water quality of the major rivers severely diminished the importance of river sport fishing before the turn of the century, making Lake Erie the focus of angler interest. Prior to their depletion, Lake Erie walleye stocks, sauger, and blue pike were of major interest to the sport fishery. However, by the middle 1950s the sport fishery was restricted to yellow perch, white bass, freshwater drum, channel catfish, and carp. Walleye made up less than one percent of the recorded angler catch. Northern pike were caught only on an incidental basis. Present harvest composition along the lakeshore of northeastern Ohio is similar to that of 1950 with the exception of walleye, which are now isolated or infrequent catches. In numbers creeled, the newly established coho salmon fishery is secondary to the warmwater fishery along the Lake.

The development of numerous small inland impoundments has encouraged the expansion of the inland warmwater fishery. Fisheries of this type, however, will not fully satisfy demand. The sport fishery harvest of these areas consists of largemouth bass, other centrarchids, carp, and members of the catfish family. Northern pike, chain pickerel, yellow perch, suckers, white bass, and rainbow trout may be caught in smaller numbers. Muskellunge and walleye, more abundant outside of the Lake Erie watershed, are caught in very limited numbers.

6.4.4 Existing Sport Fishing Demand and Current Needs

The population density of eight-county Planning Subarea 4.3, just less than 1,000 people per square mile, requires that considerable land and water area be available for recreational purposes. Because access to the lakeshore for angling is fixed (except for breakwall additions), increased fishing pressure must be directed inland or to more distant areas where there is less pressure. Larger, more productive impoundments must be constructed within the eight-county area. River sport fisheries will offer little for future angler demand in northeastern Ohio. Although a reduction in water pollution can be expected, access to the more productive river fisheries will remain relatively limited, and overall river sport fishing should not be expected to increase.

Approximately 21 percent of the total Ohio sales of resident fishing licenses are made in the eight-county area. Ignoring out- or in-migration of anglers, the ratio of resident licensed anglers to ponded water area is about nine per surface acre. This would suggest a rather high demand upon inland waters to produce suitable recreational fishing. In fact, area anglers want an appreciable increase in inland fishing areas.

6.4.5 Ongoing Programs

Fishery management efforts directed towards increasing ponded waters will help develop and expand the sport fishing potential of northeastern Ohio. Water quality improvement programs are generally ineffective at improving production of stream and river fish where pollution factors have become irreversible. Elsewhere, stream fisheries management consists of frequent maintenance plants of walleye, smallmouth bass, muskellunge, and salmonids in a few select stream and river systems. These populations must be monitored, and their effects on the ecosystem determined. A summary of base year fish habitat and management efforts is contained in Table 8–52.

Chemical eradication of rough species and establishment of primary and secondary predators have proven desirable in aiding sport fisheries. Development, preservation, and management of nursery habitats for game species is under way and expected to become an important facet of inland water management.

Current fish stocking program in Planning Subarea 4.3 is shown in Figure 8–76. Walleye

TABLE 8–52 Summary of Base Year Fish Habitat and Management Efforts, Planning Subarea 4.3

County	Total Area (sq.mi.)	Acres Ponded Waters[1]	Number Ponded Waters	Number Intensively Managed	Acres Intensive Warmwater	Acres Intensive Trout	Miles Total Streams	Miles Trout Streams	Miles Anadromous Streams
Ohio									
Ashtabula	699	3,946	38	2	22	0	371.3	19.5	14.5
Cuyahoga	456	137	35	3	79	47	200.1	0	4.0
Geauga	405	2,358	42	5	577	101	185.7	0	0
Lake	231	71	22	0	0	0	124.1	24.7	7.1
Lorain	493	708	53	5	210	65	225.2	0	0
Medina	423	527	43	3	301	0	120.7	0	0
Portage	493	6,661	111	2	1,000	8	89.1	0	0
Summit	408	4,892	57	1	600	0	120.3	0	0
Total	3,608	19,300	401	21	2,789	221	1,436.5	44.2	25.6

[1] Ponded water acreage in each county based upon acreage included within Lake Erie watershed only.

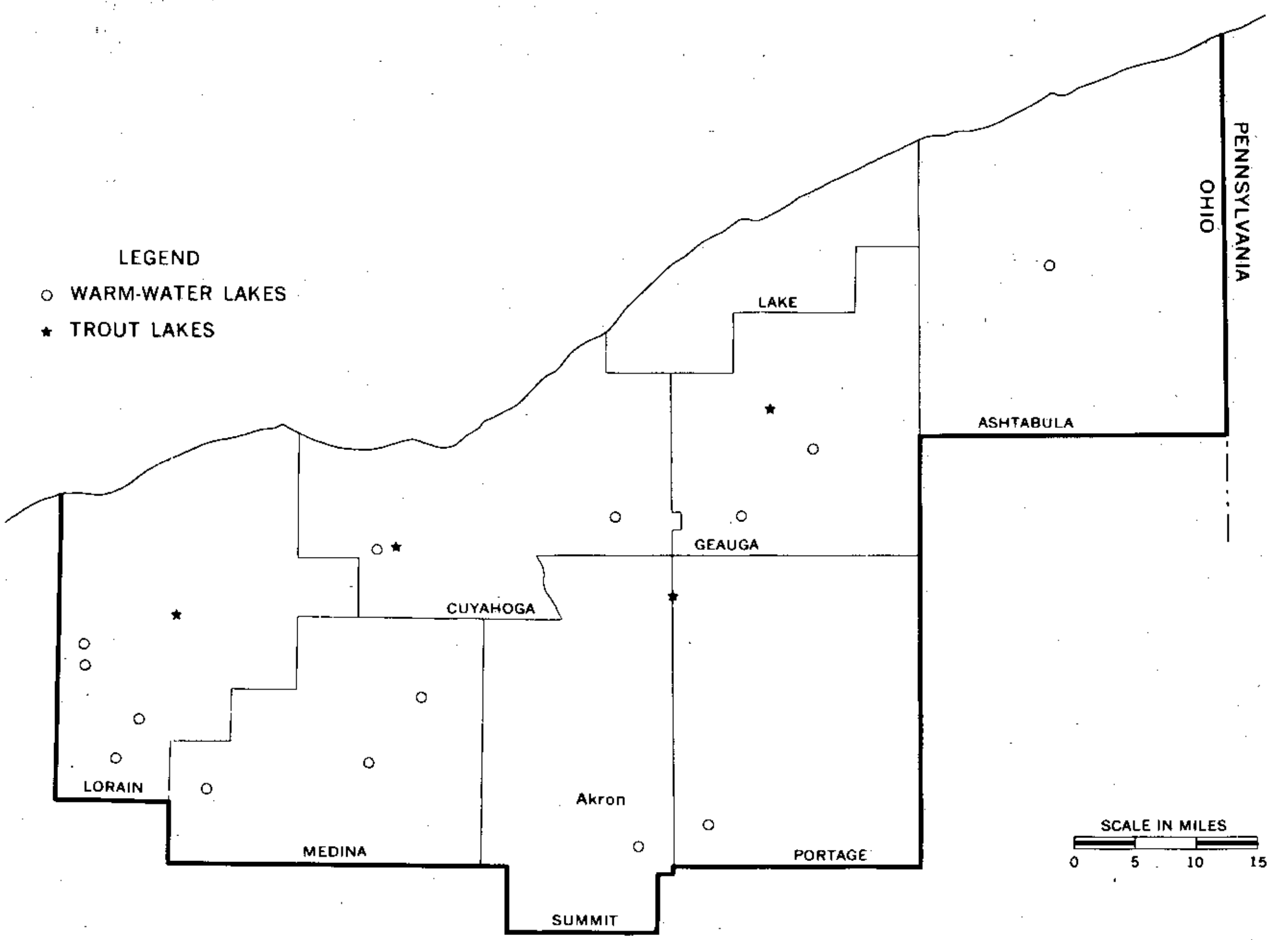


FIGURE 8–76 Current Fish Stocking Program, Planning Subarea 4.3

and the esocids, northern pike, muskellunge, and eastern chain pickerel are the main species propagated in the State hatchery system. Since 1965, ¾ million esocids and an annual average of 20 million walleye have been stocked to maintain fishery management programs. Other species stocked in inland water areas include largemouth and smallmouth bass, and salmonids.

The salmonids have been released in two rivers and several small impoundments. Based upon recent angler participation and harvest of the salmon population of Lake Erie, future expansion of the pacific salmon program will be limited. The coho salmon fishery has been limited to downstream segments of the home rivers. Adult trout stocking in ponded waters is done on a dump-harvest expectation. Two stream trout fisheries will be based upon anadromy and supported by young-of-the-year or yearling plants. Anadromous stream fishery in Planning Subarea 4.3 is shown in Figure 8–77.

Obtaining manageable waters for public use through easement or agreement and construction of impoundments has high priority in management programs. Additional access to Lake Erie shore, offshore, and breakwall fishing is required, and future acquisitions are being considered to serve this type of fishing.

6.4.6 Future Fishery Resources and Supply-Demand Relationships

Coho and chinook salmon and rainbow trout will be released as yearling or young as stream habitats become available. The 1970 plants of 120,000 coho salmon in two watersheds and 65,000 chinook salmon in one river could be increased, but a proportional increase in returns of adult salmon should not be expected.

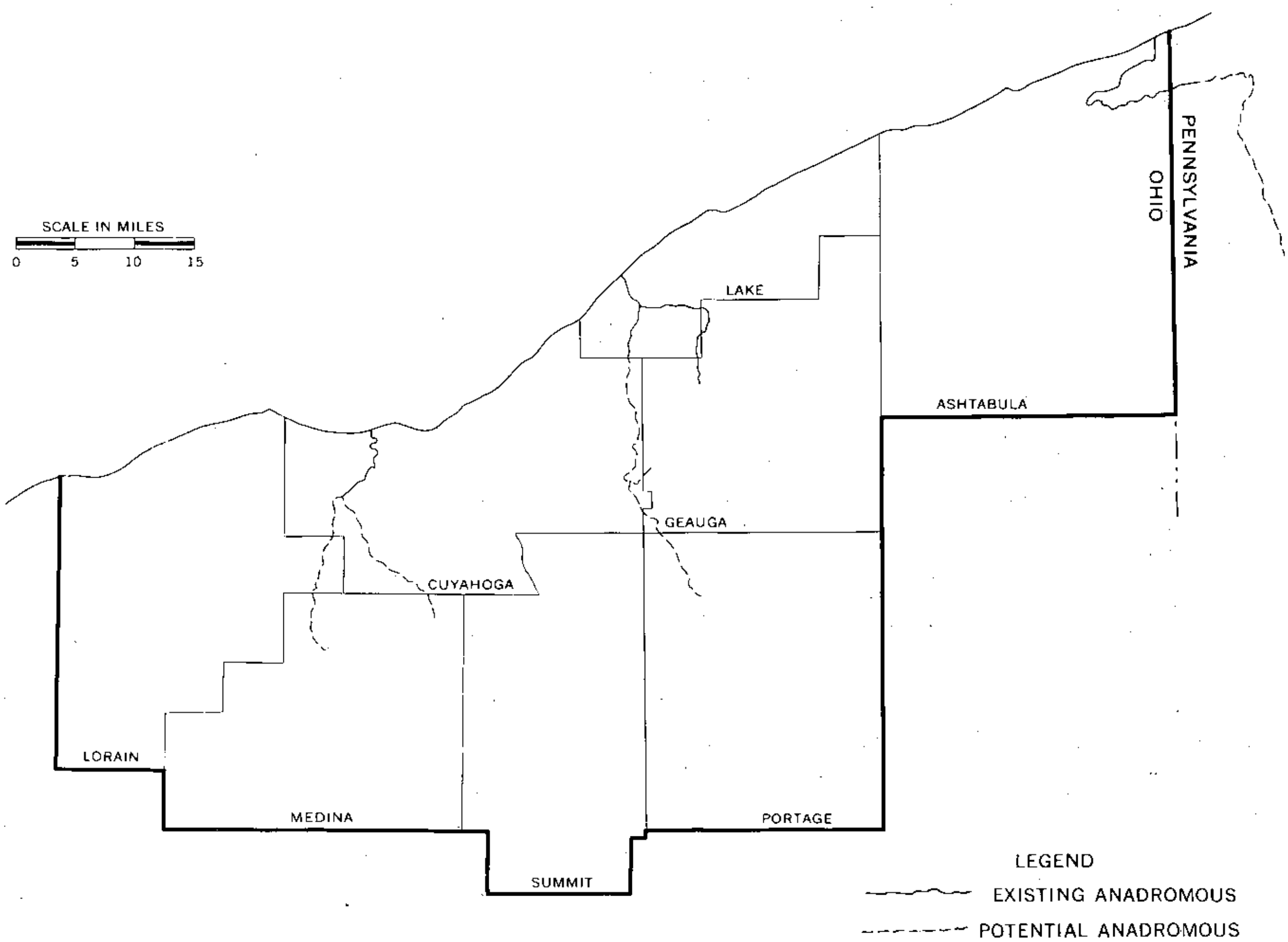


FIGURE 8–77 Anadromous Stream Fishery, Planning Subarea 4.3

Future prospects for river and stream warmwater fisheries are not optimistic. Stream channelization, failing water quality, dam construction, and lack of access will limit game fish production and the sport fisheries. Intensive monitoring of all projects that will affect the ecosystems of watersheds will continue and the specific status of aquatic wildlife resources will be seriously studied. In the Cuyahoga, Grand, Conneaut, and Black River watersheds prospects exist for improving the populations of smallmouth bass, muskellunge, and walleye. Northern pike plants will be increased along the Cuyahoga watershed, and enhancement of their spawning habitat should be considered. Future programs should investigate the possibility of obtaining additional angler access to the more productive segments of river courses.

Future warmwater fish populations will be managed to provide high yields to an intensive fishery. Primary, secondary, and tertiary predators will be firmly established in all impoundments. Undesirable rough and forage species (carp, gizzard shad, black bullhead) will be controlled or suppressed. Spawning habitat development, particularly for the esocids and walleye pike, will be developed in several existing impoundments and newly constructed reservoirs.

Based upon current prospects, in the next decade at least 2500 acres of newly impounded water will be made available to the general fishing public. This probably will be insufficient to serve the increasing numbers of anglers. For a summary of base year and projected land, water, and angler days, see Table 8–53. Increased warmwater hatchery propagation may increse angler harvest potential in northeastern Ohio, at least to the limits of reservoir biological productivity, but more anglers will travel to parts of Ohio where large areas of impounded water prevail.

6.4.7 Fishery Development Plans

Ongoing programs will probably extend to the 1980s (Figure 8–78). It is difficult to speculate much farther. Many new concepts in resource development will depend on additional tools made available to biologists through applied research. Without a new ecological awareness, however, all the advanced concepts in fishery resource development and management will be to no avail.

TABLE 8–53 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 4.3

State and Counties	Land Area (sq.mi.)	Population (1000s)	Population per sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
Ohio								
Astabula	699	94.7	135.5	3,946	.0417	722	11,530	.1218
Cuyahoga	456	1,732.0	3,798.2	137	.0001	389	84,574	.0488
Geauga	405	58.1	143.5	933	.0161	78	4,548	.0783
Lake	231	179.0	774.9	71	.0004	158	10,790	.0603
Lorain	493	242.2	491.3	708	.0029	205	18,439	.0761
Medina	423	72.9	172.3	527	.0072	33	4,574	.0627
Portage	493	110.6	224.3	6,661	.0602	188	10,532	.0952
Summit	408	540.0	1,323.5	4,892	.0091	232	35,855	.0664
Total	3,608	3,029.5	839.7	17,875	.0059	2,005	180,842	.0597

State and Years	Land Area (sq.mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand: Resident[1]	Projected Angler Day Demand: Total[2]
Ohio					
1980	3,608	3,476.4	963.5	6,198,121	5,805,000
2000	3,608	4,389.2	1,216.5	7,787,687	6,492,000
2020	3,608	5,526.5	1,531.7	9,805,581	8,191,000

[1]Demand generated within planning subarea.

[2]Total demand including in- and out-migration.

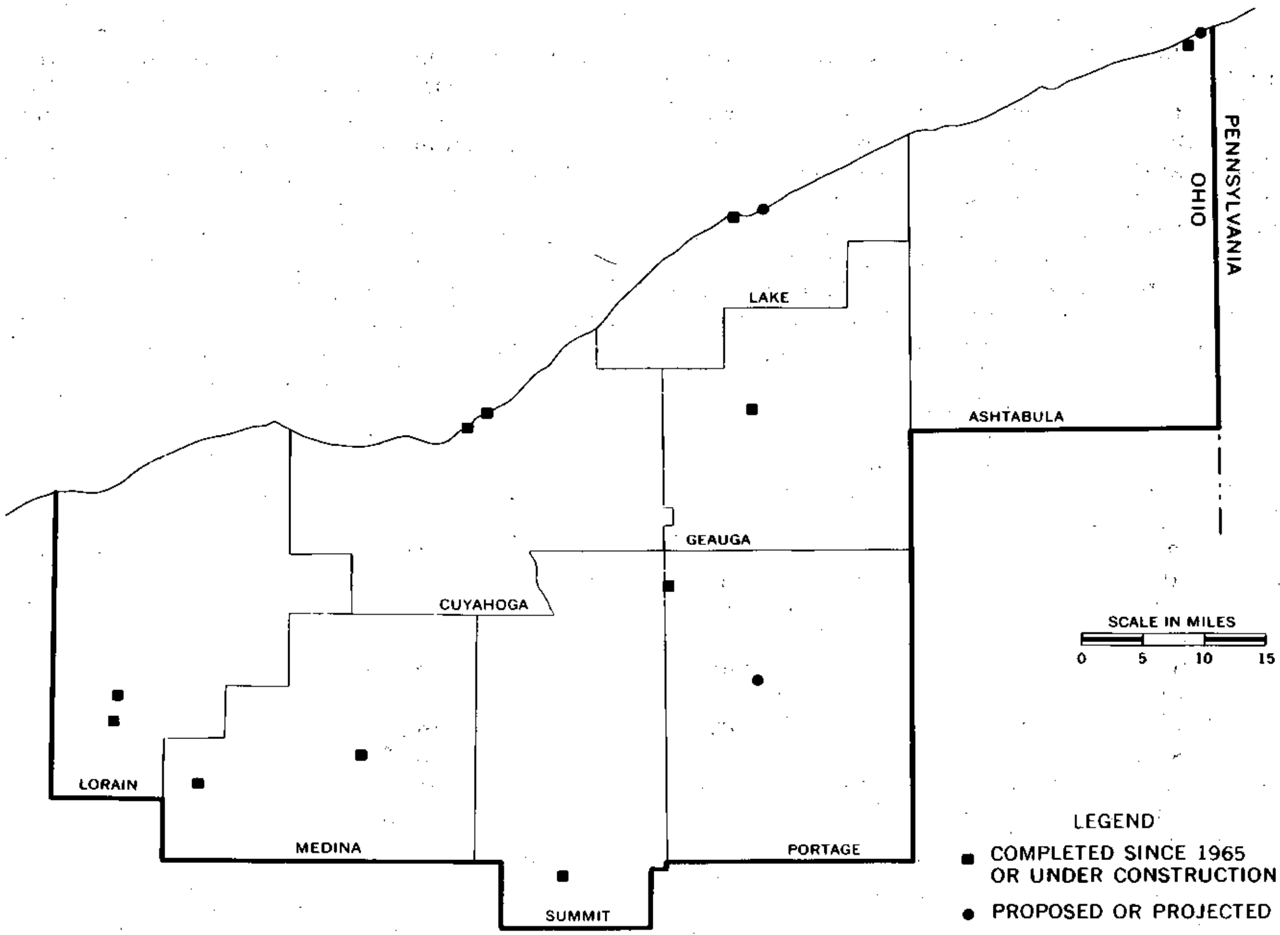


FIGURE 8-78 Capital Improvement Projects, Planning Subarea 4.3

Present fisheries programs in the eight-county area are mainly directed at the impounded water areas (Table 8-54). These provide the greatest opportunity to the angler. Streams and rivers provide only a limited fishery because of their water quality. Annual or biennial maintenance stocking of walleye, smallmouth bass, muskellunge, and salmonids has taken place in a few select streams. Ponds are being developed as nursery habitat for game species and are expected to become an important facet of the inland management program.

Rejuvenation of impoundments and the subsequent establishment of primary and secondary predators have proven desirable. The rejuvenation is completed by either chemical eradication of undesirable species (total or selective) or draining, and restocking. A large, modern warmwater hatchery, which could

TABLE 8-54 Capital Funds Allocated for Sport Fishery, 1965 to Base Year, PSA 4.3

Area	Program	Approximate funding
Spencer	Angler access and area development	$ 45,000
Akron Fish Hatchery	Installation development	7,000
Tinker's Creek	Land acquisition and facility development	370,000
Medina Reservoir	Facility development	8,000
Cleveland Marina	Facility development	700,000
Conneaut Salmon rearing pond	Construction	1,500
Wellington Reservoir	Facility development and construction	1,400,000
Headland Beach State Park	Angler access	1,000
Total		$2,532,500

serve, in part, the needs of Planning Subarea 4.3, is planned. This could be in production by 1980.

Future programs will be directed toward developing new inland water areas strictly for sport fishery and allied interests. The new inland water areas must be constructed strictly for fishing and other allied recreational uses. Flood control, low-flow augmentation, and water supply uses will adversely affect any intensive management effort. However, this will not satisfy the growing demand of this metropolitan area. Fishermen will still be forced to travel to water areas outside Planning Subarea 4.3. The Ohio Interstate Highway System has made several reservoirs in southeast Ohio accessible to anglers from Planning Subarea 4.3. Lake Erie will also absorb some of the demand. Therefore, additional access to Lake Erie for waterfront angling must be secured, particularly between Lorain and Painesville, Ohio.

Fiscal outlays directly oriented to fishery management programs are approximately $60,000. By the advent of the 1980s this annual figure is expected to approach $85,000. Costs of fishery management programs cannot be estimated beyond this period. Capital expenditures are variable. Figures range from $40,000 to $900,000 per annum for the development of new lakes and reservoirs, real estate acquisition, fisherman access facilities, and hatchery improvements.

Federal and locally funded regional watershed studies concerned with flood control, pollution control, urban and industrial water consumption, and supplies have provided feasibility designs for northeastern Ohio. Local, governmental, and private agencies have little contact with the contracted interests conducting such studies. Since obvious effects upon fish habitat will occur if any proposed physical changes in watersheds are implemented (channelization and flow augmentation reservoirs), careful review and serious consideration and consultation by fishery interests and ecologists must occur so that all options and alternatives are accessible to watershed studies.

6.4.8 Endangered, Rare, and Non-Game Species

The Grand River muskellunge (*Esox masquinongy masquinongy*) is apparently the last extant population of this subspecies. Since the subspecies *E.m. ohioensis* has been sustained in the Grand River watershed by stocking fingerlings, there is some concern the *masquinongy* form may be adversely affected by the increased presence of the *ohioensis* form.

The anadromous smelt of Lake Erie are limited to a few small streams for spawning. Stocks of Lake Erie smelt are sustained by recruitment from offshore spawning areas because larvae originating from eggs deposited in streams are insignificant in number. Although the species is abundant throughout the Lake, smelt dipping is diminishing as brood smelt returning to the streams are reduced.

Blue pike (*Stizostedion vitreum glaucum*) has been virtually lost to the sport fishery of the lakefront area. Although the species is not a rarity in Lake Erie, walleye (*S. vitreum*) only contributes to the lakefront fishery on an incidental basis.

6.5 Planning Subarea 4.4

This planning subarea, located along the eastern portion of Lake Erie, encompasses one county in Pennsylvania and four counties in New York (Figure 8–79).

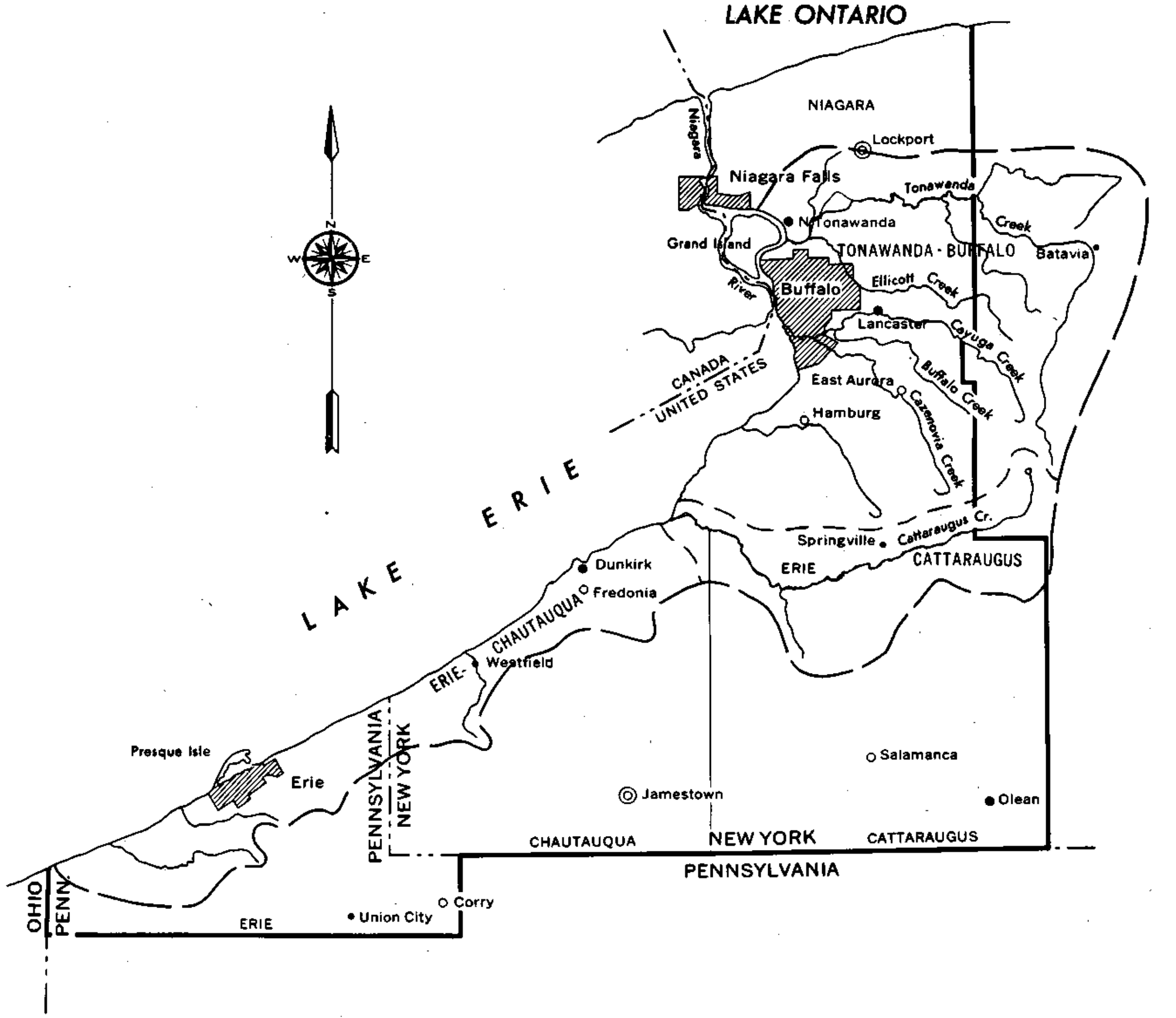
6.5.1 Species Composition, Relative Importance, and Status

New York State is currently engaged in a Statewide water resource planning program. Detailed fishery plans and needs are covered in detail as part of the Erie-Niagara Basin Plan. Much of the data in this report was obtained from the State plan.

Waters in Planning Subarea 4.4 provide a limited sport fishery primarily for warmwater species. Smallmouth bass and northern pike are the most important species. Walleye and largemouth bass fishing are available in some waters. A limited muskellunge fishery is present in upper Niagara River, covered in Plan Area 4.0.

Brown trout is the major salmonid species with incidental rainbow and brook trout in some inland waters. Recently introduced coho salmon (1968–70) and Lake Erie run rainbow provide fair angling in lower Cattaraugus Creek, Eighteenmile Creek, and a few smaller tributaries.

Panfish such as yellow perch, rock bass, black crappie, sunfish, and bullhead complete the existing sport fishery. There is no commercial fishery in the area.



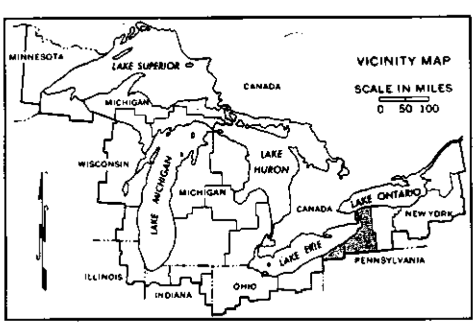


FIGURE 8–79 Planning Subarea 4.4

6.5.2 Habitat Distribution and Quantity

New York State's portion of the area contains only 1,033 ponded acres, 150 miles of warmwater and 127 miles of coldwater streams. Pennsylvania contributes 722 ponded acres and a limited mileage of small streams.

There is a need for additional fishing waters (Figures 8–80 and 8–81). The solution of this problem is a challenge to water resource planners and managers, but solution may provide great potential rewards. Bold planning and adequate funding will be needed to provide additional fishing waters through construction of ponded waters, controlled outlet structures, acquisition of fishing rights, pollution abatement, and habitat improvement programs (Figure 8–81). Such programs will result in additional license sales and greatly improve local economy. Figure 8–82 shows the current acres of ponded water.

6.5.3 Habitat Problems Affecting Production and Distribution of Important Fish Species

In addition to the lack of natural ponded waters and stream habitat, factors common to other waters as well as a nuclear waste problem exist in the area.

Pollution is a major factor limiting the quality and quantity of fishing waters. In fact, the original 1928 Biological Survey of the area by New York State Conservation Department personnel stressed the need for pollution abatement. Industries at Gowanda pollute all of Cattaraugus Creek, a potentially high-value anadromous salmonid stream. An atomic fuel service complex on an upper tributary to the same stream creates a potential threat of atomic waste pollution. Some fish, invertebrates, and terrestrial life have accumulated concentrations of atomic pollutants resulting from processing and salvaging of used atomic fuels. Other industrial, domestic, and, to some degree, agricultural pollutants contribute to the poor condition of many waters in the area.

Stream degradation through man's poor construction, agricultural, and forestry practices has long been a problem. Many intermittent streams would support fish and provide spawning areas if habitat destruction ceased and improvements were completed. High water temperatures and extreme fluctuations of stream flows are a direct result of habitat destruction and severely limit sport fishing.

Natural and man-made barriers to migrating fish are a deterrent to an expanded anadromous stream fishery particularly in the Cattaraugus Creek drainage. If fishways were constructed they could open up many miles of fishing and natural salmonid spawning sites. At the present time, the lack of adequate spawning sites makes salmonid fishing almost entirely dependent upon hatchery-reared fish. If the lower reaches of streams were cleaned up and improved, they would provide considerable spawning sites for smallmouth bass, walleye, and other species.

Public fishing access to existing waters and proposed impoundments is a high priority. A vital portion of lower Cattaraugus Creek is located on an Indian reservation. If anadromous fishing throughout the stream is to become a reality, a plan acceptable to all concerned will be required.

Unless equitable use plans can be administered, competition for water use by non-angling recreational groups will become more of a problem when new impoundments are completed.

6.5.4 History of Sport Fishery

Except for Cattaraugus Creek and a few other waters, lack of available inland fishing waters has curtailed sport fishing over a long period of time. Warmwater species provide the bulk of angling opportunities at present. If experimental anadromous fish programs are successful, the coldwater fishery will supersede the present warmwater fishery. Such an occurrence would dramatically increase license sales and aid local economy.

6.5.5 Existing Sport Fishing Demand and Current Needs

A combination of car and fishermen counts and estimates by conservation personnel in 1965 indicated the following angler use: 24,000 fishermen days per year on 127 miles of trout streams, primarily Lime Lake Outlet, Clear Creek, Mansfield Creek, Cattaraugus Creek; 16,000 angler days of warmwater fishing on 150 miles of stream; 15,000 angler days of warmwater fishing on 416 acres of lakes and ponds (Tables 8–55 and 8–56).

Most of the coldwater fishery is restricted to April, May, and June. If experimental coho and other anadromous fish programs are suc-

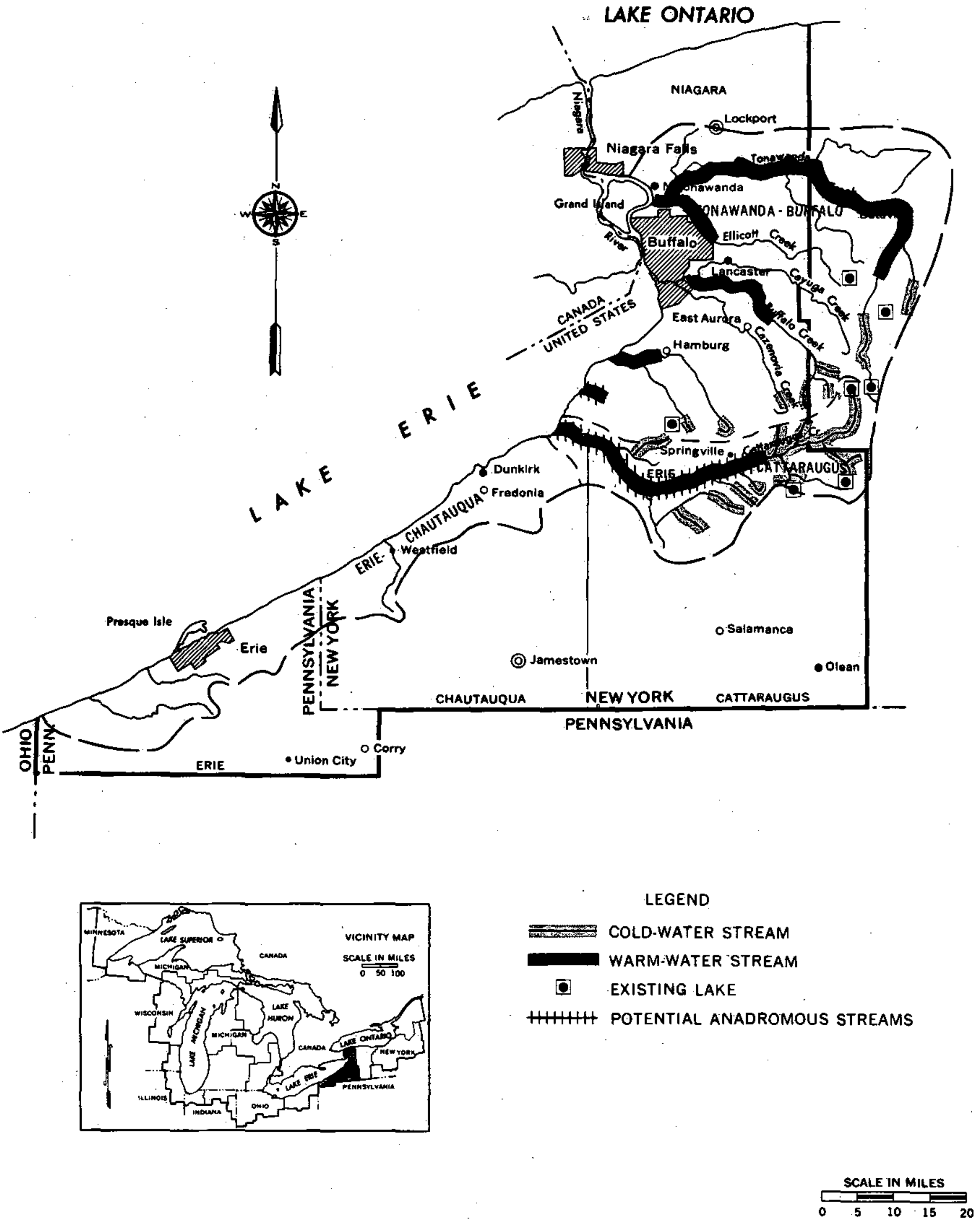


FIGURE 8-80 Fish Habitat Base, Planning Subarea 4.4

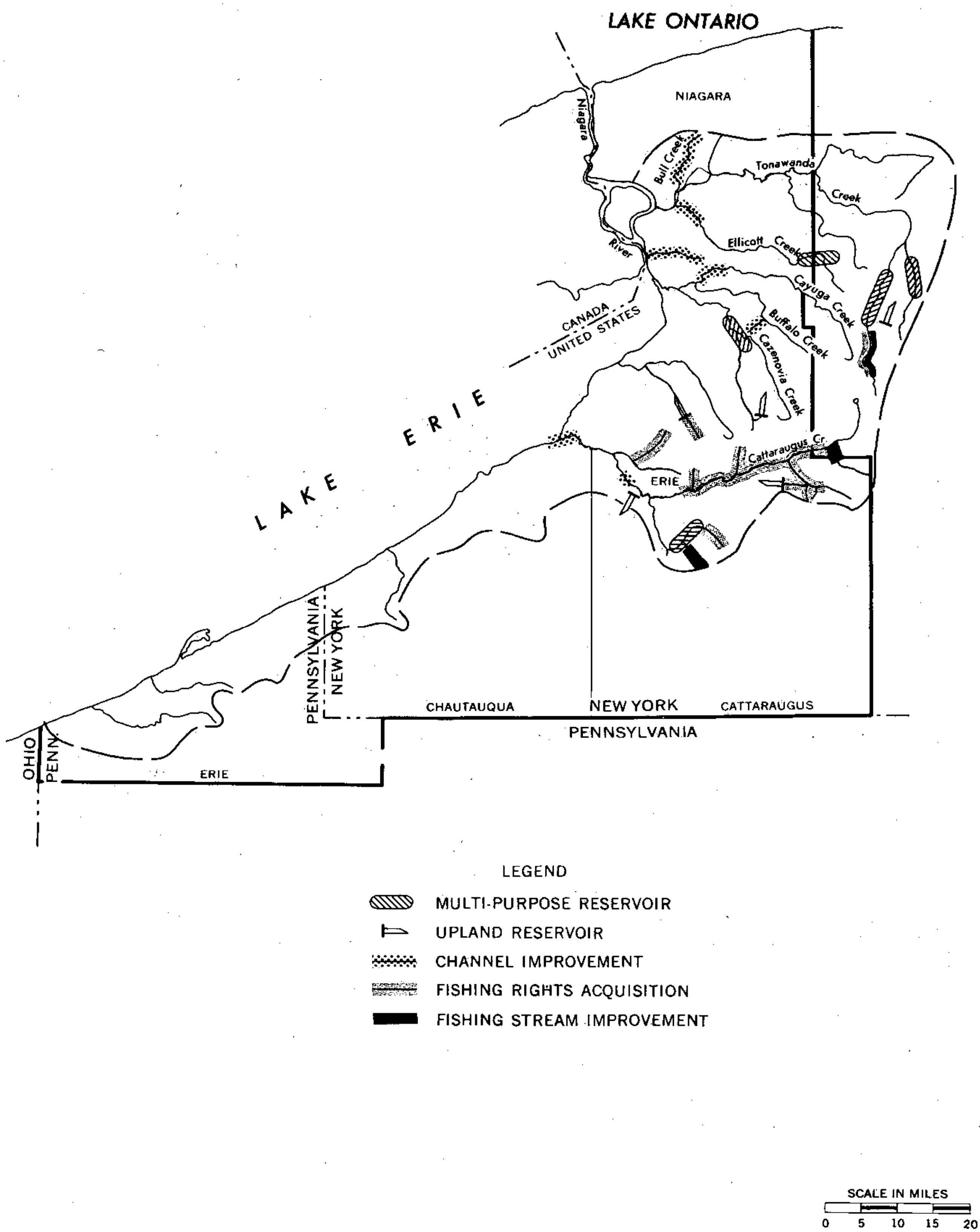


FIGURE 8–81 Fish Planning Projects, Planning Subarea 4.4

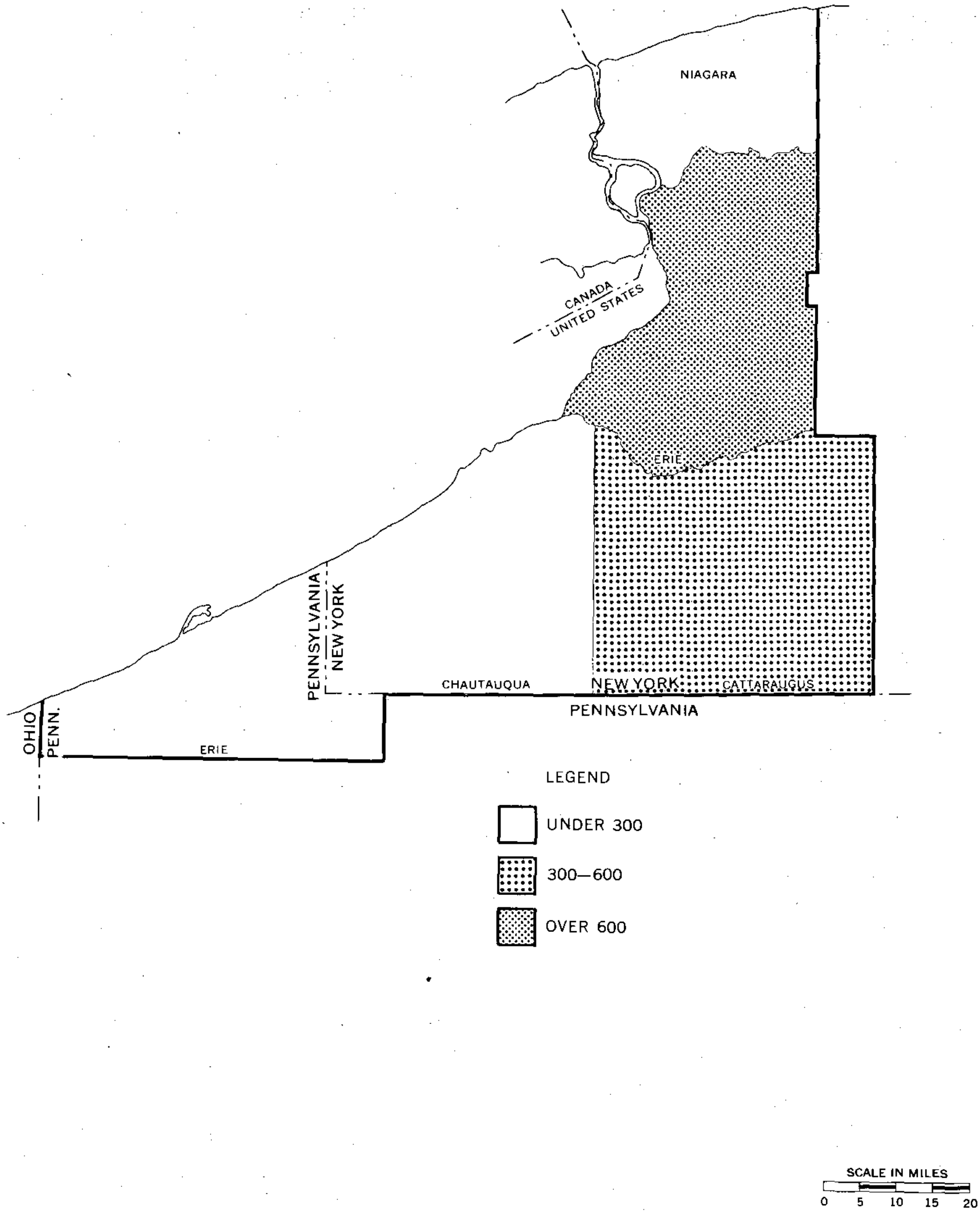


FIGURE 8–82 Acres of Ponded Water, Planning Subarea 4.4

TABLE 8–55 Present Angler Use of All Resources, Erie-Niagara Basin

Resource	Total Area (Acres)	Annual Use in Angler-Days
Trout Streams	240	24,000
Warmwater Streams	860	16,000
Niagara River	12,500	35,000
Inland Lakes & Ponds	416	15,000
Lake Erie	108,160	150,000
Total	122,176	240,000

TABLE 8–56 Present Angler Use of Principal Warmwater Streams, Erie-Niagara Basin

Stream System	Fishing Water		Annual Use in Angler Days[1]	
	Miles	Acres	Per Acre	Total
Cattaraugus Creek	35	425	10	4,250
Tonawanda Creek	87	300	30	9,000
Buffalo River	22	100	20	2,000
Eighteenmile Creek	5	30	20	600
Big Sister Creek	1	5	30	150
Total	150	860	--	16,000

[1]Estimated for all waters

cessful, the entire fishing trend will change, and sizeable fall salmonid fishery can be expected.

The need for such an inland fishery is great. Inclement weather often makes Lake Erie unsuitable for safe sport fishing. If new inland fishing waters and fisheries could be provided, license sales and local sport-fish-oriented business would flourish. It is estimated that 2,380,000 angler days will be required by 1980 for the Erie-Niagara basin, an increase of 500,000 from 1960. If waters and a fishery were made available, anglers would utilize the inland area to a greater extent.

Farm ponds are numerous in the planning subarea. Largemouth bass and panfish make up the bulk of the species caught. Some sport fishing is provided to children of pond owners. Because of the small size of the ponds and private ownership problems, farm ponds are best covered in an agriculturally-oriented plan and are not included in this report.

6.5.6 Ongoing Programs

Environmental protection and improvement is an important segment of existing programs. As of July 1, 1970, the New York State Conservation Department became the New York State Department of Environmental Conservation. Broad powers once delegated to other State agencies were placed in the Commissioner's office to allow direct responsibility for pollution abatement and other environmental problems.

Pollution abatement through New York State's Pure Waters Program is a vital part of present rehabilitation of all waterways in the State. Protection of stream and lake habitat is afforded through implementation of Section 429 of the Conservation Law, commonly refered to as the Stream Protection Law. Under this legislation, permits are required for any work by agencies or individuals in certain classified waters including all navigable waters to the high water mark.

Stream improvement has been carried on in trout streams when funds were available. Bank stabilization, plantings, and instream structures are designed to provide stable cover and pools.

A coordinated anadromous program was inaugurated in 1968 through the Lake Erie Committee of the Great Lakes Fishery Commission. Coho salmon have been planted, primarily in Cattaraugus Creek drainage, but also in Eighteenmile Creek and Dunkirk Harbor, in conjunction with stockings by Ohio and Pennsylvania. A small spawning run of rainbow trout from Lake Erie is also present in this system and a few other smaller tributaries. Proposed Federal aid projects for New York State's Great Lakes waters are expected to augment and expand the anadromous fish program.

The State Fish and Wildlife Management Act (FWMA) enables individual or multiple owners and municipalities to enter into suitable agreements for public use of lands and waters. Attica Reservoir has provided an additional 7,700 angler days through such an agreement. Additional closed waters may be opened in the future through FWMA agreement.

In addition to environmental control, habitat improvement, and the anadromous fish project, current fish management includes fisheries survey and stocking programs. The principal species stocked are brown, brook, and rainbow trout.

6.5.7 Future Trends in Habitat and Participation

Demand by 1980 will require an additional

TABLE 8–57 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 4.4

States and Counties	Land Area (sq.mi.)	Population (1000s)	Population per sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
Pennsylvania								
Erie	811	254.8	314.2	722	.0028	1,050	17,360	.0681
Total	811	254.8	314.2	722	.0028	1,050	17,360	.0681
New York								
Cattaraugus	1,333	83.2	62.4	360	.0043	1,409	8,176	.0983
Chautauqua	1,078	149.5	138.7	115	.0008	5,034	16,607	.1111
Erie	1,051	1,088.2	1,035.4	192	.0002	304	57,837	.0531
Niagara	523	235.3	450.0	55	.0002	74	12,629	.0537
Total	3,985	1,556.2	390.5	722	.0005	6,821	95,249	.0612

States and Years	Land Area (sq.mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand Resident[1]	Total[2]
Pennsylvania					
1980	811	293.0	361.3	612,726	585,000
2000	811	362.0	446.4	757,020	685,000
2020	811	452.9	558.4	947,111	852,000
New York					
1980	3,985	1,765.0	442.9	3,341,213	3,193,000
2000	3,985	2,144.0	538.0	4,058,674	3,700,000
2020	3,985	2,617.3	657.3	4,954,649	4,507,000
Total PSA 4.4	4,796	1,811.0	377.6		
1980	4,796	2,058.0	429.1	3,953,939	3,778,000
2000	4,796	2,506.0	522.5	4,815,694	4,385,000
2020	4,796	3,070.2	640.2	5,901,760	5,359,000

[1]Demand generated within planning subarea.

[2]Total demand including in- and out-migration.

TABLE 8–58 Proposed Impoundments, PSA 4.4

Reservoir	Species Management	Water Surface Acres	Angler Days
Otto	Rainbow Trout-Bass	4,450	95,100
Sandridge	Muskellunge-Bass	1,400	70,400
Sierks	Rainbow Trout-Bass	810	93,800
Linden	Rainbow Trout-Bass	920	-------[1]
Springbrook	Rainbow Trout-Bass	1,509	102,900
New Oregon	Brook-Rainbow Trout	101	26,600
Spencer	Brook Trout	49	16,400
Eastland	Brook Trout	49	11,200
Thatcher	Brook Trout	30	10,600
Total		7,318	427,000

[1]Included in angler day total for Sierks Reservoir.

minimum of 500,000 angler days for the Erie-Niagara River basin, including latent demand (Table 8–57). Present available habitat cannot meet this demand with ongoing projects.

If resources are not available to support future demand, existing and potential anglers will either fish elsewhere or direct their efforts to other forms of recreation. Such a situation will create loss of potential license sales, reduction in potential local fisherman-oriented expenditures, and an overall loss to the Great Lakes community.

With adequate public support, proposed development of five reservoirs ranging from 800 to 4,500 surface acres and four reservoirs from 30 to 100 acres will provide 427,000 additional angling days (Figure 8–83 and Table 8–58). A suitable fishway for Springville Dam on Cattaraugus Creek would provide a minimum of 11,200 angler days in conjunction with the anadromous fish program. Proposed acqusition of 68 miles of public fishing rights should provide the remaining projected need of 11,800 angler days by 1980 (Figure 8-83).

A successful anadromous fish program could increase the projected angler day need. Public access would then become more critical and purchase of public fishing rights on anadromous streams would be of highest priority.

6.5.8 Fishery Development Plans

Future programming of fishery needs must be carried out on a basinwide basis. Ongoing and proposed projects have been included in previous sections of the study. Major needs cannot be strictly listed by a numbered priority. Several important segments of an overall plan may require simultaneous action. Therefore, the following plans are submitted on a priority basis:

(1) integration of needs and programs into the overall Great Lakes Basin Plan and New York State Program. This is being accomplished through the Great Lakes Basin Commission program on a Basin scale. The State's Erie-Niagara Basin Comprehensive Water Resources Plan relates the area need to a Statewide plan.

(2) specific fishery needs for Planning Subarea 4.4:

(a) pollution abatement on all waters
(b) rehabilitation of existing waters
(c) development of additional waters
(d) insured public access to important fishing waters

6.5.9 Species Composition and Status—Pennsylvania

Pennsylvania's Erie County provides a small acreage to the Lake Erie watershed of Planning Subarea 4.4. Ponded waters are limited to farm pond structures. The major streams are of limited length and watershed.

Population of the ponded waters consists of warmwater species such as largemouth bass, bluegill, crappie, and sunfishes.

The tributaries of Lake Erie support coldwater salmonids such as rainbow trout, and coho and chinook salmon during the fall, winter, and early spring. Brown trout appear in very limited numbers. Smallmouth bass, rock bass, catostomids, and ictalurids also inhabit the pools and deepwater areas of the larger streams, Elk Creek, Walnut Creek, and Twentymile Creek. Smaller streams have terminal waterfalls at their mouths whose discharge is too limited to encourage the development of large numbers of the aforementioned species.

Seasonally, large numbers of emerald shiners and other cyprinids and several species of suckers enter the mouths of the larger streams, attracting numbers of yellow perch and smallmouth bass. Smelt also ascend several tributaries to spawn and attract a limited dip net fishery in the spring.

It should be noted that the Pennsylvania Fish Commission and cooperating citizens groups and conservation clubs sponsor the propagation, rearing, and release of salmonids along the courses of several tributaries. Rainbow trout and coho and chinook salmon can be observed during their migrations to Lake Erie. These species support the anadromous salmonid sport fisheries of the spring and fall fishing seasons. Other fish found in the tributaries of Lake Erie are cyprinids, percids, and esocids.

Presque Isle Harbor sustains the area's greatest fishing pressure and the largest sport fishery harvest. This eutrophic, natural embayment of Lake Erie produces forage, coarse, and game fish. Muskellunge and northern pike are abundant as well as channel catfish, and black and brown bullheads. Forage species such as the emerald shiner, and gizzard shad are abundant throughout the year. Coarse fish include several species of catostomids, carp, goldfish, gizzard shad, spotted and longnose gar, bowfin, and drum. White bass, American eel, alewife, and smelt may be observed irregularly or seasonally.

6.5.10 Habitat Problems

Intermittent water quality deterioration has precluded or retarded the development of anadromous salmonid fisheries on two tributaries. Construction and modification of sewerage lines and sewage treatment facilities should improve the stream habitat. Streams can only support large numbers of salmon, trout, and smallmouth bass when stream discharge is high and water temperatures are suitable. Several tributaries are too small and support only bait fishes.

Stream spawning is limited or nonexistent for salmonids. However smallmouth bass

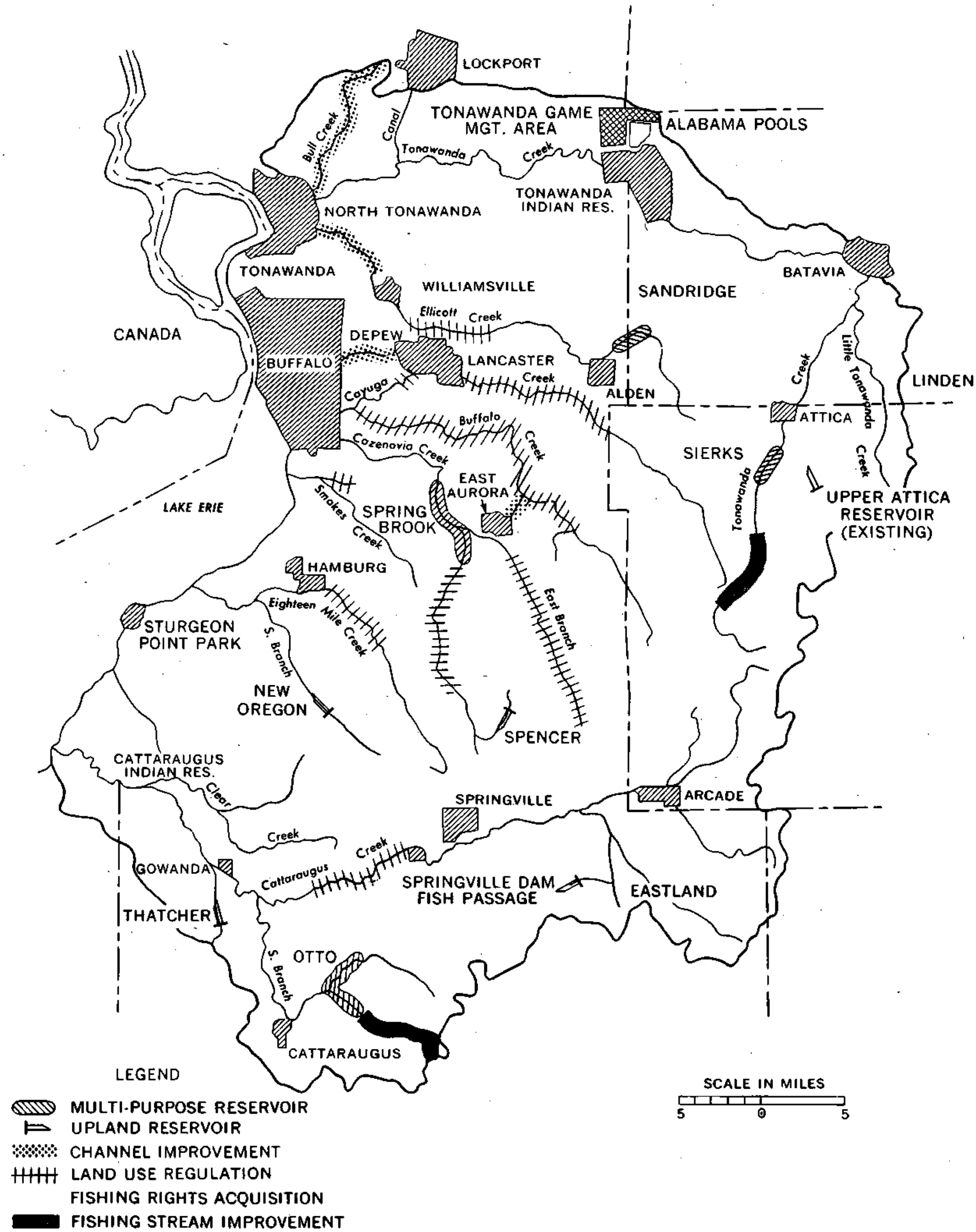


FIGURE 8–83 Fish Management Projects, Planning Subarea 4.4

sometimes produce notable year classes.

Several streams are used for agricultural purposes. Their waters are used for irrigation, and their banks are exposed to erosion and clearing. Sanitary landfill seepage, poorly treated sewage wastes, and small-industry effluent also affect water quality. Sedimentation, occasional high turbidity, increased temperature and oxygen demand, and decreased stream flow are manifestations of these problems.

6.5.11 History of Sport Fishery

Angling pressure has been greatest in the Presque Isle Harbor area. The harbor has also supported sport boats and provided for anglers seeking yellow perch, walleye, and in earlier years, the now extinct blue pike. Traditional angling and icefishing within the harbor is excellent and has drawn sport fishing enthusiasts from urban areas throughout Pennsylvania, Ohio, and New York.

Salmonids continue to attract local anglers to many Lake tributaries. The fall runs of coho salmon attract more than 20,000 anglers each year to fish at the mouths of homing streams and along the shores of the Lake.

Inland fishing demand is increasing because of the urbanization in Planning Subarea 4.4. However, sport fishing demand is still primarily directed towards the lakeshore area because of the quality, variety, and accessibility of the fishery.

Present problems suggest a future need for more public boat launching sites which would give access to the harbor and Lake Erie shore, both east and west of Erie, Pennsylvania. The need for an inland fishery is also increasing, but the demand is not as severe as the need for additional access to Lake Erie and harbor areas.

6.5.12 Ongoing Programs

The following efforts are ongoing programs to improve the recreational value of sport fishing and habitat base in Pennsylvania portion of Planning Subarea 4.4:

(1) county and municipal water quality and pollution control programs directed at local streams

(2) enforcement of Commonwealth laws established to protect habitat and aquatic life of area streams and waters

(3) establishment and management of salmonid nursery areas along the watersheds of several tributary streams of Lake Erie

(4) development of a small hatchery for coho and chinook salmon

(5) construction and acquisition of land for angler access areas

Additional programs include stream habitat improvement and cooperative efforts of local sportsman groups and State advisors to sponsor trout propagation.

Anticipated programs will be primarily directed at managing a potential nursery area in the harbor for muskellunge and northern pike and stocking these species. The salmonid program for coho and chinook salmon will continue.

6.5.13 Endangered, Rare, and Non-Game Species

The Great Lakes muskellunge *(esox masquinongy masquinongy)* is thought to inhabit the Presque Isle Bay area. Mature specimens are annually secured for propagation to insure the survival of this subspecies.

At one time, blue pike, a subspecies of the genus *Stizostedion,* was occasionally encountered in the area of Presque Isle. However, its preferred habitat was the deeper waters of Lake Erie. The subspecies is now thought to be extinct.

Section 7

LAKE ONTARIO BASIN, PLAN AREA 5.0

The comments on Plan Area 5.0 (Figure 8–84) are divided into two major parts. The first is limited to Lake Ontario, and the second treats the individual areas of the Lake Ontario Basin.

A comprehensive fish and wildlife management plan for Lake Ontario will be completed by New York in 1975. Decisions on what action will be taken on top priority fish management needs such as lamprey control and salmonid stocking will have been determined by that time.

To fully appreciate the position of Lake Ontario in the hierarchy of Great Lakes fisheries, the following clarifying statements are necessary to supplement the introductory section of the appendix.

Lake Ontario was the first of the Great Lakes settled and exploited by white men. Many fishery problems that appeared in the upper Lakes after 1930 had been present in Lake Ontario for sometime. Alewife and sea lamprey were well established prior to 1900. Although recent studies indicate that lampreys entered the Lake through the New York State Erie Canal system after 1820, they may have been an indigenous species. It may be important to determine if sea lampreys and salmonids coexisted successfully in the Lake prior to commercial fishing.

Early catch data indicate that the Lake never produced a commercial fishery comparable to the upper Lakes. The early presence of the lamprey may have caused this. Sport fishing has been important in the eastern basin and other shoal and bay areas since before 1900. Prior to the depletion of the abundant landlock salmon (1860–80), there was a limited sport and a major commercial fishery for this fine fish. Smallmouth bass continues to be the most important game fish and presently supports a multimillion dollar sport fish business complex. Yellow perch, bullhead, northern pike, and various other panfish make up the important angler species. White perch, white bass, bullhead, and eels constitute the existing major commercial catch on a dollar value basis. In 1970–71 the value of yellow perch to the Canadian commercial fishery increased considerably.

Lack of sea lamprey control in New York State waters and continued postponement of treatment by the GLFC poses a real problem. Canadian waters were treated during 1971 by Canada's GLFC lamprey control units.

Water levels in the St. Lawrence River and Lake Ontario have been controlled since completion of the hydrodams by Ontario and New York in 1958. Power demands and navigational needs of the Seaway cause continuous water level fluctuation. The effects of this fluctuation on fish and wildlife are unknown.

Since the 1940s New York and Ontario have had an informal international fisheries management association, the Lake Ontario Fish Management Committee. Field and administrative personnel from both governments have met to discuss mutual problems, outline programs, and provide solutions when possible. After the formation of the GLFC the original committee became the GLFC Lake Ontario Committee.

7.1 Resources, Uses, and Management

7.1.1 Habitat Base

Lake Ontario has the smallest surface area of the five Lakes but is third in maximum depth and second in greatest average depth. Undoubtedly, depth in relation to surface area plays a major role in the Lake's overall fish productivity.

The Lake consists of two major areas: the eastern or northeastern basin and the central-western basin. The eastern basin has the following characteristics:

(1) approximately 10 percent of the surface area

(2) a relatively shallow depth

(3) numerous islands and shoals

(4) two major bay areas, Chaumont Bay in New York and Bay of Quinte in Ontario

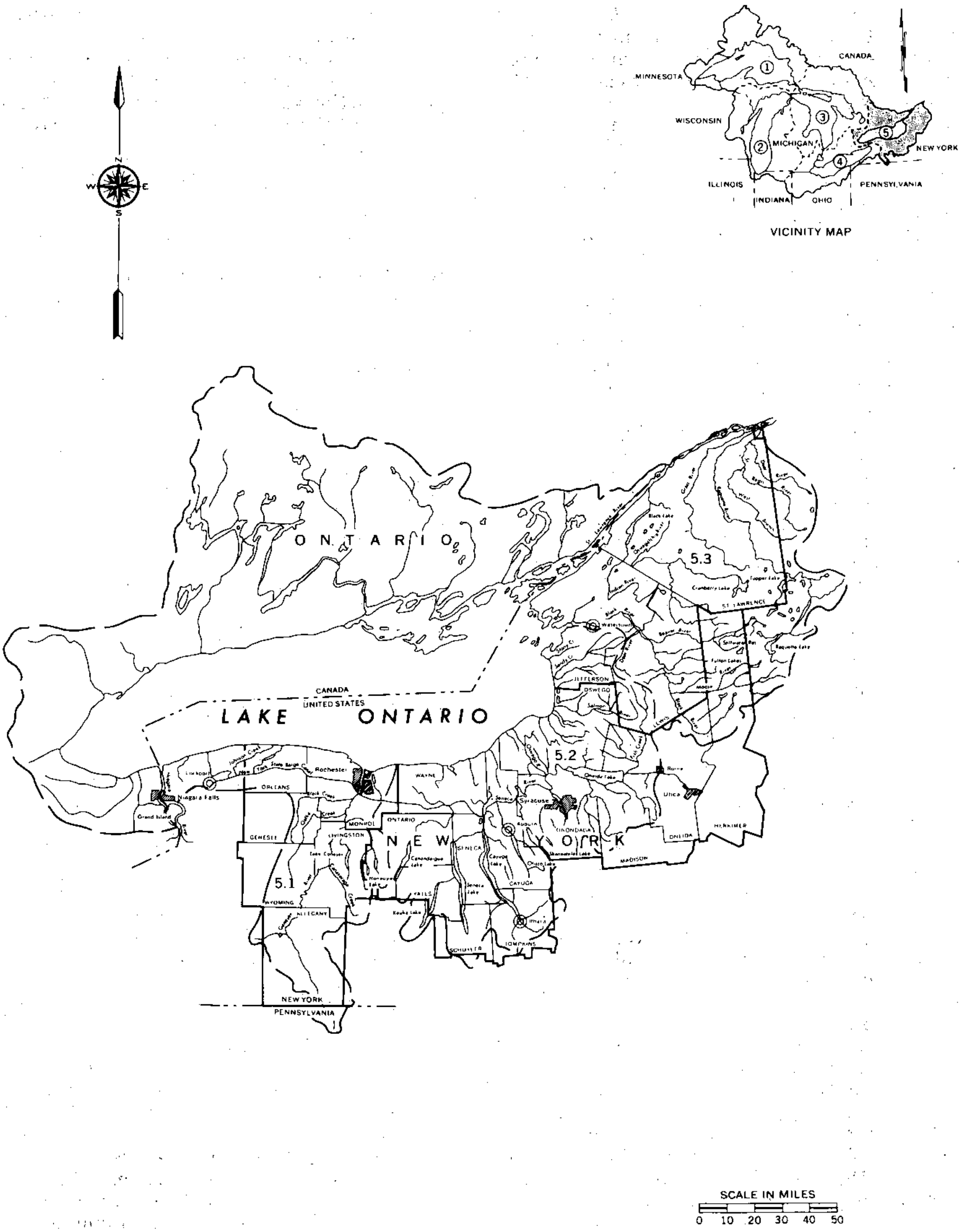


FIGURE 8–84 Plan Area 5.0

(5) almost the entire sport fishery and most of the commercial fishery in the Lake

The central-western basin is an elongated deep trough running east to west with the deepest water close to the south shore (New York waters). Only a small portion of this basin contains bays, shoals, and protected areas suitable for inshore sport fishing. Sodus Bay, near Rochester, New York is the largest bay, and at one time was a very important fishing area. Pollution and encroachment have changed the situation considerably in recent years.

Marshes and estuaries are important in any fish and wildlife management program. Many important marshes and estuaries of Lake Ontario have been destroyed or have been abused. In recent years New York State has recognized the importance of such areas. An acquisition and development program to protect remaining wetlands is now in progress.

Large centers of population in Ontario are located near the north shore of Lake Ontario. The amount of wetland acreage along the north shore is unknown, but it may equal or exceed that in New York. Encroachment of expanding population and industry, and the results of fluctuating water levels present serious hazards to remaining wetlands and estuaries.

Data on tributaries are available from the original New York State Biological Surveys. Additional surveys of the tributaries in the early 1950s by State management personnel, and surveys of many streams in 1966, 1969, and 1970 to determine distribution of lamprey ammocetes and wild rainbow trout were taken. Major tributaries of Lake Ontario are discussed in the subsections dealing with Planning Subareas 5.1, 5.2, and 5.3. Several tributaries are potentially important anadromous streams.

Although flushing rate is a physical characteristic, it also relates to the problems of removing deposited materials from the Lake. The major inflow is from the Niagara River which has a mean annual discharge of 195,000 cfs. This accounts for over 80 percent of the total inflow. The Great Lakes system has a mean annual outflow of 232,000 cfs into the St. Lawrence River.

Lake Ontario can be classified as monomictic, stratifying only during the summer months. During late fall, winter, and early spring, total volume of the Lake is generally well mixed. Ice develops in the nearshore regions in the winter, but it seldom covers more than a small fraction of the Lake surface.

The major factor in the circulation of water in Lake Ontario is wind stress. Throughout the year the prevailing winds vary from northeast to southwest with a net transport of water from the west. Because of the size of the Lake basin, Coriolis effect results in strong flows being confined mainly to the south shore. Return transports occur either along the opposite (north) shore or in deep water. The prevailing winds and currents due to Coriolis effect result in a major upwelling region near Toronto. Other shore regions also have intermittent periods of upwelling, which is more pronounced during summer stratification in a period of relatively strong westerly winds and is easily identified by cold surface temperatures and the lifting of the thermocline to shallow depths. Once salmonids have become established, these areas should provide excellent salmonid fishing in summer months.

Lake Ontario's deep average depth has saved it from reaching the level of eutrophication found in Lake Erie. Because it is the last in the chain of Great Lakes, Lake Ontario receives large quantities of pollutants from the upper Lakes as well as from within its own drainage basin. As a result, the concentrations of ions such as sodium, calcium, sulphate, and total dissolved solids are the highest of any of the Great Lakes (Figure 8–85). Although the total impact on the Lake from the increase of such ions is difficult to measure, these increases have helped increase productivity per unit of volume of water.

Increases in elements active in the biological process have not been as rapid as increases in ions. Phosphorous, nitrogen, and carbon are partially removed from the water by sedimentation. Because of this and other natural self-purification processes, characteristics of the water change more slowly despite the large pollution inputs. However, Lake Ontario is changing from an oligotrophic to a mesotrophic lake.

In order to limit productivity and prevent oxygen depletion in the hypolimnion during summer stratification, control of the chemical characteristics of Lake Ontario may be necessary. In 1967 the maximum oxygen level was 60 percent saturation, occurring in the bottom water of the shallow northeast corner of the Lake. Although this minimum value is still considered adequate to support desirable fish species, it does indicate a deficiency and shows that unlimited eutrophication cannot be allowed to continue. Sections of the Bay of Quinte, in Canada, approach conditions found during summer months.

The important feature of phosphorus in relation to eutrophication is that it is a growth-limiting factor. The present total phosphorus loading in Lake Ontario is 0.7 g/m²/yr, which is nearly at the point where serious problems may occur (0.75 g/m²/yr). In addition, present loadings are much higher than those likely to initiate nuisance growths of algae, weeds, and slimes (0.17g/m²/yr).

Phosphorus compounds are highly reactive. They can be removed by a variety of methods during sewage treatment, and also tend to be removed from lakes by natural processes. At the present time 57 percent of the total phosphorus in Lake Ontario is attributable to municipal and industrial sources. Phosphorus loadings in Lake Ontario could be reduced to 0.17/m²/yr if all phosphorus were eliminated from detergents and the predicted 1986 load of phosphorus were reduced by 95 percent at municipal and industrial waste treatment plants. Such a reduction would allow Lake Ontario to return to an oliogotrophic state.

A sound understanding of the dynamics of the various phytoplankton populations is important to management of fish resources. Planktonic algae are the primary producers of organic matter in Lake Ontario. Unfortunately, published data on the composition of phytoplankton in Lake Ontario are scarce in comparison with the other Great Lakes. Recent studies by Dr. R. A. Vollenweider, C.C.I.W., have shown that no break in the food chain is required to produce phytoplankton in the Lake. The following general discussion of phytoplankton has been taken directly from the 1969 International Joint Commission (IJC) report:

> Results indicated that phytoplankton levels throughout Lake Ontario were moderate-to-low. Generally, inshore populations declined from the western to the eastern end of the Lake. With minor exceptions, the classical biomodal pattern of phytoplankton development was evident throughout the Lake, unlike portions of Lake Erie where a breakdown of this pattern was reported to indicate increasingly eutrophic conditions. Phytoplankton concentrations in the main body of the Lake suggest a condition between oligotrophy and mesotrophy. The waters of Hamilton Harbor and the Bay of Quinte, on the other hand, are eutrophic in character.

Nonplanktonic plants are also becoming a major problem in Lake Ontario. Growths of filamentous green algae, *Cladophora*, and rooted vascular plants have increased greatly in the last decade. This increase caused large accumulations on shore after storms with subsequent rotting and odor; restriction of commercial fishing due to the fouling of nets; reduction of open water areas desirable for sport fishing; restriction of small craft navigation in shallow waters; and fouling of swimming beaches.

Growth of *Cladophora* and rooted aquatic plants in Lake Ontario is limited by suitable substrate and the depth of light penetration. *Cladophora* requires a rocky substrate and is found in a discontinuous band around the entire shoreline of Lake Ontario. Because of the area occupied and the volume of material produced, it is a greater problem than the rooted aquatics. However, the rooted plants are a more serious problem than would be indicated by the volume of water they occupy. These plants are found throughout the shallow bays and harbors where the majority of boating and sport fishing activities are located.

The increase in production of *Cladophora* and rooted aquatics is considered detrimental to the overall aquatic resource, but it has been beneficial to some species of fish and fish-food organisms. The largemouth bass *(Micropterus salmonides)* is an example of a fish species which has benefited from increased growth in aquatic vegetation. Amphipods, *(genus Gammarus)* have also increased because of more abundant food supply. However, to insure maximum utilization of the aquatic resource, increases in desirable aquatic organisms as a result of eutrophication must be carefully weighed against the negative factors.

Published data on crustacean zooplankton in Lake Ontario are incomplete and scattered. During 1967 a limited amount of sampling was carried out for the IJC report. Overall abundance and species composition in particular parts of the Lake were different, but the following general pattern of distribution was evident.

> On the average the eastern part of the lake was 1.7 times richer in planktonic crustaceans than the western and central parts (610 as against 350 animals/m³). Most species appeared in June and July in relatively high numbers and expanded toward the west in August. In September, some of the species, *Bosimina longirostris* and *Ceriodaphnia lacustris* were abundant farther west, disappearing from the east. Others like *Daphina retrocurva* and *Cyclops biscuspidatus thomasi* were distributed throughout the lake showing a tendency to concentrate in deep water areas.

Few data on bottom fauna in Lake Ontario have been published to date. Available data can only present a general picture of the existing conditions.

The bottom fauna of Lake Ontario is qualitatively uniform throughout the Lake. Scuds, *Pontoporeia affinis*, and to a lesser extent oligochaete worms, are the dominant forms.

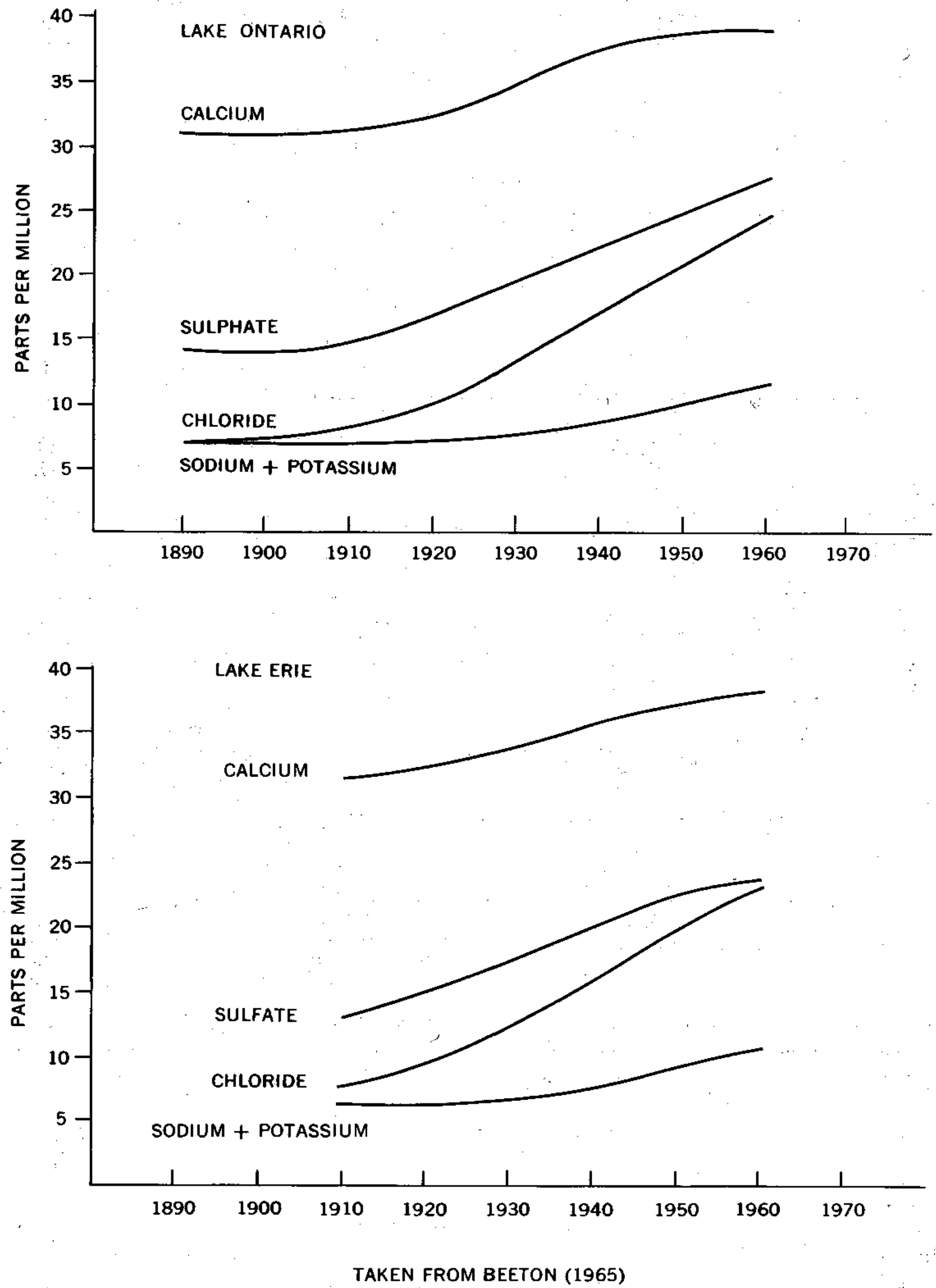


FIGURE 8–85 Chemical Constituents of Lake Ontario Compared to Lake Erie, 1890–1970

The predominance of *Pontoporeia affinis (Amphipoda)* in the offshore waters indicates that the benthos is more similar to that of the upper Great Lakes (oligotrophic) than that in Lake Erie. However, organic enrichment is evident at several inshore locations including the area near Toronto and the mouths of the Niagara, Genesee, and Oswego Rivers. Combinations of existing natural conditions and the results of man's activities have accelerated eutrophication. In these areas, the percentage of tubificid worms *(oligochaets)* and pollution-tolerant chironomids *(Tendipedidae)* has increased greatly.

7.1.2 Fish Resources—A Summary of Major Changes

A list of species found in Lake Ontario and adjacent waters is included in the appendix. General information on major species has been discussed in Section 2.0.

The New York commercial fishery is divided by legal boundaries and regulations into two areas, Lake Ontario proper and Chaumont Bay. Commercial fishing is less important than the sport fishery, and is valued at less than $100,000 per year to fishermen. In order to assure maximum social benefit from the fishery resource, the commercial fishery should be regulated so as to be consistent with sport fishery programs.

Little is known about the detailed composition of fish stocks. However, Tables 8–59 and 8–60 show changes in the contribution of some species. Historically, the Lake abounded with Atlantic landlock salmon and some sea-run salmon from the Gulf of St. Lawrence. Lake trout and whitefish were common-to-abundant in the eastern basin. Chubs and deepwater sculpin were present in the deeper waters. Cisco and lake sturgeon were common-to-abundant throughout the Lake (Figures 8–86, 8–87).

The extinction or near extinction of salmonid species prior to the present generation contributed to the lack of public and professional interest in intensive fish management. Few people could recall this fishery and therefore, were not interested in it. In the upper Lakes, the demise of salmonids was relatively recent; therefore the public was aware of the problem and demanded a solution.

A complete stock inventory of the Lake has never been undertaken. Such an inventory was started in 1971 by BSFW, Province of Ontario, and New York State personnel through the GLFC Lake Ontario Fish Stock Inventory Sub-Committee. The first phase consisted of training cruises. Until such an inventory has been completed and several years of fish stock monitoring recorded, there will be many gaps in fish species composition data for the Lake. In addition, intensive netting data in the early 1940s by New York State management personnel is available to provide a comparison base for future fish stock monitoring. The following general review will suffice for this section.

Approximately 10 percent of the Lake, the shallow areas, supports nearly 100 percent of the sport and commercial fisheries. The remaining 90 percent of the Lake supports an unknown amount of fish life. There is a tremendous potential for salmonid production in the Lake, and this is the primary objective of present management.

7.1.2.1 Value of Individual Species to the Ecosystem

Many of the more abundant species have been introduced: carp, rainbow smelt, alewife, white perch, and white bass. Rainbow trout, coho and chinook salmon, and various other species have also been introduced.

Smallmouth bass continues to be the most economically important species in the sport fishery. Yellow perch, brown bullhead, northern pike, rock bass, common bluegill, sunfish, largemouth bass, white perch, white bass, black crappie, carp, channel catfish, American eel, freshwater drum, and walleye make up the major angling species and are listed on a priority basis.

After 1950 smelt dipping became a major family-type sport fishery during the spring spawning run. A winter ice fishery is popular for yellow perch and, to lesser degree, northern pike. Smelt have not produced a winter fishery to date.

Before 1880 the Atlantic landlock salmon provided good fishing. Until the 1930s lake trout were also desirable game fish. From the 1930s until 1968 there was no salmonid fishery. However, rainbow trout and lake trout provided by joint New York and Ontario experimental stockings in the mid-1950s and 1963-64, were occasionally caught. Native lake trout are probably extinct and native salmon are surely extinct. The results of lake trout stocking in the 1950s were very encouraging. Survival was excellent until the fish reached a size vulnerable to lamprey predation (12 in-

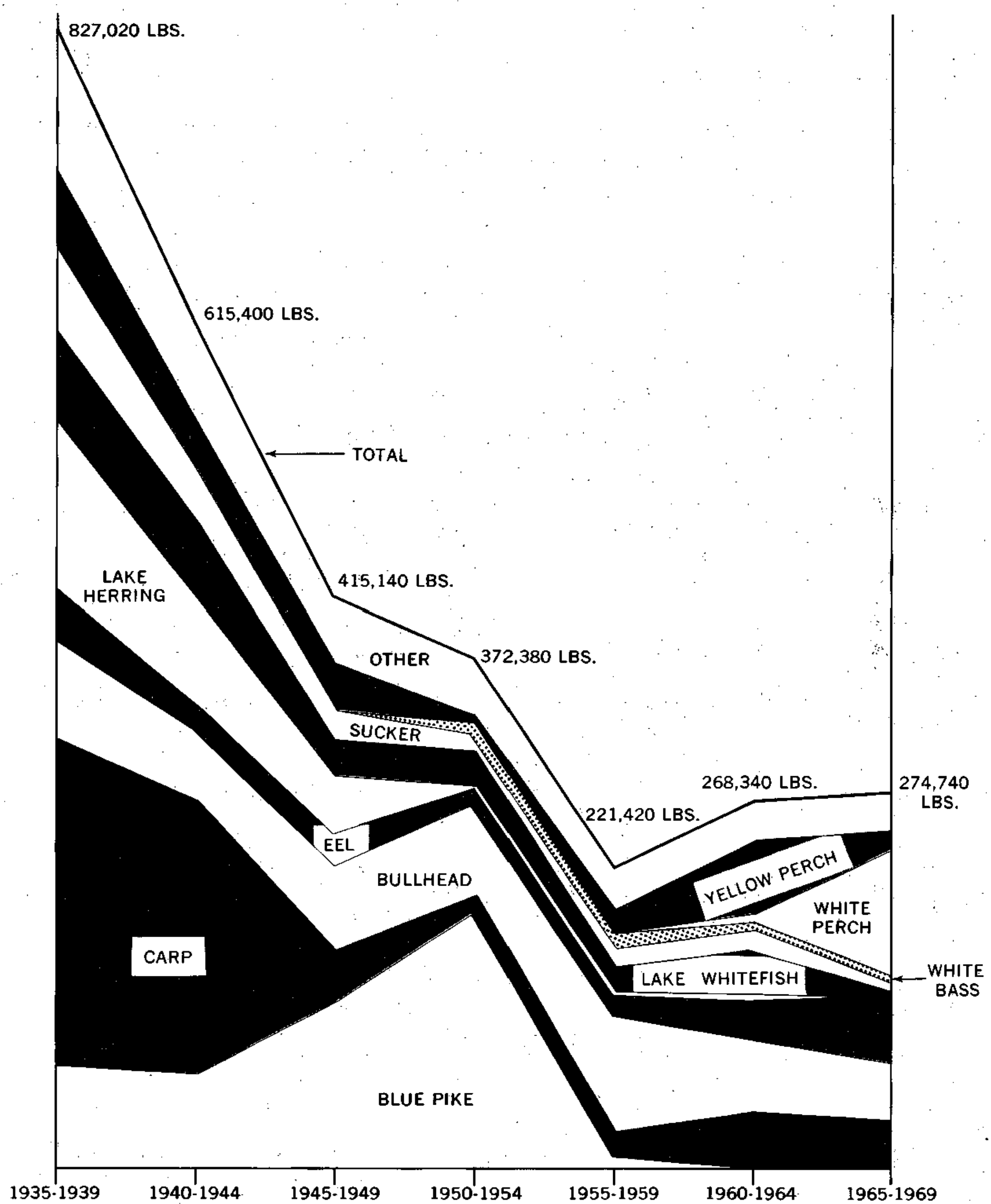


FIGURE 8-86 Average Annual Production (Pounds) of Major Species by the U.S. Lake Ontario Commercial Fishery for 5-Year Periods, 1935–1969

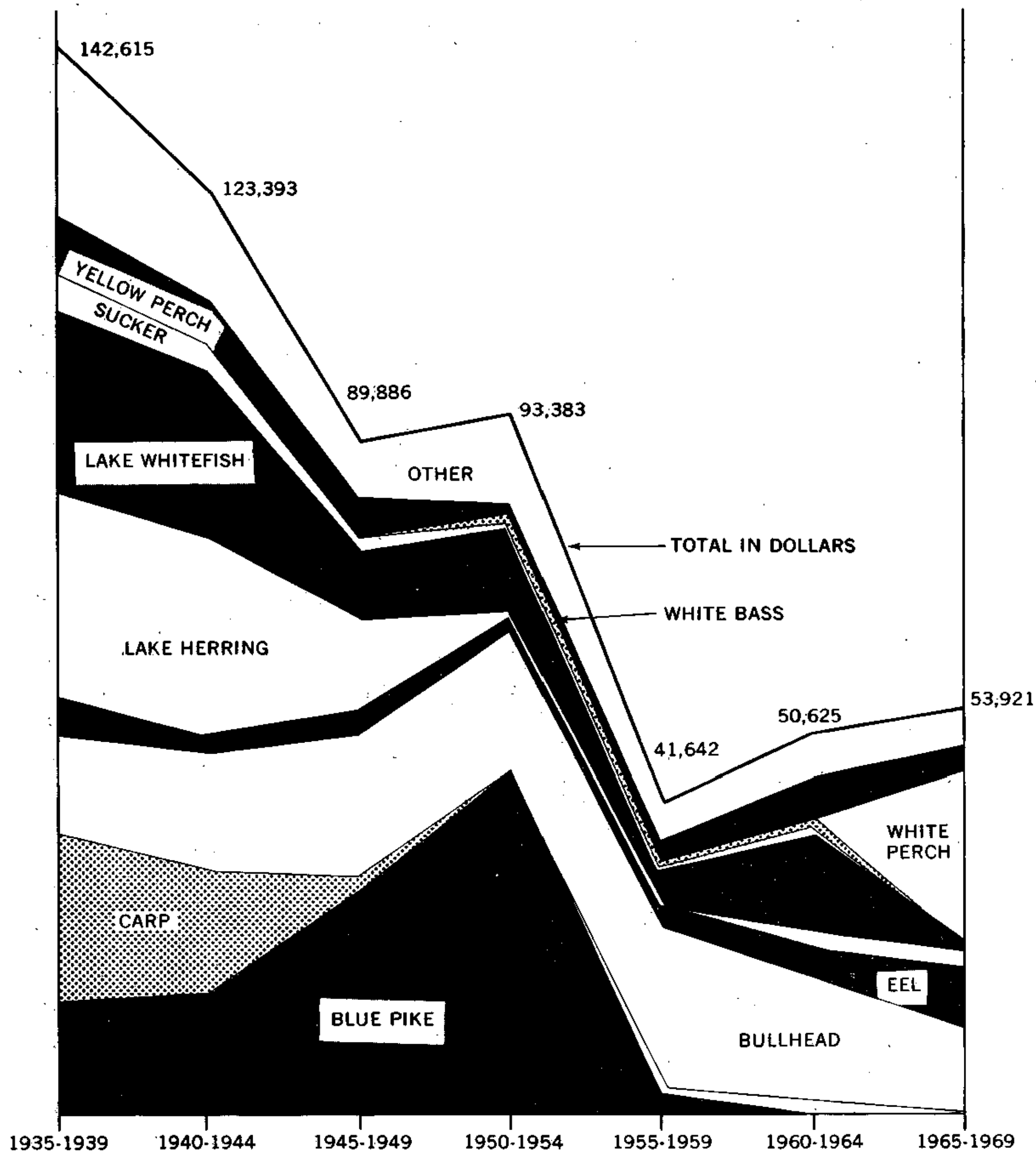


FIGURE 8–87 Average Annual Production (Dollars) of Major Species by the U.S. Lake Ontario Commercial Fishery for 5-Year Periods, 1935–1969

TABLE 8–59 Average Pound and Percent Contribution of 13 Major Species in the U.S. Waters of Lake Ontario

Species	1935–1939	1940–1944	1945–1949	1950–1954	1955–1959	1960–1964	1965–1969
Blue Pike							
Lbs.	76,860	72,220	123,660	188,660	12,660	1,040	---[1]
% of Volume	9.3	11.7	29.8	50.7	5.7	.4	---[1]
Burbot							
Lbs.	15,080	13,160	---[1]	100	220	620	---[1]
% of Volume	1.8	2.1	---[1]	---[1]	.1	.2	---[1]
Carp							
Lbs.	235,000	198,020	35,580	10,380	11,360	37,080	35,200
% of Volume	28.4	32.2	8.6	2.8	5.1	13.8	12.8
Bullhead							
Lbs.	74,820[2]	53,120[2]	64,280[3]	67,020	90,940	58,940	44,000
% of Volume	9.0	8.6	15.5	18.0	41.1	22.0	16.0
Chub							
Lbs.	---[4]	---[4]	---[4]	13,640	360	---[1]	120
% of Volume	---[4]	---[4]	---[4]	3.7	.2	---[1]	---[1]
Eel							
Lbs.	36,340	16,800	21,060	8,660	18,280	26,900	41,340
% of Volume	4.4	2.7	5.1	2.3	8.2	10.0	15.0
Lake Herring							
Lbs.	123,660	81,340	46,220	4,520	780	5,400	3,860
% of Volume	15.0	13.2	11.3	1.2	.4	2.0	1.4
Lake Trout							
Lbs.	12,240	5,000	580	3,220	340	2,160	---[4]
% of Volume	1.5	.8	.1	.9	.2	.8	---[4]
Lake Whitefish							
Lbs.	61,960	55,100	21,740	23,660	10,740	30,820	3,920
% of Volume	7.5	9.0	5.2	6.4	4.9	11.4	1.4
Suckers							
Lbs.	64,120	36,840	22,140	13,040	11,080	14,180	6,780
% of Volume	7.8	6.0	5.3	3.5	5.0	5.3	2.5
White Bass							
Lbs.	1,100	---[1]	---[1]	7,920	13,260	6,540	520
% of Volume	.1	---[1]	---[1]	2.1	6.0	2.4	.1
White Perch							
Lbs.	---[4]	---[4]	---[4]	---[1]	580	3,000	85,220
% of Volume	---[4]	---[4]	---[4]	---[1]	.3	1.1	31.0
Yellow Perch							
Lbs.	54,940	31,620	31,120	5,800	18,540	52,940	24,580
% of Volume	6.6	5.1	7.5	1.6	8.4	19.7	8.9
Average Total Volume	827,020	615,400	415,140	372,380	221,420	268,340	274,740

[1] Less than 100 pounds or .1%

[2] Includes catfish catch

[3] Based on a four-year average

[4] Absent from the commercial catch

TABLE 8–60 Average Value and Percent Contribution of 13 Major Species in the U.S. Waters of Lake Ontario

Species	1935–1939	1940–1944	1945–1949	1950–1954	1955–1959	1960–1964	1965–1969
Blue Pike							
Dollars	14,619	15,878	29,592	45,397	2,723	387	---[1]
% of Value	10.3	12.9	32.9	48.6	6.5	.8	---[1]
Burbot							
Dollars	1,138	1,314	---[1]	---[1]	---[1]	---[1]	---[1]
% of Value	.8	1.1	---[1]	---[1]	---[1]	---[1]	---[1]
Carp							
Dollars	22,236	16,593	2,295	400	577	1,207	981
% of Value	15.6	13.4	2.6	.4	1.4	2.4	1.8
Bullhead							
Dollars	13,211[2]	15,671[2]	18,922[3]	18,489	21,906	16,154	9,215
% of Value	9.3	12.7	21.1	19.8	52.6	31.9	17.1
Chub							
Dollars	---[4]	---[4]	---[4]	5,262	74	---[1]	---[1]
% of Value	---[4]	---[4]	---[4]	5.6	.2	---[1]	---[1]
Eel							
Dollars	5,311	1,866	2,797	1,518	2,331	5,055	9,776
% of Value	3.7	1.5	3.1	1.6	5.6	10.0	18.1
Lake Herring							
Dollars	27,916	27,246	12,392	1,243	183	1,526	1,432
% of Value	19.6	22.1	13.8	1.3	.4	3.0	2.7
Lake Trout							
Dollars	4,594	1,816	264	654	195	1,222	---[4]
% of Value	3.2	1.5	.3	.7	.5	2.4	---[4]
Lake Whitefish							
Dollars	24,277	22,298	9,428	11,306	4,578	13,646	1,916
% of Value	17.0	18.1	10.5	12.1	11.0	27.0	3.6
Suckers							
Dollars	4,526	3,234	1,629	978	586	498	237
% of Value	3.2	2.6	1.8	1.0	1.4	1.0	.4
White Bass							
Dollars	136	---[1]	---[1]	848	1,395	755	---[1]
% of Value	.1	---[1]	---[1]	.9	3.3	1.5	---[1]
White Perch							
Dollars	---[4]	---[4]	---[4]	---[1]	---[1]	219	22,554
% of Value	---[4]	---[4]	---[4]	---[1]	---[1]	.4	41.8
Yellow Perch							
Dollars	7,977	5,816	5,177	1,145	2,099	5,299	3,045
% of Value	5.6	4.7	5.8	1.2	5.0	10.5	5.6
Average Total Value	142,615	123,393	89,886	93,383	41,642	50,625	53,921

[1] Less than $100 or .1%

[2] Includes catfish catch

[3] Based on a four-year average

[4] Absent from the commercial catch

ches). Sub-legal fish (15 inches) were also very vulnerable to nylon whitefish gill nets.

In 1968 New York started an experimental coho salmon stocking program. In 1969 chinook salmon were stocked by New York and coho salmon by Ontario. Ontario has stocked some rainbow trout, kokanee salmon as eyed eggs or fry, and splake.

Coho, chinook, rainbow trout, and splake are also decimated by lampreys once they reach a vulnerable size of about 12 inches. Kokanee stocking by Ontario has been totally unsuccessful. Unfortunately, very little information has been obtained on salmonids in the open Lake because there is no monitoring system and practically no commercial fishing in New York waters. The little available data have been provided by a few Canadian commercial fishermen.

Alewife and smelt make up the bulk of the fish population in numbers and poundage. Estimates of overall abundance have not been made. A brief BSF&W exploratory cruise in 1968 indicated that, in a standard trawl haul, alewife were as abundant in Lake Ontario as in Lake Michigan. Slimy sculpins are common-to-abundant down to 50 fathoms and should provide good salmonid forage. Deepwater sculpin are very scarce or extinct.

Little is known about the present status of ciscoes and chubs. At one time both supported a major commercial fishery and at least a few still remain in the Lake.

Lake whitefish, once very abundant, are practically extinct in New York waters. Remnants of one or two distinct populations related to Canadian spawning stocks remain in the eastern basin. Netting on the spawning grounds and lamprey predation have put this species in an endangered situation. Lake whitefish might be saved with proper management practices, but the future is not encouraging for this once abundant and valuable commercial species.

Blue pike provided much of the high-value commercial catch and supported an important sport fishery. The population fluctuated tremendously over the years. However, few have been caught since the early 1950s, and blue pike are functionally extinct in both Lakes.

The inshore sport fishery remains good-to-excellent for several important species in spite of introductions, changes in water quality, pollution, and other factors. The open Lake provides practically no commercial or sport fishery.

In addition to their sport and commercial value, long-lived predators are an excellent indicator of subtle pollutant levels and other environmental problems. Warmwater inshore species are suitable for such monitoring as are coldwater species such as lake trout. Should their commercial feasibility be questioned, management of long-lived salmonids such as lake trout could be justified solely by their value to ecological surveys and the sport fishery.

7.1.3 The Fisheries

7.1.3.1 Historical Background and Economic Contribution of the Lake Ontario Fishery

Commercial catch data seldom, if ever, portray the actual abundance of a species in relation to other fish. Some species may be abundant but have no great market value in that particular fishery. Alewife is an excellent example for this Lake. Commercial catch records are better indicators of the abundance of valuable species. As fish population diminishes, fishing effort may increase. Lake trout catch records for Lake Ontario exemplify this. At best, commercial catch records can be interpreted as trends. Unfortunately, they also pinpoint the historical period in which a major species was decimated.

With the exception of trawls, various types of commercial fishing gear common to the upper Lakes have been used in Lake Ontario. Some experimental trawling has occurred but there is no commercial trawling in New York waters. Deepwater trap nets have been outlawed. Management of the commercial fishery has been restricted by regulations on gear, protection of certain species from commercial sale, closure of certain areas to commercial fishing, and special fishing dates in some areas. None of these measures has been effective.

At present there is one major commercial fisherman operating in New York waters of the open Lake. The Canadian commercial fishery has been more extensive, but in recent years the number of fishermen has also declined. Until the late 1960s Canadian fish management was oriented to commercial fishing. Because valuable stocks have been depleted and human population has expanded along the lakeshore, sport fishing has become more important in recent years.

The Chaumont Bay fishery was established during World War II when many worldwide fish supplies were shut off. Basically, it is an inshore trap net fishery with some gill netting and seining. Various changes have been made in the open season. The fishery was open from mid-September to mid-June. Then, it was shortened to May 28. Since 1971, it has closed on May 15.

Commercial fishing will not regain a prominent position in Lake Ontario unless other sources of food fish collapse throughout the world. By public mandate, future commercial fisheries will be strictly controlled so they will not endanger the sport fishery. The number of commercial fishermen operating on Lake Ontario has declined since 1930 (Table 8–61). One fact is certain: open Lake management must be coordinated between Ontario and New York to be successful.

The annual value of the commercial fishery in recent years has been less than $100,000. These figures are only an estimate because many fish are caught and sold without being reported. In addition, many fish pass through a middleman before eventually reaching the consumer. However, the overall value of the commercial catch and the number of persons associated with the fishery in Lake Ontario are small compared to other Great Lakes.

On the other hand, the sport fishery is a major factor in the economy of many communities. The business complex supported by smallmouth bass and associated species is a multimillion dollar one. In addition, excise taxes on fishing tackle help support many of the State's fish research programs.

The sport fishery can be separated into the relatively expensive openwater bass fishery and the inexpensive shore fishery for bullheads, smelt, and panfish. A major investment is involved in boat and motor purchase, or a boat rental. Guide service on a party boat is required for the open lake fishery. In comparison the shore fisherman's investment often is an inexpensive rod, reel, and can of worms.

Utilization of the sport fishery is dependent on availability of suitable fishing boats, access sites, and safety harbors. At present there are major marinas located in every community along the lakeshore. The actual number of private boats kept at marinas, those available for rental, and boats towed to the location by owners is not known.

In recent years New York has developed more boat launching sites. In addition, State and local government parks also provide boat access. Long-range plans call for access sites and safety harbors strategically located along the entire south shore of the Lake.

Party boats or guide boats have been a part of the sport fishery of the Lake for a long time. Early guides rowed or sailed. The number of guides is now decreasing due to operating cost, the number of private boats, and above all, the lack of an openwater salmonid fishery. Party or guide boat service would quickly become a major industry again if a good salmonid fishery is provided.

The sale of bait has economic importance. Until recent years, bait such as minnows, worms, and crayfish were obtained from local sources. In the past decade, most retailers have obtained bait supplies from distributors who import bait from out-of-state bait farms.

There are no reliable figures available on the actual value of the sport fishery. One of the best indexes is the volume of bait handled in relation to the fishery. A creel census and aerial survey of sport fishing boats on Lake Ontario has provided some data relating to the economics of the fishery. More intensive census data are required and will be a high-priority management need in the comprehensive management plan.

7.1.4 Effects of Non-Fishery Uses on Fish Resources

Uses associated with the upper Lakes are also present in Lake Ontario. Good coordination is required between most users for overall management of the Lake. The effect of the following uses on the fish resources is of particular concern:

(1) wildlife management on estuary and wetland areas

(2) thermal discharges

(3) recreational boating and water skiing

(4) construction, dredging, spoil, and filling operations

(5) proposed seaway navigation throughout the year

(6) fluctuations of water levels from hydro demands

(7) uses of tributary streams and upper Lakes drainage for industrial and domestic dumping of wastes

Monitoring systems are essential to measure the effects of various uses so that sensitive controls can be implemented. Generally speaking, uses that do not deteriorate the habitat base are compatible with fisheries.

7.1.4.1 Effects of Chemical Changes

A detailed discussion has been given in Subsection 7.1.1. Figure 8-85 lists the loadings of some chemical substances in Lake Ontario. Although the depth of Lake Ontario dilutes the effects of chemical pollution from the upper Lakes, continued pollution could eventually destroy the water quality of the Lake.

Adverse effects of pesticides on lake trout reproduction have been documented. Mercury contamination has been found in species destined for human consumption. The effects of other chemical pollutants present in the Lake on fish life are not known. Future management must understand the total effects of numerous chemicals on fish life and human beings who have eaten contaminated fish. However, a sensible approach should be adopted in solving this problem. Hysteria and misinformation can destroy an entire community's economy, often without sound basis.

7.1.4.2 Effects of Physical Changes

Major physical changes in the Lake are obvious along the shore and marsh areas where marinas and private dock construction have altered or destroyed considerable habitat. The overall effects of these changes have not been determined. Physical effects of excessive plant life have been described previously.

The effects of water level control for hydropower on the fishery resources have not been studied. In general, high water levels enhance the fishery resource base in the shoal, estuary, and marsh areas of the Lake. The proposed extension of the navigation season through part or all of the winter will affect ice fishing in some areas. However, it may provide some openwater fisheries in the eastern basin during the winter months. More important is the potential danger from undetected navigational oil pollution during the winter months, and the possible subtle changes that it could cause in the entire ecosystem. Effects of dredging and spoil dumping in the Lake pose a continuing problem.

7.1.4.3 Effects of Biological Changes

Biological changes have affected the species composition in the Lake. Predatory salmonids were decimated because of overharvest by commercial fishing, sea lamprey predation, and degradation of spawning grounds. The tremendous numbers of alewife and smelt reflect the lack of abundant salmonid predators. Introduction of coho and chinook salmon, rainbow trout, splake, and eventually other salmonids in conjunction with lamprey control may reverse some of these changes.

Effects of biological changes produced by increased phytoplankton and rooted aquatic growth have been described previously. The effects of micro- and macrozooplankton on the overall biological community are not completely understood. Physical and chemical changes can have important effect on the entire biological community. The effects of these two factors on the biological community make aquatic plant and animal life, and particularly fish, excellent monitors of environmental changes.

There have been both blatant and subtle biological changes in the Lake. The subtle changes are not well understood at present. Intensive IFYGL and other studies in the next few years should shed light on the entire biological-chemical-physical complex in the Lake.

7.1.4.4 Effects of Non-Fishery Uses on the Fisheries

Lake Ontario was settled first and therefore exploited first. It is also the lowermost of the Lakes, and therefore vulnerable to effects by other users of the Great Lakes Basin. It is miraculous that the changes to the fishery and habitat base have not been more serious. It is also surprising that the inshore warmwater fish species such as smallmouth bass, northern pike, yellow perch, and other panfish have continued to provide a strong fishery.

Competition for marsh and estuary areas between marina operation, private docks, commercial harbors, and fish management personnel has been severe. Fortunately, State regulations will have complete control of this situation.

The St. Lawrence Seaway and hydroelectric power dams have subtle effects on the Lake. The chance of a major oil spill from commercial vessels and unknown effects of a proposed year-round Seaway could cause major problems for the fishery. The effects of constant variations in water levels due to hydroelectric demands are unknown and must be studied. Obviously, fluctuations during critical spawning periods could be detrimental to fish production in marsh and other shallow areas.

Direct and indirect effects of industrial, domestic, and agricultural use of the drainage basin have been severe in certain inshore and tributary areas.

TABLE 8–61 Commercial Operating Units and Productivity in the U.S. Waters of Lake Ontario

Year	Number of Fishermen[1]	Pounds Landed per Fisherman	Value of Catch per Fisherman[2]	Number of Vessels	Number of Boats
1930	177	3,853	$ 780	1	67
1931	150	2,944	624	1	43
1932	135	3,861	776	1	51
1934	205	3,496	653	3	67
1936	136	4,420	762	4	35
1937	158	3,914	702	4	40
1938	167	4,129	758	3	44
1939	169	8,616	1,508	2	49
1940	143	9,503	1,504	2	50
1950	146	1,292	351	1	82
1954	84	3,698	772	1	57
1955	63	3,695	682	1	44
1956	61	2,945	532	1	45
1957	55	3,747	757	1	42
1958	67	3,923	719	1	42
1959	92	2,452	465	2	42
1960	73	3,538	752	–	36
1961	77	4,638	858	1	36
1962	60	3,880	791	3	43
1963	71	3,278	582	1	37
1964	48	5,554	904	1	25
1965	57	3,801	853	1	30
1966	50	4,744	1,163	1	22
1967	42	6,761	1,418	1	21
1968	60	5,705	1,084	1	29
1969	46	6,380	841	1	22

[1]Refers to all fishermen engaged in harvesting.

[2]Value deflated by wholesale price index (1957-1959=100).

7.1.5 Fisheries Management

7.1.5.1 Past and Present Fish Management

The Lake was not managed for fish until the late 1800s. At this time the Federal Cape Vincent Fish Hatchery began propagation and stocking of lake trout and whitefish fry. There was an attempt by Ontario and New York to propagate and stock Atlantic salmon from remnants of the original Lake Ontario stock. There were also efforts to stock other species. Today propagation on an expanded and sophisticated scale is a primary goal of fish management. Without major hatchery support a good salmonid fishery will be impossible in Lake Ontario even if degraded spawning streams are restored.

Regulations on commercial fishing have already been mentioned. Sport fish regulations deal with size limits and closed seasons during spawning periods for important game species. With these restrictions New York has been able to maintain a healthy warmwater sport fishery in Lake Ontario under present conditions.

The following is an outline of fish administration and management in New York:

(1) regulations in the mid-1800s

(2) formation of fish commissions and hatcheries in the late 1800s
(3) extensive fry stocking of lake trout, whitefish, and other coldwater species in the late 1800s and early 1900s primarily by the Federal Cape Vincent Hatchery
(4) formation of a State Conservation Department with subsequent Division of Fish and Wildlife
(5) original biological surveys on a watershed basis with fish management recommendations
(6) formation of State fish management districts in the 1940s to 1950s
(7) formation of combined State fish and wildlife management regions in 1960 with increased emphasis on acquisition, development, and habitat protection
(8) formation of Department of Environmental Conservation on July 1, 1970, with main emphasis on pollution abatement and protection and enhancement of the resource base
(9) formation of regional offices responsible for all field services under a regional director in 1971

Management has been concerned with the following programs:
(1) Federal fry stocking and State biological surveys mentioned above
(2) some fairly extensive openlake exploratory gill netting in 1942–43
(3) Federal recording of annual commercial catch
(4) an intensive smallmouth bass study in eastern Lake Ontario-upper St. Lawrence River in the late 1940s
(5) joint Ontario-New York experimental lake trout stocking project in eastern Lake Ontario in the mid-1950s and 1963–64
(6) opening of the State's Cape Vincent Fisheries Station by lease of the closed (1964) Federal Hatchery Facilities in 1965
(7) coho and chinook salmon stocking in 1968–71

Opening of the Capt Vincent Station marked a modest beginning for eventual intensive fish management of the Lake. Between 1965 and 1970 the following Lake-oriented projects were carried on from the station: sport fishing creel census and aerial boat counts; Federal Aid Projects under PL88–309 Commercial Fish Project and the AFC lake sturgeon study.

In 1971 Federal Aid Project FA–2–1, "Anadromous Fish Enhancement in Lake Ontario," supported by Anadromous and D-J funds was initiated. This project included:
(1) completion of a comprehensive Lake Ontario fish and wildlife management plan
(2) planning, development, and coordination of a salmonid fishery
(3) planning and evaluation of lamprey control
(4) abundance and distribution of salmonids and other species in the Lake and associated tributary waters
(5) evaluation of the present condition of the aquatic habitat

The immediate development of a salmonid sport fishery in the Lake is the highest work priority.

Results from New York and Ontario experimental 1968–1970 salmon stockings were very poor because of high mortality from lamprey predation. Returning coho and chinook jacks were heavily scarred. Adults were practically 100 percent scarred with an average of twelve or more lamprey marks on the few surviving fish. It is evident that a sport or commercial salmon fishery cannot be provided without lamprey control. Canadian GLFC lamprey control units completed treatment in the fall of 1971. New York waters must be treated as soon as possible to complement Canadian lamprey control efforts.

In addition to lamprey control, adequate salmonid stocking must be insured. Plans for expansion of existing State hatchery facilities and possible construction of one or two State and Federal hatcheries have been approved. The New York State legislature approved funding for this project in 1973. Federal funds are expected shortly.

The need for adequate salmonid stocking between completion of lamprey control and increased hatchery production from additional facilities (1972–1977) is vital for evaluation of the overall program. Existing hatchery facilities are not adequate to provide sufficient fish stocks. It may be possible to obtain additional fish from the following sources: existing Federal hatcheries which now provide fish for the upper Lakes; arrangement with upper Great Lakes States for salmonids; conversion of some Lake Ontario tributary ponds to rearing ponds.

Proposed long-range plans call for annual stocking in Lake Ontario of 2,000,000 salmonids in New York waters and similar numbers in Canadian waters. Coho and chinook salmon, rainbow (steelhead) trout, splake, and brown trout are proposed. Splake initially will be provided by Ontario. Lake trout will be stocked if splake are unsuccessful, and if subtle pollutants are at tolerant levels. A major goal is to provide a fishery made up of Atlantic salmon and other salmonids. Special hatchery facilities may be required to produce Atlantic salmon smolts.

Intensive management of anadromous streams will require extensive acquisition, development and maintenance funds for public fishing rights, habitat improvement, weirs, barriers, and fishways. Similar funding will be required for Lake-oriented management to provide:

(1) public access
(2) fishing piers
(3) artificial reefs
(4) safety harbors
(5) adequate work vessels for creel census, research, and fish stock monitoring
(6) a new station for the western basin

In addition to salmonid management, funding for expansion of the inshore and marsh area warmwater fisheries is anticipated. Wetland development will be coordinated with wildlife management programs.

7.1.5.2 Cost of Fish Management Programs and Development

Known costs of fish management and development programs are listed in Table 8–62. Many costs cannot be presented at this time because adequate planning has not been developed. Previous management and enforcement costs have been part of overall region or bureau budgets unrelated to specific cost for individual waters. Until recently management expenditures for Lake Ontario have been minimal. Management cost estimates will be included in the comprehensive plan.

7.1.5.3 State Costs for Enforcement of Commercial and Sport Fisheries

Commercial enforcement costs have been insignificant due to the unimportance of the fishery. For the Lake and inshore areas the 1970 expenditure was approximately $24,000. Future costs will be considerably more if a salmonid fishery is created in the Lake and tributaries.

7.1.5.4 Fishing Stocking Costs

Present cost estimates for New York to hatch, rear, and stock coho smolts are $2.40 a pound. Chinook spring fingerling cost is $9.20 a pound. These figures may change if hatchery facilities are modernized and automated. Annual costs will depend on available fish supplies for Lake Ontario.

7.1.5.5 Fish Research Costs

In addition to the cost of staffing and operating the Cape Vincent Station research projects, additional costs of State, Federal, and academic personnel associated with Lake Ontario research must be considered. These costs have not been included in Table 8–62.

7.1.5.6 Marketing Promotion Costs

New York anticipates no marketing or promotional costs for the commercial catch in the near future. Sport fish costs for support of lamprey control, stocking, acquisition, development, and habitat enhancement needs are considered part of several departmental activities and have not been isolated.

Promotion costs to teach the public how to utilize a successful fishery in the open Lake may be substantial. Cost for special gear and radio, television, and other advertising must be determined. Such information is not now available.

7.1.5.7 Gear Research and Technical Assistance Costs

Costs of special gear and technical assistance for promotion have been mentioned above. Other such costs would be covered as part of other projects.

7.1.5.8 Sea Lamprey Control Costs

The cost of stream surveys by State personnel in 1963-70 and ongoing lamprey control work has been included under station research and regional management costs. The GLFC cost of initial treatment of New York tributaries in 1972 was $79,612. Lamprey control programs will be repeated every two years. Expansion of lamprey control within the Lake drainage area to include Oneida Lake and some Finger Lakes may be desirable at a future date. No cost estimates have been made. Lamprey control by use of spawning barriers and weirs in some or all ammocete streams may be necessary in the future in place of chemical treatment. Feasibility and

TABLE 8–62 Estimated Costs of Cape Vincent Fisheries Station in Thousands of Dollars[1]

Year[2]	State Proposals	Federal Aid[3]	Stocking	Total[4]
1965	32.7	0.0	0.0	32.7
1966	33.5	6.0	0.0	39.5
1967	38.6	24.0	0.0	62.6
1968	40.0	24.0	3.0	67.0
1969	50.0	68.0[5]	14.8	132.8
1970	72.0	40.0	38.6	150.6

[1]Includes entire cost of New York's Great Lakes programming for Lake Erie, Lake Ontario, and St. Lawrence River from the Cape Vincent Station and New York State Lake Ontario fish stocking costs.

[2]New York State Fiscal Year April 1, 1965 to March 31, 1966, etc.

[3]Federal aid funds include both State and Federal shares.

[4]Does not include expenditures of Regional Fish Management Personnel.

[5]Includes $12,000 AFS funds for a fish weir constructed at the mouth of Spring Brook, Salmon River drainage.

cost estimates for physical control will be estimated under Federal Aid Project FA–2–1.

7.1.6 Projected Demands

Demands for Lake Ontario commercial fish products in the immediate future are incidental to sport fishery demands. Obviously there will be a demand for all salmonid, walleye, sturgeon, whitefish, and other high quality species available for market. The commercial demands are outlined in detail in Section 2.0 of this appendix. The problem is that the commercial demand can be satisfied only after the sport demand is met. These surplus fish must then be harvested without jeopardizing the sport fishery. Therefore, there is always the possibility that the commercial demand cannot be met.

Maximum sport fishery demand must be determined. Undoubtedly it will increase in the first years of a successful salmonid program, but it should eventually level off, and demand may not reach the maximum the Lake could safely support. Management needs would then be less than maximum production of the Lake. If management were geared to demand, and demand should exceed the safe level of maximum sustained Lake production, the fishery would collapse. The determination of these factors will be of high priority to future management of the Lake fishery. Therefore, there is a crucial need for continuous fish stock monitoring.

Sport fishery demand cannot be sensibly predicted at this time, but it seems likely that demands similar to those experienced and listed for Lake Michigan can be expected. Determination of the demands and associated cost benefit analyses will be of high priority in the comprehensive plan and future management.

7.1.7 Problems and Needs

7.1.7.1 Resource Base Problems and Needs

Most of the problems and needs related to the habitat base have been covered earlier in the report. Most habitat problems and needs common to the upper Lakes also pertain to Ontario. Unique problems such as water level fluctuations from hydrodams have also been listed.

Close coordination with intrastate, interstate, Federal, international, and Canadian agencies involved with the use and protection of the Great Lakes habitat is vital because of Lake Ontario's location. Monitoring of environmental conditions throughout the Lakes must also be coordinated.

There are potential problems of thermal discharge from nuclear power plants and other major heated discharges. Two nuclear plants are completed, another is nearly completed, and many more are proposed. Danger from dredging, filling, erosion, oil and other pollutants, and general degradation is ever present.

Funds and personnel are necessary to carry out habitat protection and enhancement programs throughout the system. Present laws can afford protection against most problems if they can be enforced.

7.1.7.2 Problems and Needs of the Total Fishery of Lake Ontario

The major fishery problems and needs alluded to throughout this report will be listed below in order of priority. To fulfill these needs, comprehensive planning and adequate funding will be required.

(1) protection and enhancement of the habitat base

(2) development of a major salmonid sport fishery through the following programs:
 (a) lamprey control
 (b) salmonid stocking
 (c) acquisition and development
 (d) promotion
(3) development of a fish stock monitoring system for the open Lake and inshore areas
(4) protection and enhancement of the existing inshore warmwater fishery
(5) development of a commercial fishery where compatible to the sport fishery
(6) automated processing of all data
(7) coordination with Ontario and upper Lakes to insure total fish management of the Lake on a sound basis
(8) research to develop management methods to solve present and predicted needs
(9) cost/benefit data to help determine the most justifiable total fishery for the Lake
(10) education of the public as to the potential of the Lake and best methods available to provide the potential and utilize the total fishery.

7.1.8 Probable Nature of Solutions

Any effort to maintain or improve the water quality of Lake Ontario will depend on water quality improvement in the upper Lakes. However, localized State efforts could have beneficial effects in embayments, estuaries, tributaries, and wetlands.

The broad protective powers mandated to the Commissioner of the Department of Environmental Conservation on July 1, 1970, provide means to prevent habitat abuse in New York State. Such authoritative power has already resulted in prevention of much degradation, and has in some instances enhanced the habitat. Continued diligent use of these powers will be necessary to solve many habitat problems.

An international and interstate authority is needed to control detrimental practices throughout the Great Lakes Basin. Comprehensive planning with all water level users on a local, State, and international basis will be required. Hopefully, the GLBC can help fulfill this need in conjunction with other offices.

Comprehensive programming and coordination of fish and wildlife management will prevent destruction of habitat. For example, development of waterfowl areas at the expense of fish spawning runs cannot be tolerated, nor can the breaking of barrier bars that retain wetland water levels to provide fish access to the interior. Both needs can be met if properly and cooperatively planned and managed.

New York has passed stringent regulations on the use of phosphates, application of chemicals, violation of State water quality standards, and activities harmful to the habitat. New York field and administrative personnel are expending more of the available manpower and funds to protect the habitat base. If all Great Lakes States and Provinces do the same, degradation processes in Lake Ontario could be reversed, even with increased use of the aquatic resource.

Basically, the fishery resource is divided into inshore warmwater species such as bass, yellow perch, and sunfish, and salmonid species that will utilize the open lake as well as inshore and tributary waters. Forage fish are available to support predators. Various low-value species complete the fish stocks. This is a change from the usual concept of sport and commercial species. The commercial fisheries in Lake Ontario must be completely controlled and compatible or complementary to the sport fishery.

Solutions to the problems and needs of Lake Ontario are the same as those discussed in the upper Lakes. A comprehensive outline of the Ontario Fish and Wildlife management plan is now available. It is a detailed reference to proposed solutions of the problems and needs of the Lake Ontario resources and uses.

Lake Ontario has the potential to provide the public with the greatest fishery in the State and one of the greatest in the nation, but first, professional fish managers have to develop it through sound planning and research.

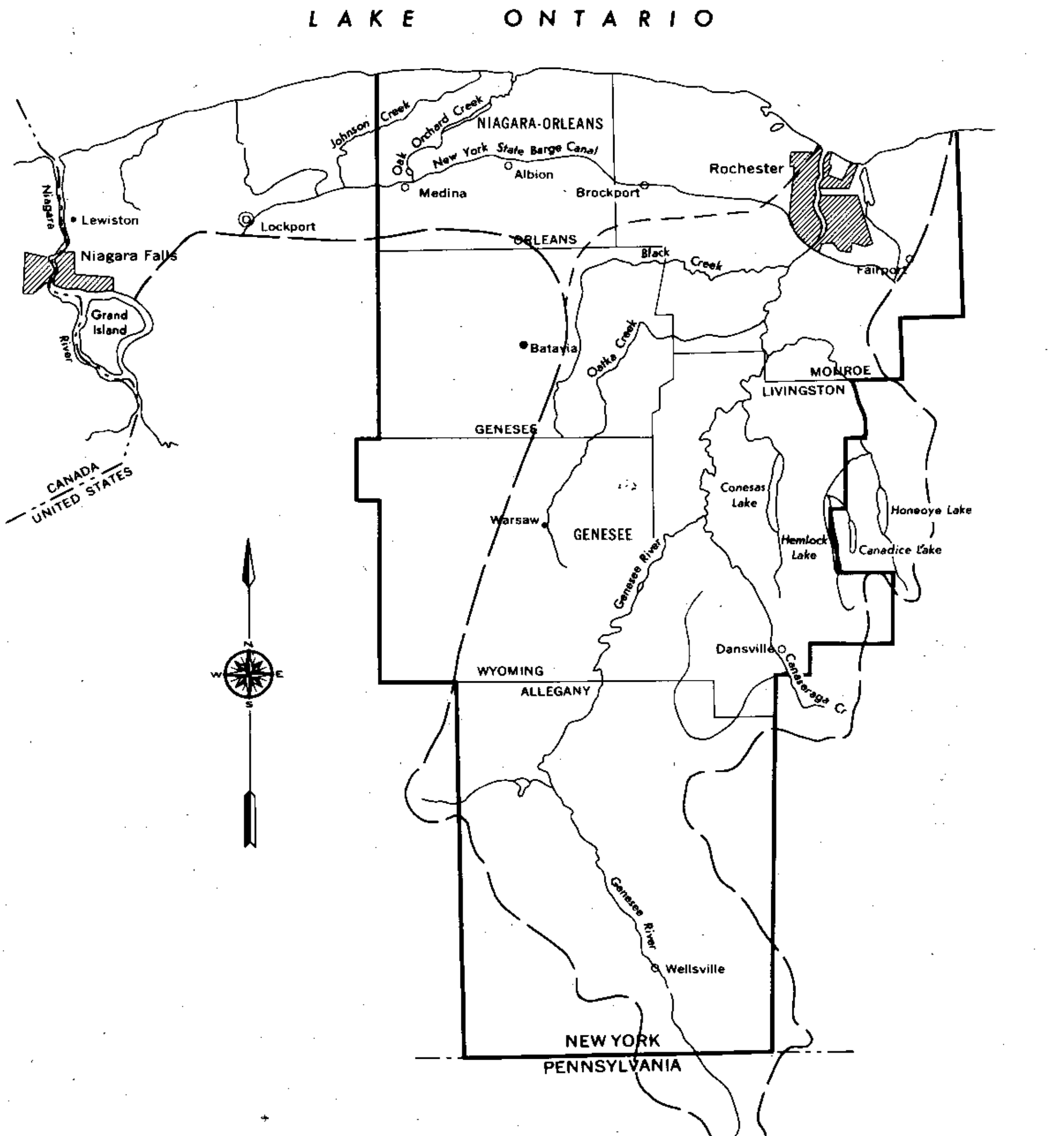
7.2 Planning Subarea 5.1

This planning subarea includes six counties in New York (Figure 8–88).

7.2.1 Species Composition, Relative Importance, and Status

New York State is currently engaged in a Statewide water resource planning program. Detailed fishery plans will be included in the State's Genesee Basin Plan. Much of the data in this report was obtained from the Genesee Basin Plan files.

The waters of this planning subarea offer considerable variety in fish habitat, and there are a large number of important species. Yel-



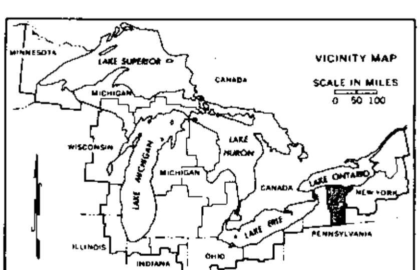


FIGURE 8–88 Planning Subarea 5.1

TABLE 8–63 Summary of Base Year Fish Habitat and Management Efforts, Planning Subarea 5.1

County	Total Area (sq.mi.)	Acres[1] Ponded Waters	Number[1] Ponded Waters	Number Intensively Managed	Acres Intensive Warmwater	Acres Intensive Trout	Miles Total Streams	Miles Trout Streams
New York								
Allegany	1,048	1,038	310	4	-----	631	116	83
Wyoming	598	1,005	236	3	815	2	80	65
Livingston	638	5,355	461	4	3,251	1,858	178	75
Genesee	501	206	116	1	47	-----	32	8
Monroe	673	3,306	317	2	2,055	-----	112	13
Orleans	396	766	642	1	-----	335	40	--
Ontario[2]	-----	2,291	2	2	1,670	621	6	--
Total	3,854	13,967	2,084	17	7,838	3,447	564	244

[1] Includes Farm Ponds.

[2] Only Honeoye Lake and Canadice Lake in Genesee Watershed are included.

low perch, northern pike, walleye, smallmouth bass, and largemouth bass are the most important warmwater species. Chain pickerel, black crappie, rock bass, common sunfish, bluegill, carp, bullhead, catfish, and suckers are less important. Lake and rainbow trout occur in three lakes and provide moderately important fisheries.

The rivers and streams provide both warmwater and coldwater fisheries. Smallmouth bass, walleye, northern pike, and rock bass are the principal warmwater species, and brown trout is the predominant coldwater fish. Brook trout and rainbow trout occur in a few streams.

Wiscoy Creek in Wyoming County and the upper Genesee River in Allegany County are considered among the top 50 trout streams in the State. Spring Creek in Monroe and Livingston Counties and sections of Oatka Creek in Monroe County provide exceptionally high-quality trout fishing.

There is good potential for the improvement or enhancement of many of the waters through pollution abatement, better access, stream improvement, special regulation, water level control, and stocking.

7.2.2 Habitat Distribution and Quantity

The natural lakes, ponds, reservoirs, and farm ponds provide 13,967 acres of fishable water. The bulk of this acreage is located in the lower or northern portion of the basin (Figure 8–89 and Table 8–63). There is a need for additional lake-type fisheries in the upper portion of the basin.

7.2.3 Habitat Problems Affecting Production and Distribution of Important Fish Species

Fishing potential is limited by water pollution caused by sewage, other nutrients, industrial wastes, and pesticides. It occurs in all parts of the basin and affects both stream and lake environments. The effects of eutrophication are becoming more apparent in Conesus, Honeoye, and Silver Lakes and in the bays along Lake Ontario. Destruction of stream trout by pesticides has been a problem in areas adjacent to potato fields. Pollution effects are accentuated during periods of low flows.

High intensity of boat use and the development of shorelines is a problem on the larger lakes. Because of water skiing and boating it is difficult to fish some of the lakes during daytime hours, especially on weekends. Fish spawning habitat has been destroyed by filling for cottage development.

Drawdown and water level regulation are problems on some of the lakes. Yearly water level fluctuations as great as 65 feet occur as water stored in Rushford Lake is released to help maintain the volume of the Genesee River for power generation. Lowering of water levels after northern pike spawn in the spring of the year has been a problem on Silver and Conesus Lakes.

Destruction of trout stream habitat through gravel removal and channel dredging is a problem which has been brought under control recently by the implementation of Section 429 of the Conservation Law (Stream Protection Law). Irrigation is a growing threat to some of the trout stream resources of the basin. The reduction of flows during low water periods may threaten trout survival or seriously interfere with the reproduction of these fish.

Flooding that results in the erosion of stream banks is common to most streams in the basin. Protection of trout stream habitat from serious erosion is a continual problem.

7.2.4 History of Sport Fishery

Both trout and warmwater fisheries have been important for many years. There has been a steady increase in the utilization of the stream and lake fishery resources over the last 30 years. Fisherman use of the better trout streams including the upper Genesee River, Wiscoy Creek, Oatka Creek, and Spring Creek has recently reached peak levels. A rainbow trout fishery of moderate size has developed in Springwater Creek since 1960. The lakes are also heavily fished during the summer, and several of them support winter fisheries. A large winter fishery for yellow perch has developed on Conesus Lake. On the other hand, there has been deterioration due to pollution in some formerly important warmwater fisheries, particularly Irondequoit Bay and Braddock Bay.

7.2.5 Existing Sport Fishing Demand and Current Needs

From field surveys it was determined that fishing use of the Genesee basin's lakes and streams amounted to 370,000 man-days in 1964. This use was attributable to 80,000 fishermen who spent an average of five days each, fishing in the basin. Approximately 50 percent of this number are from the Buffalo metropolitan area. Base year and projected angler day demand is shown in Table 8–64.

7.2.6 Ongoing Programs

Protection of stream and lake habitat is an important segment of the ongoing programs. Protection is afforded through the implementation of Section 429 of the Conservation Law known as the Stream Protection Law. Under this legislation, permits are required for any work by agencies or individuals in certain classified waters including all navigable waters to the highwater mark. Abatement programs dealing with major sources of pollution are also under way.

Current fish management programs include stocking, stream improvement, and special fishing regulations (Figure 8–90 and Table 8–63). The trout stocking program totals 100,000 yearling trout and 22,000 fingerling trout annually. The species stocked are lake trout, rainbow trout, brown trout, and brook trout. Two-story stocking (warmwater and trout combination) with rainbow trout is being tried in Conesus Lake. Warmwater stocking is limited to walleye fry in several of the warmwater lakes and bays.

Stream improvement has been completed in the larger trout streams and this work is continuing when funds are available. The work includes bank stabilization with plantings and instream structures to provide better cover and pools.

Special regulations help provide quality fishing on sections of Wiscoy Creek and Oatka Creek. Under these regulations trout may be taken only by angling with artificial lures and anglers are limited to three trout not less than 12 inches long.

7.2.7 Future Trends in Habitat and Participation

By 1980, those seeking fishing opportunities in the basin will number 136,000 and the extent of their use (if the resources are available to support it) will amount to 2.1 million man-days annually. Of the 136,000 fishermen, 30,000 would come from the latent demand group.

With adequate public support, the Division of Fish and Wildlife in New York State and the Fish and Game Commission of the Commonwealth of Pennsylvania will be able by 1980 to raise present capabilities of the basin's fishery resources to the level of supporting 715,000 man-days of use. This will be done as a part of the ongoing State programs.

The rate of increase in needs related to fish and wildlife, however, is too rapid to be met entirely by the normal management and development programs of the responsible State agencies. If a large measure of the anticipated needs of 1980 are to be served, then such programs will have to be augmented very substantially by early institution of measures to overcome specific problems.

For fisheries the important problems are lack of public access, pollution, periods of extremely low or extremely high flows, use of

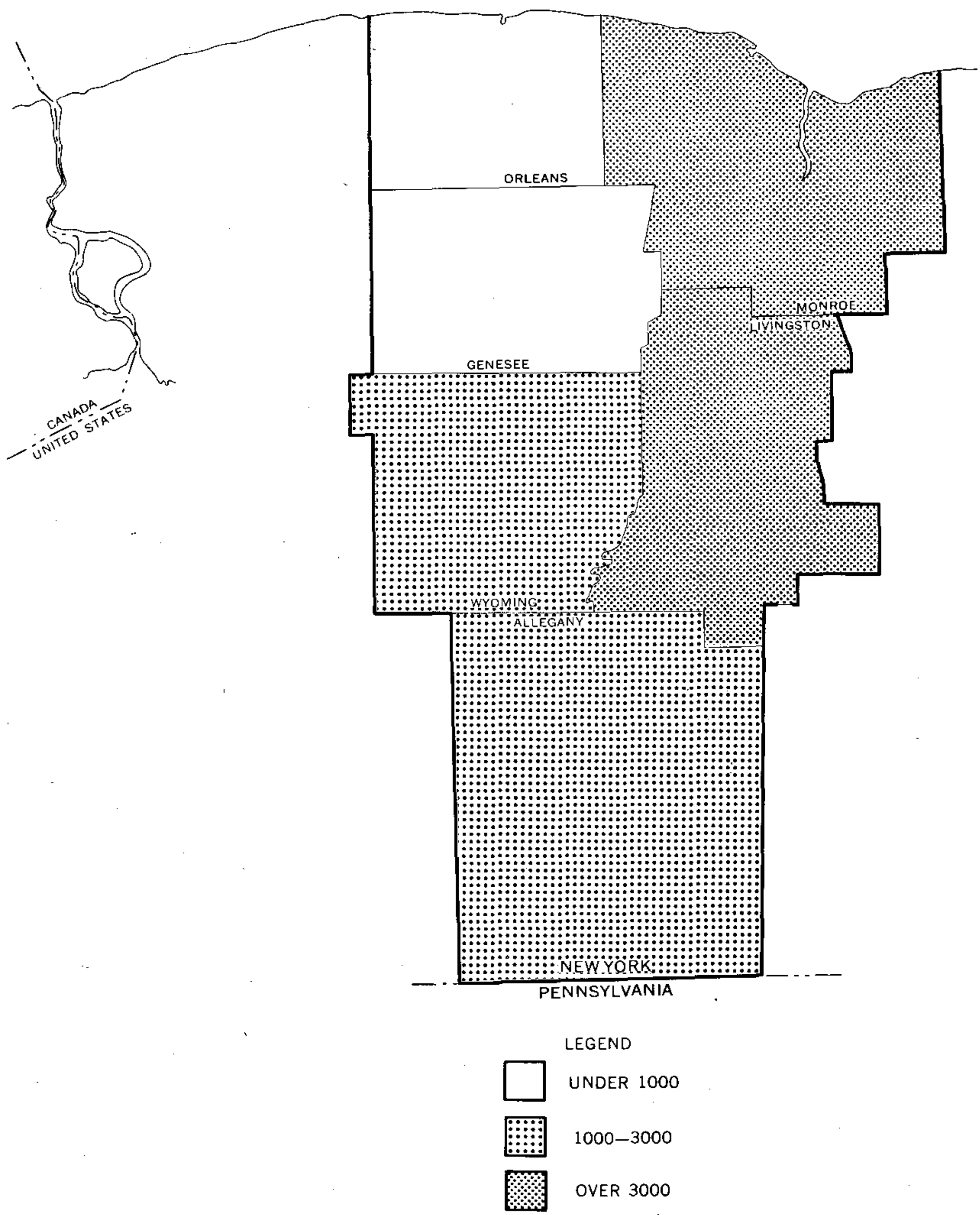


FIGURE 8–89 Acres of Ponded Water, Planning Subarea 5.1

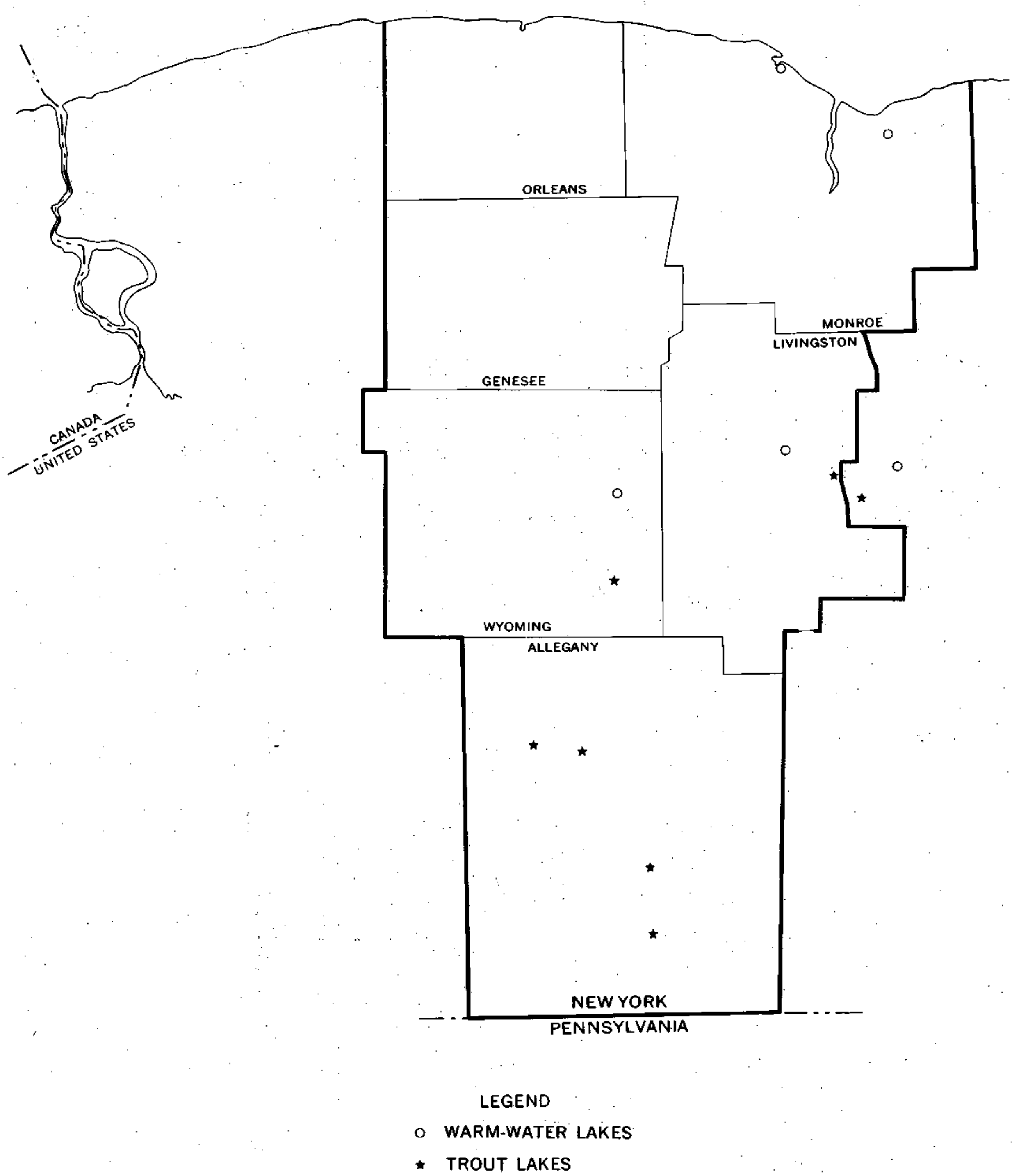


FIGURE 8–90 Current Fish Stocking Program, Planning Subarea 5.1

TABLE 8–64 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 5.1

State and Counties	Land Area (sq.mi.)	Population (1000s)	Population per sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
New York								
Allegany	1,043	43.9	42.1	1,293	.0295	337	4,909	.1118
Genesee	500	59.8	119.6	196	.0033	22	5,033	.0842
Livingston	636	50.5	79.4	5,186	.1027	72	4,904	.0971
Monroe	673	655.6	974.1	3,366	.0051	566	52,443	.0800
Orleans	394	37.7	95.7	556	.0147	26	4,474	.1187
Wyoming	595	37.6	63.2	1,266	.0337	74	3,857	.1026
Total	3,841	885.1	230.4	11,863	.0134	1,097	75,620	.0854

State and Years	Land area (sq.mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand: Resident[1]	Projected Angler Day Demand: Total[2]
New York					
1980	3,841	978.2	254.7	2,488,605	2,581,000
2000	3,841	1,221.8	318.1	3,108,340	2,798,000
2020	3,841	1,538.0	400.4	3,912,774	3,511,000

[1]Demand generated within planning subarea.

[2]Total demand including in- and out-migration.

surface water for irrigation, and an insufficient amount of fishery habitat.

Under a single-purpose fish and wildlife plan developed by the Fish and Wildlife Service and the New York State Division of Fish and Wildlife, the capability of existing resources augmented by the creation and development of new habitat would make 2.0 million man-days of fishing opportunity available by 1980.

7.2.8 Fishery Development Plans

In order to meet the 1980 needs, ongoing programs to preserve and enhance existing fishery resources must be continued and expanded. Anadromous stream fisheries can be developed in the lower Genesee River and the Irondequoit Bay system (Figure 8–91). Allen Lake in Allegany County needs repairs to the dam and chemical rehabilitation.

Additional programs to meet 1980 needs include stream access (Figure 8–92 and Table 8–65), pollution abatement, and the development of new fishery habitat. A substantial part of the plan for meeting future needs consists of the development and management of new waters for fishing. The fish and wildlife plan includes the construction of Stannard and Tuscarora dams and reservoirs which together would provide 216,000 man-days of trout fishing annually, and the Portage Dam and Reservoir which would handle 492,300 man-days of warmwater fishing. Their combined potential represents 34 percent of the anticipated 1980 needs. The development and management of 17 smaller upland reservoirs would create 485,200 additional man-days of fishing.

7.3 Planning Subarea 5.2

This planning subarea includes 12 counties in north-central New York (Figure 8–93).

7.3.1 Species Composition, Relative Importance, and Status

New York State is currently engaged in a Statewide water resources planning program. Detailed fisheries plans will be included in the State Oswego River Basin Plan. Much of the data included in this report were obtained from the Genesee Basin Plan files.

The waters of Planning Subarea 5.2 are complex. They offer an excellent variety and abundance of fish habitat and consequently a large number of important sport species. This presents a problem in determining the most important species on a priority basis.

Lake and rainbow trout are extremely valuable sport fish in the Finger Lakes. Brown,

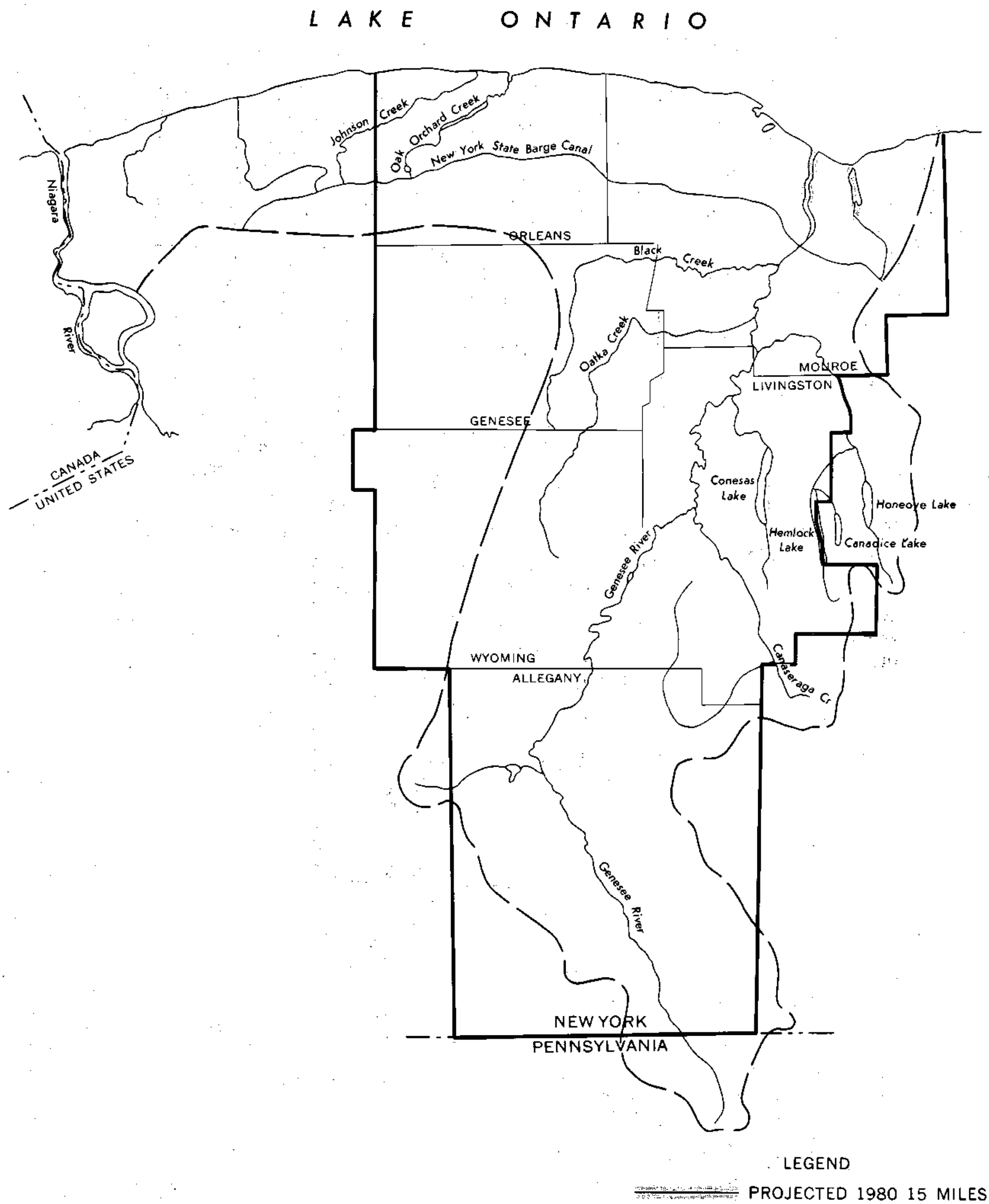


FIGURE 8–91 Anadromous Stream Fishery, Planning Subarea 5.1

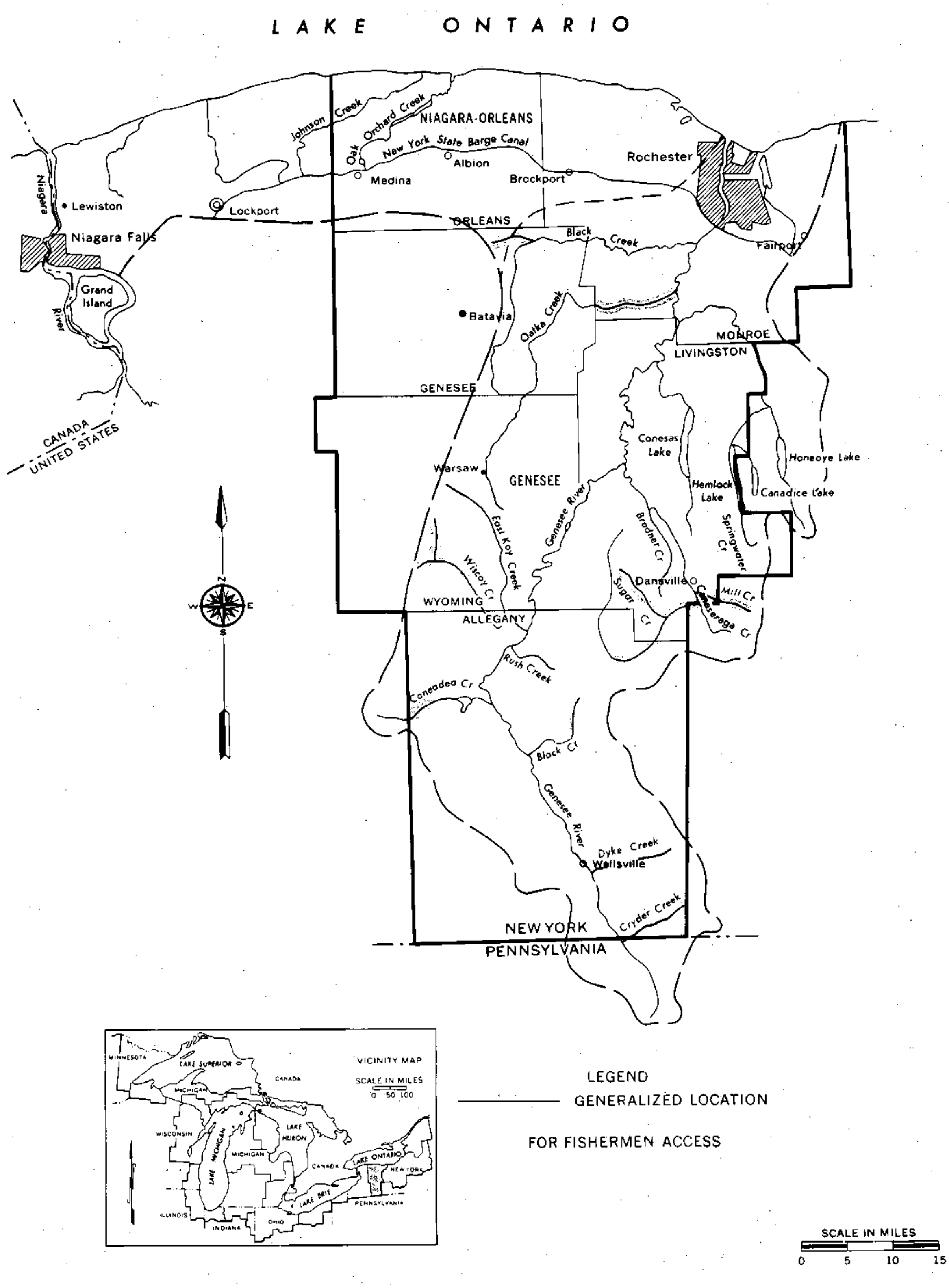


FIGURE 8–92 Priority Stream Acquisition Areas, Planning Subarea 5.1

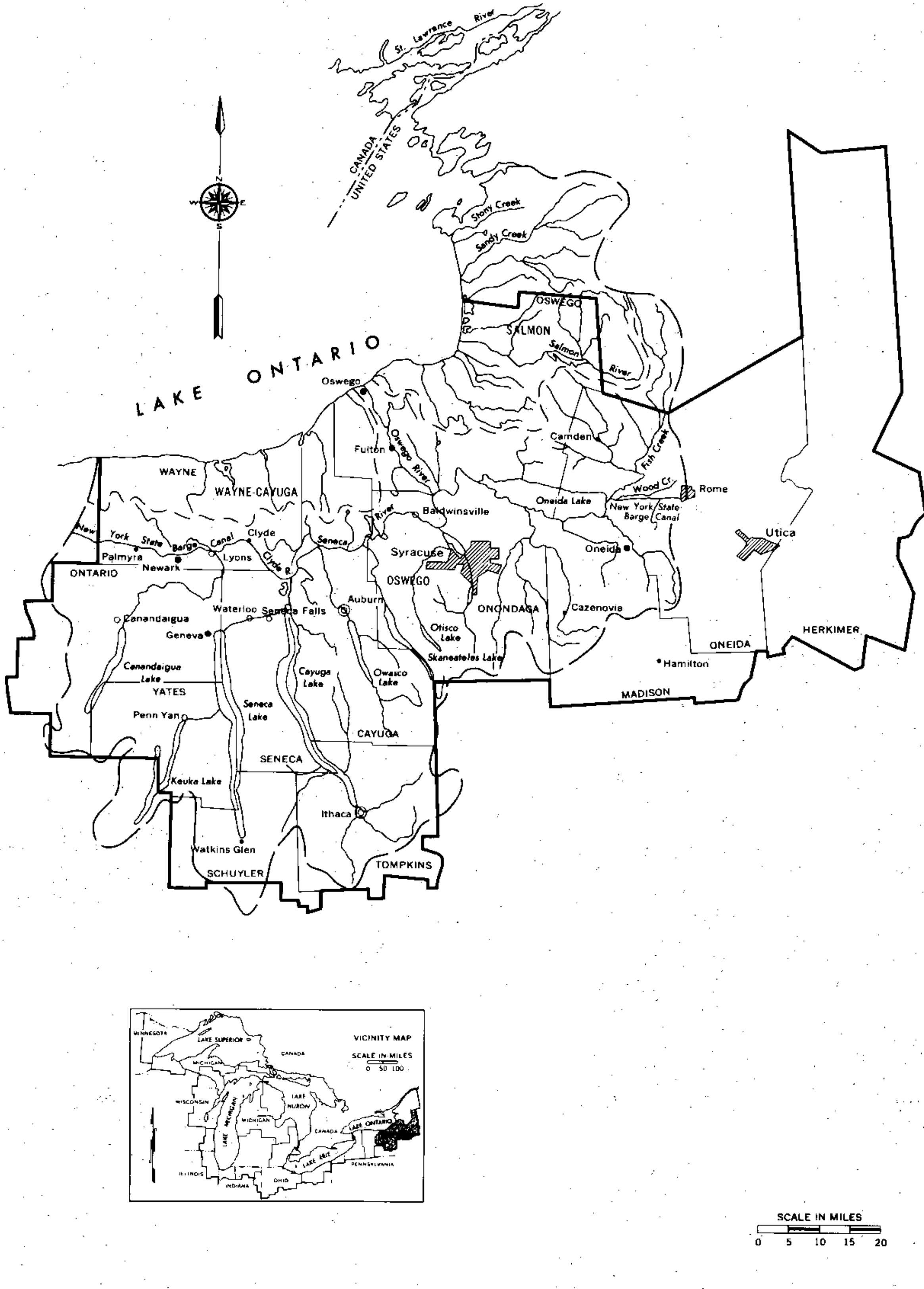


FIGURE 8–93 Planning Subarea 5.2

TABLE 8–65 Priority Stream Acquisition Needs, Planning Subarea 5.1

County	Stream	Miles	Acres	Cost
Genesee	Spring Creek	4	6	$10,000
Monroe	Oatka Creek	4	24	16,000
Livingston	Canaseraga Creek	5	9	12,500
	Spring Creek	0.5	1	2,000
	Springwater Creek	4	6	14,000
	Sugar Creek	10	15	20,000
	Bradner	4	4	8,000
Wyoming	Wiscoy Creek	6	18	21,000
	Trout Brook	5.5	7	16,500
	N. Branch Wiscoy	5	5	15,000
	East Koy Creek	6	15	21,000
	Oatka Creek	4	5	8,000
Allegany	Black Creek	3	7	6,000
	Rush Creek	3	4	4,500
	Caneadea Creek	4	10	6,000
	Genesee River	6	36	12,000
	Dyke Creek	7	17	14,000
	Cryder Creek	8	20	16,000
	Canaseraga	8	15	20,000
Total		97	224	$242,500

brook, and rainbow are important to the trout stream fishery. Atlantic salmon have provided good limited angling in the Finger Lakes when suitable smolt stock has been available. Kokanee salmon have been successfully stocked in a few waters but are of minor importance to date. Coho salmon stocking by New York since 1968 and the Province of Ontario since 1969 has provided some angling and holds considerable promise for the future if sea lamprey control scheduled in Lake Ontario is successful. Resident-strain rainbow and west coast-strain steelhead may also provide excellent angling if lamprey control is a success. Dipping for smelt at spawning time is very popular in many Lake Ontario tributaries as well as some Finger Lakes streams.

Smallmouth bass, walleye, and northern pike are very important in the rivers and ponded waters throughout the area. Largemouth bass and chain pickerel *(Esox niger)* have moderate importance as game fish.

Panfish such as yellow perch, rock bass, sunfish, bullheads, crappies, and white perch are listed in their order of importance to the sport fishery. Channel catfish, suckers, carp, and eels are of minor importance in the overall sport fishery. Alewife serve as a forage species for large salmonids.

Until recently, several species of minnows were of great commercial value to bait dealers. However, farms in other States have relegated native bait minnows to minor importance.

A small commercial set line fishery exists in Oneida Lake and carp seining under special permits occurs in a few area waters.

Sea lamprey are present in Cayuga and Seneca Lakes as well as Oneida Lake.

7.3.2 Habitat Distribution and Quantity

Planning Subarea 5.2 has an abundance of good fishable waters, particularly in Seneca, Cayuga, Oswego, and Oneida Counties (Figure 8–94). Proper management of existing water should supply angler needs through 1980. Brook trout ponds may be constructed in the Tug Hill section of Lewis, Oneida, and Oswego Counties.

There are 1,181 miles of trout streams and 371 miles of warmwater streams, rivers, and canals (Table 8–66). Most are productive angling waters, but pollution abatement is necessary in some sections. In addition, there are many miles of smaller streams that provide some angling and fish spawning habitat.

Major lakes cover 182,890 surface acres (Figure 8–94). Lesser lakes and ponds total 5,450 acres. Included in the total are the unique Finger Lakes of New York State. There are also several hundred farm ponds within the area.

7.3.3 Habitat Problems Affecting Production and Distribution of Important Fish Species

Industrial, agricultural, and domestic pollution are the major problems throughout the area. The drainage is a major source of pesticide, phosphate, and mercury pollution in Lake Ontario and the St. Lawrence River. In 1970 Onondaga Lake was closed to all fishing due to very high levels of mercury in fish. The outflow eventually reaches Lake Ontario via the Oswego River. Thermal pollution presents a potential problem, particularly in the Finger Lakes region.

The famed vineyards of the Finger Lakes region as well as its orchards and muck farms have accounted for large quantities of pesticide and inorganic fertilizer pollution. All have contributed to high pesticide levels in certain species of fish. Excessive algae and

TABLE 8-66 River and Stream Fisheries, Planning Subarea 5.2

Region[1]	Trout Miles	Trout Acres	Warmwater Miles	Warmwater Acres
1	63	103	146	1,658
2	49	61	2	15
3	507	800	157	2,570
4	562	854	66	2,988
Total	1,181	1,818	371	7,231

[1] New York State Department Environmental Conservation Regional Fish & Wildlife Offices.

Region 1 - Wayne, Ontario, Yates, Seneca Counties.
Region 2 - Steuben, Schuyler, Chemung Counties.
Region 3 - Cayuga, Tompkins, Ononadaga, Cortland, Madison Counties.
Region 4 - Oswego, Oneida, Lewis Counties.

noxious rooted aquatics are also symptoms of eutrophication caused by pesticides and inorganic fertilizers.

Domestic sewage comes from residential, school, restaurant, and business complexes. In addition, cottage owners contribute excessively to the pollution of many waters in the planning subarea. Fluctuating water level is a problem on many waters (Table 8–67). The New York State Barge Canal System has a vital effect on habitat through navigational pollution, and it causes large water level fluctuations. Dredging and dumping of spoil, primarily in the Barge Canal System, has been a real problem. Irrigation and poor logging practices also contribute to degradation.

Natural and man-made barriers are a problem to anadromous fish management. Suburban expansion and increased population have brought activities causing habitat degradation. Highway construction and private development along stream and lake shores also contribute to the overall problem.

Closely associated with habitat deterioration are high water temperature, flooding, erosion, dry stream beds, and siltation. In addition to problems created by man, beavers have caused tremendous deterioration of high-quality streams in the past 20 years. This is particularly true of spring streams in upper Salmon River, and Fish Creek tributaries located in the Tug Hill section. Cutting of cover and shallow flooding of vegetation create drastic changes in the water quality of once excellent trout streams. Because of the low value of beaver pelts and historical sympathy for the picturesque rodents, these areas have too many beavers for the resource to handle.

Fluctuation of water levels in Lake Ontario, partially due to drawdown by New York State and Ontario hydroelectric plants on the St. Lawrence River, creates low water levels in estuaries and important marshes near some stream mouths. These low water levels are very detrimental to reproduction of many species of fish and affect available fish stocks.

The abundance of large deep lakes and major stream systems has helped prevent deterioration of the aquatic habitat in the area until the past few years. Morphometric data for several of the planning subarea's lakes are shown in Table 8–68.

Competition for recreational water use and lack of public access to some waters are problems related to habitat availability that must be solved.

7.3.4 History of Sport Fishery

Both salmonid and warmwater fisheries continue to be important. Atlantic salmon from Lake Ontario were abundant in many streams until the advent of dams and pollution around 1880. The Salmon River was aptly named. Large native brook trout were plentiful in streams and lakes in early times. Until the late 1930s brook trout over two pounds were common in Redfield Reservoir and the upper branches of Salmon River. Habitat deterioration has created abrupt changes in the past three decades.

Salmonid fishing has improved through modern fish management. Research by Cornell University and Conservation Department personnel paved the way for improved lake trout, rainbow trout, and salmon fishing in Cayuga and some other Finger Lake waters. A few years ago only Catherine Creek, a tributary to Seneca Lake, was famous for spring run rainbow trout fishing. In recent years, several tributaries to other Finger Lakes have become excellent rainbow streams.

Introduction of brown trout many years ago enabled certain streams such as Fish Creek to provide fair-to-good angling.

Coho, chinook, and kokanee salmon have been stocked by New York and Ontario in conjunction with the Great Lakes Fishery Commission's fisheries program. In 1968 the first coho were stocked in a tributary pond of Salm-

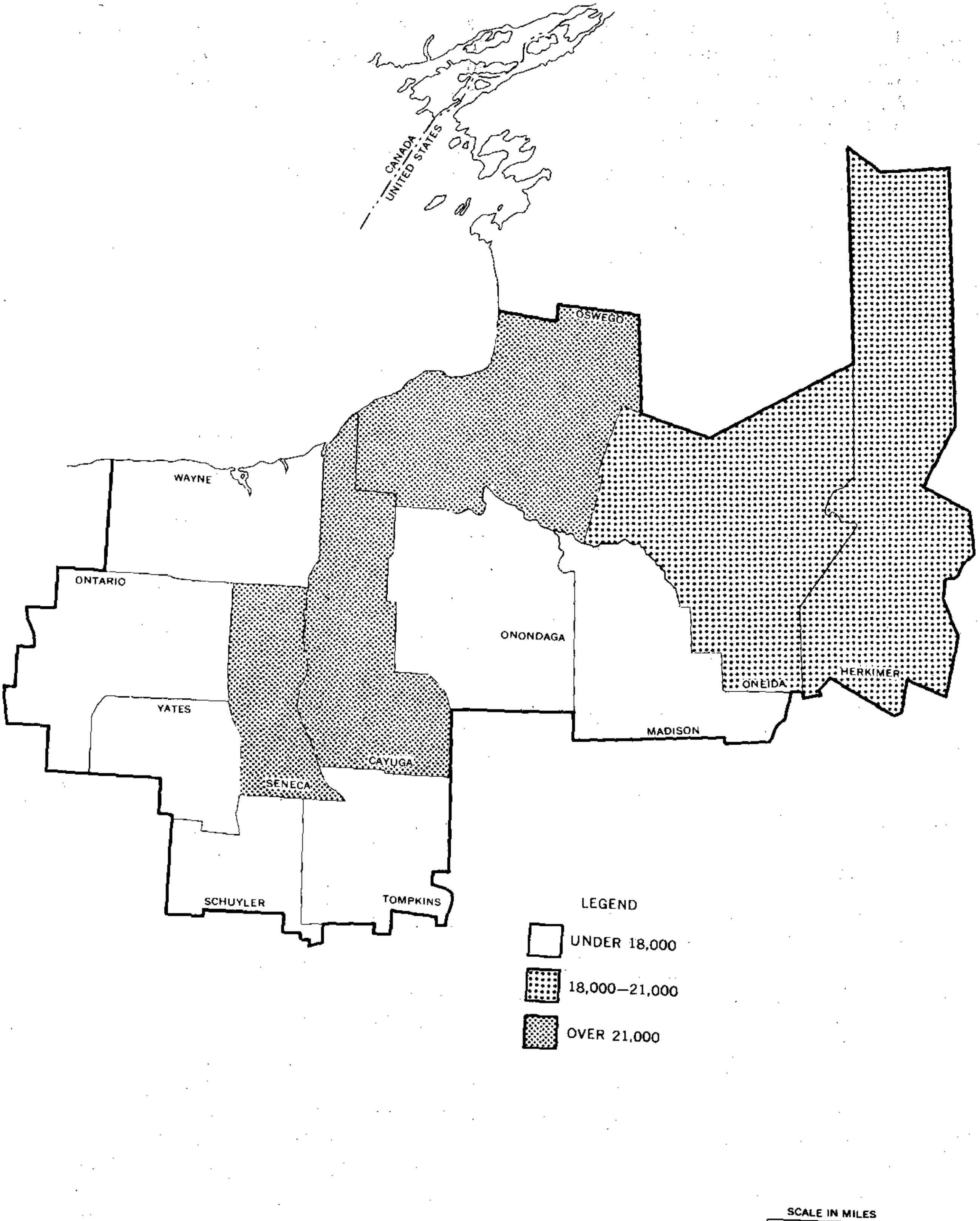


FIGURE 8-94 Acres of Ponded Water, Planning Subarea 5.2

on River. Some limited coho fishing has been provided. If proposed lamprey control is successful for Lake Ontario, coho and chinook salmon as well as rainbow trout fishing may soon be of major importance in the lower reaches of anadromous streams.

Smelt dipping has become a major spring fishery in several Lake Ontario tributaries since the early 1950s. Cayuga Lake provided such a fishery before 1950.

Oneida Lake continues to be one of the best warmwater fishing lakes in the East. Walleye and bass fishing are still excellent there, as well as angling for such panfish as yellow perch, bullheads, crappies, and sunfish. Good fishing is available for most of these species throughout the area. Factors relating to warmwater species management have been studied in detail by Cornell University biologists at Shackelton Point Research Laboratory. The program is primarily funded through State-sponsored Dingell-Johnson studies.

In recent years a major northern pike fishery has been built in Seneca Lake because its heavy aquatic plant growth provides a food source. The Oswego, Seneca, and Oneida Rivers still provide fair-to-good warmwater fishing, but pollution and excessive pleasure boating have curtailed fishing considerably.

Although considerable deterioration has taken place in certain waters, present fishing opportunity is considered good. If proper management practices are instituted, the future sport fishing potential could be better than existing conditions.

7.3.5 Existing Sport Fishing Demand and Current Needs

Sport fishing demand can be met with existing resources through 1980 if properly managed and developed. A considerable influx of unpredicted angling pressure could also be absorbed, particularly if new anadromous fish research projects were successful in Lake Ontario and inland lakes. Base year and projected angler day demand is shown in Table 8–69.

Tables 8–70 and 8–71 compiled for the New York State Oswego Basin Fishery Resource Plan are estimated on an average of 5 to 18 angling days per year per angler. The estimate does not include anglers below age 15 or waters in the Salmon River, Little Salmon River, and other small drainages outside the Oswego drainage but included in Planning Subarea 5.2.

Projections obtained for this study have been estimated at 3,428,048 current angler days and 4,045,064 for the year 1980. This projection was based on an average of 10 angler days per year per angler.

In recent years angler use on some waters in the area has substantiated the conservativeness of these estimates. For example, Green Lake, 60 acres in Green Lake State Park, provided 99 angler days per acre per year without use of boats. Chenango Valley State Park's Lily Lake provided 362 angler days per acre per year. Small trout ponds provide approximately 500 man-days per acre per year.

7.3.6 Ongoing Programs

Environmental protection and improvement has the highest priority in ongoing programs. Protection is afforded through implementation of Section 429 of the Conservation Law, commonly called the Stream Protection Law. Permits are required by individuals, agencies, or corporations before work can be carried out in certain classified waters, including navigable waters to the high-water mark. Pollution abatement is underway through the State's Pure Waters Program.

As of July 1, 1970, the New York State Conservation Department became the Department of Environmental Conservation. Many administrative responsibilities for protection of the environment, previously shared by several agencies, were placed directly under the Commissioner of the reorganized Department. The change will expedite present and future habitat improvement programs.

Acquisition needs on 83 streams involving 459 miles of trout water, 12 boat access sites on warmwater rivers and streams, 17 angler access sites on major lakes, and 21 sites on smaller ponded waters will be purchased as money becomes available.

Stream improvement has been completed in large trout streams throughout the area. Bank stabilization, including plantings and instream structures to provide cover and pools, is recommended on 355 miles of stream when funds become available.

Special research projects involving warmwater species management, lamprey control, rainbow and lake trout production, and practicality of artificial spawning channels are being conducted in the Finger Lakes by Cor-

TABLE 8-67 Effects of Water Level on Fish and Wildlife, Oswego Basin

Lake	Water Level Elevations and Effects on Wildlife[1] Flood Stage	Normal	Low	Best	Damage Begins	Tolerable Limits	Agency Responsible for Regulation	Comments
Canandaigua	689'	688'	684' (686.7')	688'	686'	687'-689'	City of Canandaigua	High Tor Marsh is dry at elevation 685.5'.
Keuka	717' (715.5')	713.5'	(712.5')	---[2]	---[2]	---[2]	Village of Penn Yan	No apparent effect on fish or wildlife under present regulations.
Seneca	446.5'	445.5'	442.5' (445.3')	---[2]	---[2]	---[2]	N.Y. Electric & Gas Co. & N.Y. State Dept. of Transportation	Lake level has little effect on adjacent marshes.
Cayuga	383.5'	382'	378.5' (381.8')	383'	380.5'	381'-383.5'	N.Y. State Dept. of Transportation	Canoga Marsh would be dry at elevation 380'.
Owasco	714.7'	710'	(709.3')	---[2]	---[2]	---[2]	City of Auburn	Drawdown after Nov. 1 limits Lake Trout reproduction. Marsh not dependent upon lake level.
Skaneateles	865.2'	863'	(860.3')	---[2]	---[2]	---[2]	City of Syracuse	Potential effect on Lake Trout reproduction if drawdown comes after Nov. 1.
Otisco	791.3'	788'	(782.6')	788'	786'	787'-791'	N.Y. State Dept. of Transportation	Summer and fall drawdown adversely affect fish and wildlife.
Oneida	371.6' (370.6')	369'	368.5' (368.6')	374.6'	370'	---	N.Y. State Dept. of Transportation	Desirable level for wildlife is higher than flood stage of 371.6'. Diking may be necessary to realize full potential of marsh lands.

[1]Mean elevations are shown in parentheses. All elevations are U.S. Coast and Geodetic Survey Datum (Mean sea level).

[2]Water level in adjacent marshes is not dependent on lake level or the marsh area is insignificant.

TABLE 8-68 Morphometric Data, Planning Subarea 5.2

Lake	Area Acres	Sq.Mi.	Drainage (sq.mi.)	Depth in feet Maximum	Mean	Shoal Area to 20' (acres)	Percentage Lake Area	Maximum in miles Length	Width
Canandaigua	11,456	17.9	189	274	127	1,922	16.8	15.5	1.5
Seneca	43,264	67.6	714	633	289.6	5,591	12.9	35.1	3.0
Cayuga	42,816	66.9	780	435	178.8	10,906	25.5	38.1	3.5
Keuka	11,584	18.1	179	183	99	1,209	10.4	19.6	1.9
Owasco	6,592	10.3	208	177	95	1,028	15.6	11.1	1.25
Skaneateles	8,896	13.9	73	297	142.7	1,444	16.2	15.0	1.4
Otisco	1,856	2.9	34	70	-----	946	50.9	5.8	0.8
Onondaga	3,040	4.75	240	73	-----	762	25.1	4.6	1.2
Oneida	51,072	79.8	1,265	55	25	19,890	38.9	20.8	5.5
Cross	2,176	3.40	-----	64	-----	1,062	48.8	4.5	1.0
Cazenovia	1,100	1.72	10	48	-----	588	53.5	3.7	0.7

TABLE 8-69 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 5.2

State and Counties	Land Area (sq.mi.)	Population (1000s)	Population per sq. mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
New York								
Cayuga	696	75.1	107.9	25,646	.3415	180	8,729	.1162
Herkimer	1,416	67.7	47.8	19,429	.2870	333	8,084	.1194
Madison	660	57.6	87.3	1,207	.0210	197	8,303	.1441
Oneida	1,218	282.0	231.5	20,689	.0734	308	28,633	.1015
Onondaga	790	457.8	579.5	14,854	.0324	488	45,554	.0995
Ontario	648	76.6	118.2	10,651	.1390	284	9,638	.1258
Oswego	964	96.4	100.0	32,439	.3365	248	14,622	.1517
Schuyler	329	16.7	50.8	7,074	.4236	514	3,077	.1843
Seneca	329	33.8	102.7	56,934	1.6844	295	4,633	.1371
Tompkins	481	74.7	155.3	9,281	.1242	216	7,525	.1007
Wayne	606	74.2	122.4	4,917	.0663	151	10,762	.1450
Yates	343	19.5	56.9	8,828	.4527	296	3,101	.1590
Total	8,480	1,332.1	157.1	211,949	.1591	3,510	152,661	.1146

State and Years	Land Area (sq.mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand	
				Resident[1]	Total[2]
New York					
1980	8,480	1,571.7	185.3	5,395,940	6,496,000
2000	8,480	2,015.9	237.7	6,920,961	8,252,000
2020	8,480	2,556.5	301.5	8,776,942	10,387,000

[1]Demand generated within planning subarea.

[2]Total demand including in- and out-migration.

nell University through cooperative State-Federal programs.

A Lake Ontario anadromous fish project in cooperation with the Province of Ontario was started in 1968. Coho and chinook salmon have been stocked in various tributaries. Salmon River and Little Salmon River have received most of New York's stocking. A collecting weir has been constructed at the mouth of Spring Brook on the Salmon River near the Village of Pulaski to monitor fish runs.

Tributaries to Lake Ontario have been surveyed and laid out for proposed lamprey control by control crews funded by the Great Lakes Fishery Commission. An expanded Federal Aid Anadromous Sport Fish (AFS) and Dingell-Johnson (D-J) joint project has been proposed for the State's Great Lakes Fisheries Research Station, Cape Vincent. If successful, the anadromous program will greatly increase fish populations and fishing pressure within the next few years. Hatchery needs, fishways, spawning channels, and other structures will be considered then.

Current fish management programs by the four regional Fish and Wildlife Offices include:

(1) fish collections to determine existing pesticide, mercury, and other pollution levels

(2) biological surveys of troubled waters to determine feasibility of special management practices

(3) administration of the Stream Protection Law

(4) stream and lake reclamation where desirable

(5) special season and size regulations for quality fishing in certain waters

(6) two-story management of rainbow trout and bass in certain waters

(7) annual stocking of lake, brook, brown, and rainbow trout as well as walleye fry stocking

Evaluation of walleye fry stocking is being conducted by Cornell's research staff at Shackelton Point and regional biologists.

7.3.7 Future Trends in Habitat and Participation

Existing available waters in the area are capable of supporting angler need to 1980 and

TABLE 8–70 Present and Projected Angler Day Demand, Oswego Basin

Item	1965	1985	2000	2020
Population in Service Area[1] age group (15-69)	1,541,028	2,078,252	2,562,769	3,363,411
Number of licensed, resident anglers[2]	259,666	350,185	431,826	566,734
Angler days in basin at present rate of 5 days/angler	1,294,958	1,750,925	2,159,130	2,833,670
Angler days in basin at rate of 10 days/angler	---	3,501,850	4,318,260	5,667,340
Angler days in basin at rate of 18 days/angler[3]	---	6,303,330	7,772,868	10,201,212
Maximum potential in angler days for present resources[4]	---	7,408,620	7,408,620	7,408,620

[1] Counties of Wayne, Ontario, Yates, Seneca, Steuben, Schuyler, Chemung, Cayuga, Tompkins, Cortland, Oswego, Lewis, Oneida, Onondaga, Madison, Monroe, Livingston, Tioga, and Broome are included. Projections from N.Y.S. Office of Planning Coordination. Arrangement of data did not permit exlucison of the 15-year-old age group.

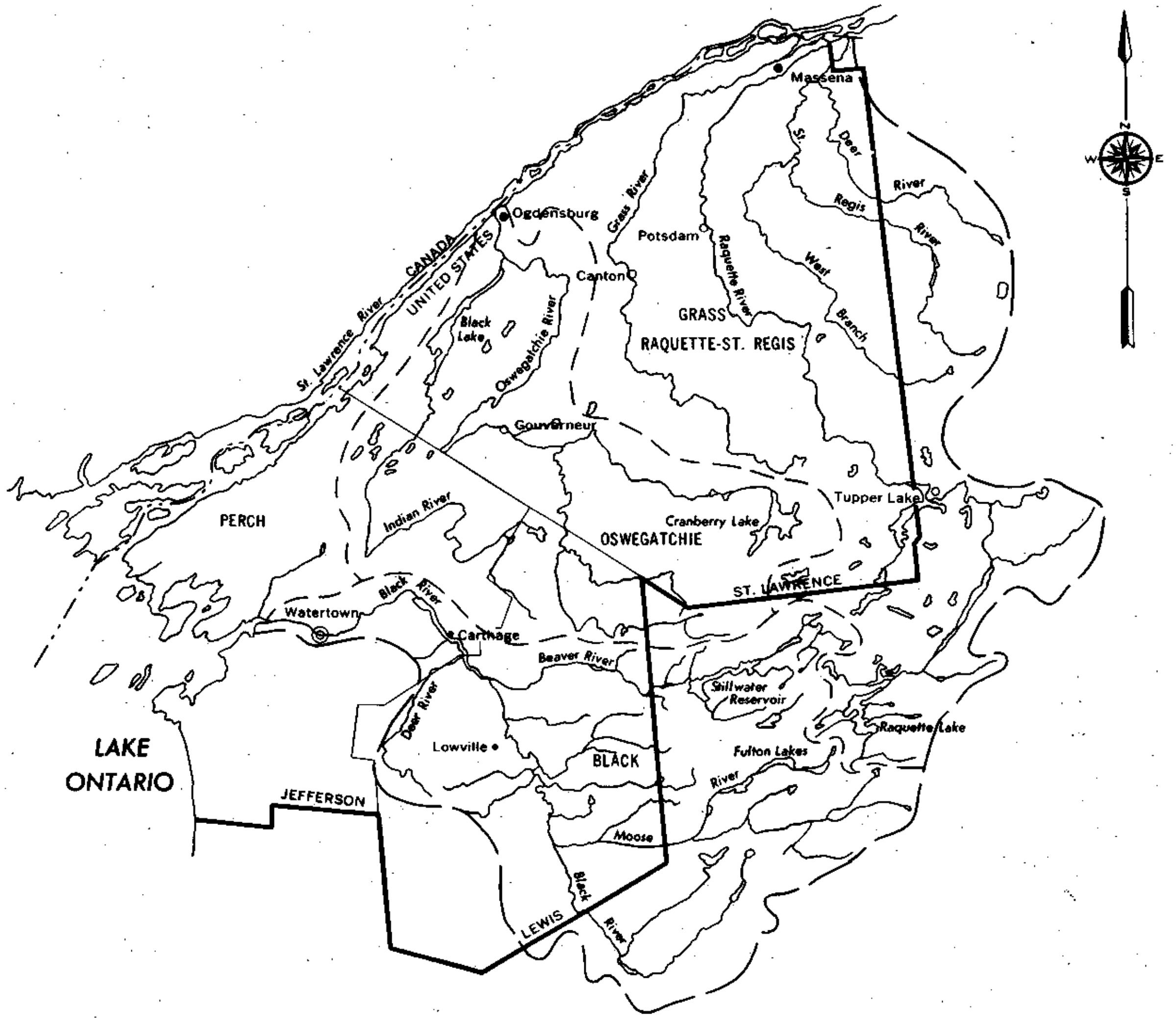
[2] Assumed that 16.8 percent of the 15-69 age group will continue to buy licenses.

[3] National Average - National Survey of Fishing and Hunting (1965).

[4] Maximum potential of 7,400,000 angler days will require pollution abatement, stream improvement, and improved management of fisheries including fishing piers and zoning of fishing grounds.

TABLE 8–71 Present and Projected Fishery Resource Use, Oswego Basin

Resource	Area (Acres)	Annual Number of Fisherman-days			
		Present	1985	2000	2020
Major Lakes	182,890	617,801	2,005,200	5,116,000	6,090,000
Lesser Lakes and Ponds	5,449	124,182	164,190	202,590	224,655
Warmwater Streams	4,625	80,239	145,305	203,910	278,320
Trout Streams	1,861	461,636	622,035	732,945	798,995
Smelt Streams	-----	11,100	16,650	16,650	16,650
Total	194,825	1,294,958	2,953,380	6,272,095	7,408,620



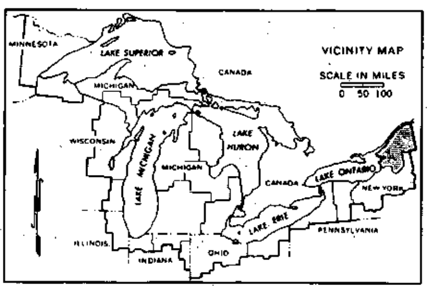


FIGURE 8–95 Planning Subarea 5.3

beyond if ongoing programs are fully supported. If pollution abatement, public access, and habitat control programs are successful, the supply of quality fishing waters will exceed projected needs.

7.3.8 Fishery Development Plans

New York State's plans for the area will be completed in detail under the Oswego River Basin Plan. Included in the study are plans by Cayuga Basin, Wa-Ont-Ya (Wayne, Ontario, Yates Counties), and the Eastern Oswego Water Resources Plan. Sources of funds for implementing these plans have not been determined to date.

A lamprey control program for Lake Ontario was implemented in 1972 through the Great Lakes Fishery Commission. Funds for this project must be provided if major tributaries to Lake Ontario are to provide anadromous fishing.

A Federal aid anadromous sport fishery project (AFS) under PL89–304 for New York State's Great Lakes waters began in 1971. The first phase of the study is to design a detailed projected Anadromous Fish Plan for all New York State's Great Lakes waters. These waters have great potential for such a fishery.

A joint AFS/D-J study, the FA2R, has been proposed to evaluate the biological and economic impact of lamprey control and the anadromous fish program in New York State's Great Lakes waters for the period April 1, 1971 to March 31, 1976. Acquisition and construction needs will be included in the program. It is now running on schedule.

Each State and Regional Fish and Wildlife Office has projected plans for acquisition and development of public fishing streams, fishing access sites, and wetlands on a priority basis. Special funds may be requested annually on a Statewide basis, or bond issues may be approved to carry out such programs.

Plans beyond 1980 are speculative and depend considerably on the success of new programs in the area. If the lamprey control and anadromous fish programs are successful, they will provide economic justification for bold future planning to obtain the maximum possible fisheries in the area. The degree of water pollution abatement and habitat protection accomplished in this decade will determine the success or failure of most projected plans for Planning Subarea 5.2 and the State.

7.4 Planning Subarea 5.3

This planning subarea is composed of three counties in northern New York (Figure 8–95).

7.4.1 Species Composition, Relative Importance, and Status

New York State is currently engaged in a Statewide water resources planning program. Detailed fisheries plans and needs will be covered in the St. Lawrence River Basin Plan which includes the Oswegatchie, Grasse, and Raquette Rivers.

Because of the variation in habitat, from mountain to low level lake basins, Planning Subarea 5.3 supports a large number of fish species. Coldwater species such as brook, brown, rainbow, and lake trout are listed in order of importance. Splake have shown promise in a few waters. Atlantic salmon smolt stockings have been very successful in a few Adirondack lakes when stock has been available. Kokanee show promise on a limited basis. Coho, chinook, and rainbow spawning run fishing has great potential if the Lake Ontario anadromous fish program and lamprey control are successful. Lake whitefish and round whitefish, once abundant, are nearly gone. In recent years smelt dipping has become a major spring fishery in several waters.

Warmwater species provide more angling than salmonids. Smallmouth bass, northern pike, walleye, largemouth bass, muskellunge, and chain pickerel are important game species in the order listed.

Panfish probably support more angling than game species. Yellow perch, bullheads, sunfish, rock bass, crappies, suckers, and catfish are important. Carp are abundant below natural barriers, but absent from Adirondack waters. Round whitefish *(Prosopium cylindraceum)*, lake whitefish *(Coregonus clupeaformis)*, landlocked salmon *(Salmo salar sebago)*, lake sturgeon *(Acipenser fulvescens)*, and lake chub *(Couesius plumbeus)* can be listed as the endangered native species.

7.4.2 Habitat Distribution and Quantity

Four major river systems, the Black, Oswegatchie, Grasse, and Raquette, provide ponds, lakes, and streams in their upper reaches. Below the mountain elevations, all these rivers provide a considerable amount of good-to-fair warmwater stream and pond

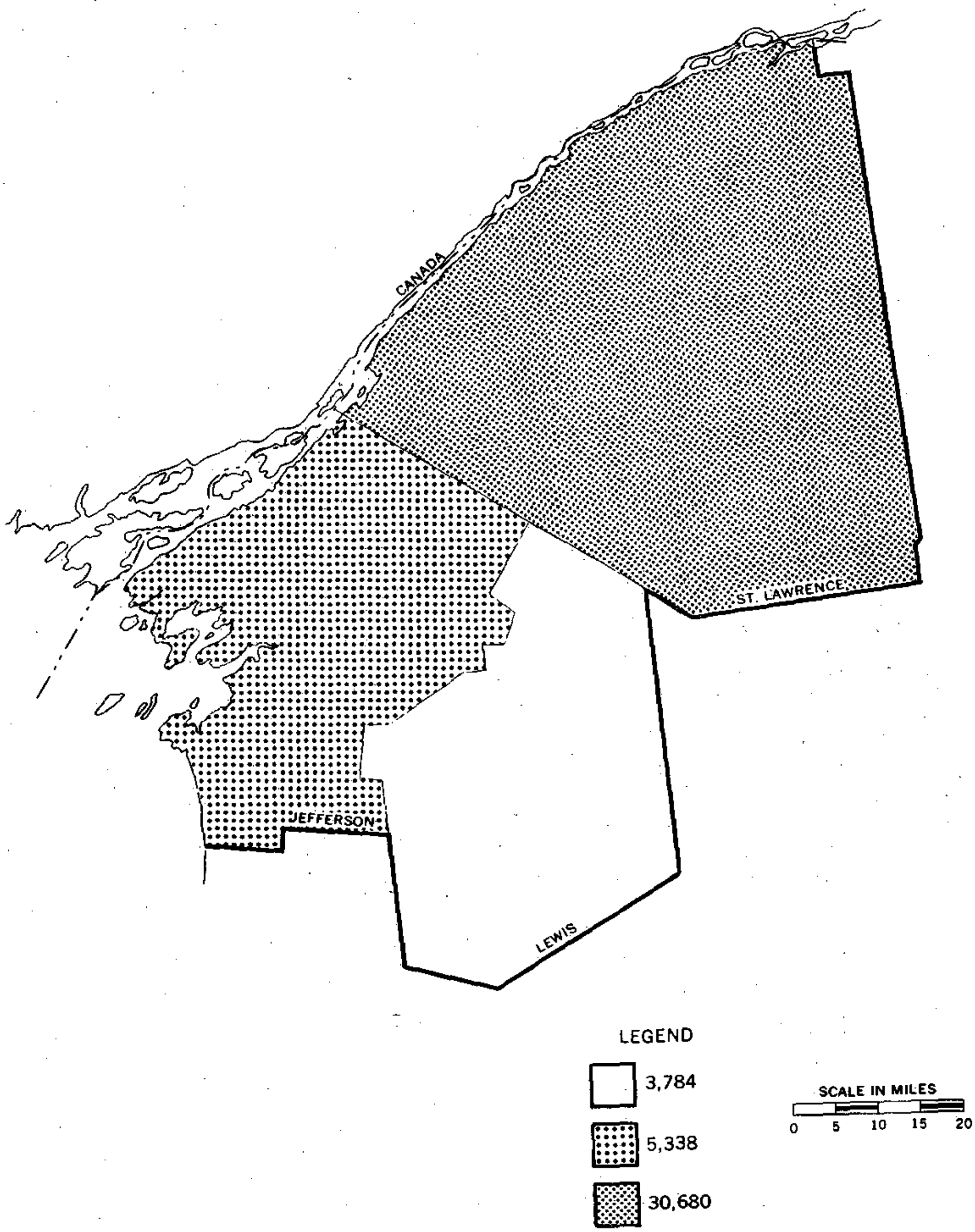


FIGURE 8–96 Acres of Ponded Water, Planning Subarea 5.3

habitat. In addition, a series of large warmwater ponds (Big Sandy, South Sandy, Lakeview) are located west of Salmon River just south of Lake Ontario (Figure 8-96 and Table 8-72). Important marshes are associated with these ponds and all major Lake Ontario tributaries (Table 8-73). Fishable waters excluding marshes and farm ponds include approximately 31,000 acres of ponded cold water, 28,250 acres of ponded warm water, 2,360 miles of coldwater streams, and 721 miles of warmwater streams. Much of the designated coldwater habitat also supports warmwater species.

Ponded trout waters are needed in most of the area outside the Adirondack Mountains. Except for this, Planning Subarea 5.3 is capable of supporting present and projected angling demand through 1980. If habitat improvement and intensive management practices are implemented, it could support considerably more angling pressure than has been projected.

7.4.3 Habitat Problems Affecting Production and Distribution of Important Fish Species

Because of the lack of industrialization, pollution is not as severe in the Adirondack region. Though cumulative effects of paper pulp and saw mill wastes as well as physical destruction from poor logging practices in the past will be felt in the aquatic habitat for many years to come, present regulations should soon bring such degradation completely under control. All major rivers have been subject to habitat destruction resulting from the logging industry.

Domestic sewage is a major problem. Many communities have only primary treatment systems or none at all. Adirondack communities and summer cottage colonies have caused considerable eutrophication in lakes adjacent to the dwellings. Laundromats in resort towns are particularly noxious due to excessive phosphate wastes.

Beginning in the late 1940s pesticide spraying and DDT blocks were used extensively throughout the upland areas to control biting flies, and crop spraying took place in the valley areas. These two practices have combined to create excessive pesticide pollution. Many species of fish, even in remote mountain areas, contain high concentrations of DDT and other pesticides. Some control has been instituted, but much more is needed.

Dams for power generation also pose problems. All major rivers have a number of dams located throughout their drainage basins. Tremendous daily fluctuations of flow take place, particularly on sections of the Raquette, Oswegatchie, and Beaver Rivers. Flows vary daily from zero to several thousand cfs. Low flows coupled with pollution compound the harm done to the habitat.

Although certain dams provide lake habitat for summer recreationists, the reservoirs fluctuate excessively from a few hundred acres of natural stream and ponded habitat to several thousand flooded acres at high water. Sometimes fluctuations take place after lake trout have spawned, and then the year's hatch is lost. Constant minimum stream flows and scheduled minimum lake level regulations are needed.

Physical obstruction from existing dams presents a major obstacle to anadromous fish management. This is particularly true of the Black River. It shows promise of providing fishing for spawning salmon and rainbows on about 100 miles of its course. Many tributaries should provide good spawning and fishing sites also.

Hydropower dams on the St. Lawrence River often cause excessively low water levels in the river and to a degree in Lake Ontario. Marshes and estuaries located near the mouths of tributaries are dewatered, with subsequent loss of habitat, fish, and other aquatic organisms. Minimum water levels adequate to protect wetlands are necessary. Oil pollution from commercial vessels using the St. Lawrence Seaway and spillage from bulk storage compounds are also problems in marsh management.

Dairy product plants are a major cause of fish-kills due to dumping of wastes. In addition to adult fish, progeny of smallmouth bass and other Lake Ontario species using the lower sections of tributaries for spawning are often destroyed by pollution from dairy plants.

Cumulative effects of farming and poor highway and other construction practices have practically destroyed many streams as suitable fish habitat. Loss of cover has caused flooding, erosion, heavy silting, high water temperatures, and low or intermittent flows as the result of uncontrolled abuse of many streams. Until recently, uncontrolled development on lakeshores and major river banks has caused considerable habitat degradation. Recent regulations have started to control and eliminate the problem.

Competition for use of waters by non-

TABLE 8–72 Fishing Waters within Planning Subarea 5.3

Watershed	Acres of Ponded Water		Miles of Streams	
	Coldwater	Warmwater	Coldwater	Warmwater
Black River	18,143	1,223	1,113	116
St. Lawrence River[1]	9,319	24,152	1,119	575
Lake Ontario	3,506	3,865	316	30
Total	30,968	29,240	2,628	721

[1]Includes Oswegatchie, Grass, and Racquette Rivers

TABLE 8–73 Wetlands at Mouths of Tributaries to the St. Lawrence River and Lake Ontario, Planning Subarea 5.3

Watershed	County	Acreage
St. Lawrence River	St. Lawrence[1]	3,002
	Jefferson	1,200
Lake Ontario	Jefferson[2]	3,452
	Oswego	1,584

[1]Includes State owned 1,675 acre Wilson Hill Marsh.

[2]Includes State owned 2,000 acre Lakeview Marsh.

angling recreationists poses a problem particularly in the summer months. Lack of access to desirable fishing waters also limits full use of good fishing habitat. Extensive tracts of private land, particularly in the Adirondacks, are closed to the public.

In the upper reaches of the river systems and to some degree in the downstream drainage, beaver have damaged once excellent trout waters in the past 20 years. Depletion of cover and excessive shallow flooding of large areas have caused stagnation, siltation, high water temperatures, and poor water quality. No single factor has destroyed more good water in the Adirondack Mountains in recent years than the uncontrolled beaver population. Many ponds and lakes undeveloped by man have undergone drastic changes in water quality because entire tributary systems have been degraded by beaver. The conditions will worsen unless stringent controls are instituted where necessary.

7.4.4 History of Sport Fishery

Originally the lowland lakes and streams below natural barriers abounded with smallmouth bass, northern pike, walleye, muskellunge, native panfish, and other species. A few deep cold lakes also provided lake trout, whitefish, cisco, and some brook trout fishing. Tributaries to Lake Ontario supported large runs of Atlantic landlock salmon until about 1880. Today, carp and other species have found their way into the waters. Warmwater fishing, although not as good as before, is still considered fair-to-very-good under present standards. A limited lake trout fishery is still available in a few deep lowland lakes.

Above natural barriers, native brook trout, lake trout, and whitefish flourished until about the turn of the century. Lake trout grew slowly in most waters and could not stand excessive exploitation. Whitefish populations are all but gone from the area. Brook trout have remained in many waters, and through modern management practices, provide better fishing than in the past. Nearly all original native brook trout strains are gone or mixed with hatchery strains. A special program is under way to save remaining strains and develop other wild strains. At present nearly all salmonid fishing is dependent upon hatchery stocking. In certain lakes where pH is above 6.5, rainbow trout have provided fair-to-good angling. Introduced brown trout have also been successful and are self-sustaining in some streams. In recent years smelt dipping has become an important spring fishery in some waters.

7.4.5 Existing Sport Fishing Demand and Current Needs

The entire area is sparsely populated and present resources can supply existing needs. The largest business is recreation, much of which is oriented to sport fishing. If a new fishery on a major scale such as high quality and quantity salmon fishing can be produced,

TABLE 8–74 Base Year and Projected Land, Water, and Angler Days, Planning Subarea 5.3

State and Counties	Land Area (sq.mi.)	Population (1000s)	Population per sq.mi.	Ponded Waters (Acres)	Ponded Waters Per Capita	Non-Res. Fish Licenses	Res. Fish Licenses	Res. Licenses Per Capita
New York								
Jefferson	1,292	89.8	69.5	5,338	.0594	1,874	22,432	.2498
Lewis	1,287	24.9	19.3	3,784	.1520	77	3,230	.1297
St. Lawrence	2,711	113.1	41.7	30,680	.2713	1,280	17,990	.1591
Total	5,290	227.8	43.1	39,802	.1747	3,231	43,652	.1916

State and Years	Land area (sq.mi.)	Population (1000s)	Population (sq.mi.)	Projected Angler Day Demand Resident[1]	Total[2]
New York					
1980	5,290	225.7	42.7	1,339,703	2,718,000
2000	5,290	257.2	48.6	1,526,680	3,194,000
2020	5,290	298.6	56.4	1,772,420	3,789,000

[1] Demand generated within planning subarea.

[2] Total demand including in- and out-migration.

fishing pressure will increase and so will business.

There is a need for quality salmonid fishing in the Adirondack section. Outside anglers are primarily attracted by good salmonid fishing. Even when warmwater species such as walleye populations in the Raquette River are abundant, little fishing pressure is realized. Base year and projected angler day demand is shown in Table 8–74.

7.4.6 Ongoing Programs

Environmental protection and improvement is an integral part of ongoing programs. As of July 1, 1970, the New York State Conservation Department became the New York State Department of Environmental Conservation. Broad powers, once delegated to other State agencies, became the specific responsibility of the new department's office to facilitate pollution abatement and other environmental control programs.

Pollution abatement through the State's Pure Waters Program is a vital part of present rehabilitation of waterways in the State. Protection of stream and ponded habitat is afforded through implementation of Section 429 of the Conservation Law, commonly called the Stream Protection Law. Under this legislation, permits are required by individuals, agencies, or corporations to undertake any work in certain classified waters, including all navigable waters to the high-water mark.

Stream improvement is carried on in major streams when funds are available. Bank stabilization with plantings and instream structures to provide better cover and pools are part of the standard program.

The State Fish and Wildlife Management Act (FWMA) Program has been utilized extensively to provide public access to private waters in the area. Under the program the owner and the State enter into an agreement in which the State carries out certain management practices on the lands and waters in return for controlled public use. Large tracts of Boy Scout property, sections of military reservations, mining company waters, and logging company lands, have been opened up to public use through FWMA.

Many miles of public fishing rights and boat access and launching sites have been acquired for public use on major waters. More will be purchased when funds become available. In addition, some major Lake Ontario marshes have been acquired for future fish and wildlife development. Others will be obtained when possible.

The Lake Ontario Anadromous Fish-Lamprey Control Program and proposed AFS/D-J joint Federal aid program discussed under Planning Subarea 5.2 is an integral part of the Planning Subarea 5.3 program.

Other current fish management practices in addition to items mentioned include: biological surveys of problem waters for special management consideration; monitoring of fish populations for pesticide, mercury, and other subtle pollutants; regular stocking of brook, brown, rainbow and lake trout as well as stockings of splake and kokanee. Walleye fry are also stocked for special study. Special regulations have been placed on certain waters to provide quality salmonid fishing as part of the new Statewide program. Regional fisheries personnel also cooperate in a wild strain brook trout study and a special lake trout study in Adirondack waters.

7.4.7 Future Trends in Habitat and Participation

Existing habitat conditions should almost certainly improve under the present environmental approach to conservation. Many miles of potentially excellent stream habitat and ponded waters should become productive. Present resources in the area could support considerably more fishing pressure. If proposed programs and habitat rehabilitation are undertaken, additional anglers will be attracted due to quality angling on a quantity basis.

7.4.8 Fishery Development Plans

In order to provide the best sport fishing the following activities must be incorporated into a development plan for action in the near future:

(1) pollution abatement and habitat rehabilitation
(2) guaranteed minimum constant flows in all rivers controlled by dams
(3) guaranteed minimum drawdown on reservoirs on a controlled time basis
(4) lamprey control in Lake Ontario and expansion of the anadromous fish program
(5) development of necessary fishways, weirs, and other structures
(6) modernization and expansion of hatchery facilities to insure necessary fish stocks
(7) control of water level in important marshes
(8) control of beaver
(9) development of brook trout ponds where needed
(10) public access to important waters through acquisition and other agreements
(11) funds to carry on practical fish research and management-related needs.

SUMMARY

Sportfishing demand was originally calculated for each individual planning subarea and included at the end of each section. However, this demand was based on the year 1967 and did not compensate for in-and-out migration of fishermen who bought licenses in one area but fished in another; nor did it include Great Lakes fishermen. The tables have been amended to include these figures taken from Table 8–75.

Tables 8–76, 8–77, and 8–78 indicate planned capital and operational expenditures for various fish management programs in each planning subarea, separated by States. Total dollar expenditures represent an estimate of total capital and estimated phased expansion of operational programs at each target year.

The projected costs for creating new angler days range from $1.60 per year for each new angler day to a low of $0.06. The higher costs per angler day usually occur in or near urban areas where needs are high and the resource supply limited.

If the basic fish habitat can be preserved, planned fish management programs can generally meet the recreational fishing needs of people living in the Great Lakes Basin at least through the year 2020.

Table 8–79 summarizes the expected trends in demand and supply for commercial food fishes of the Great Lakes.

TABLE 8–75 Summary of Sport Fishing Demand (1,000 Angler Days)

	1970				1980				
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(5)
Lake Superior Plan Area 1.0	4,192	2,900	-----	7,092	4,205	3,874	-----	8,079	987
Planning Subarea 1.1	2,691	1,700	-----	4,391	2,840	2,324	-----	5,164	773
Wisconsin	785	499	-----	1,284	550	797	-----	1,347	63
Inland	755	477	-----	1,232	510	737	-----	1,247	15
Great Lakes	30	22	-----	52	40	60	-----	100	48
Minnesota	1,906	1,201	-----	3,107	2,290	1,527	-----	3,817	710
Inland	1,898	1,199	-----	3,097	2,280	1,500	-----	3,780	683
Great Lakes	8	2	-----	10	10	27	-----	37	27
Planning Subarea 1.2	1,501	1,200	-----	2,701	1,365	1,550	-----	2,915	214
Michigan	1,501	1,200	-----	2,701	1,365	1,550	-----	2,915	214
Inland	1,400	1,000	-----	2,400	1,215	1,100	-----	2,315	-85
Great Lakes	101	200	-----	301	150	450	-----	600	299
Lake Michigan Plan Area 2.0	35,212	9,000	15,958	28,254	49,535	10,755	21,501	38,789	10,535
Planning Subarea 2.1	5,510	5,500	-----	11,010	7,562	6,555	-----	14,117	3,107
Michigan	60	50	-----	110	68	70	-----	138	28
Inland	50	50	-----	100	53	55	-----	108	8
Great Lakes	10	-----	-----	10	15	15	-----	30	20
Wisconsin	5,450	5,450	-----	10,900	7,494	6,485	-----	13,979	3,079
Inland	5,350	5,350	-----	10,700	7,094	5,885	-----	12,979	2,279
Great Lakes	100	100	-----	200	400	600	-----	1,000	800
Planning Subarea 2.2	15,474	-----	12,308	3,166	21,884	-----	16,134	5,750	2,584
Wisconsin	5,034	-----	3,805	1,229	9,457	-----	6,957	2,500	1,271
Inland	4,705	-----	3,705	1,000	7,857	-----	6,357	1,500	500
Great Lakes	329	-----	100	229	1,600	-----	600	1,000	771
Illinois	8,200	-----	6,583	1,617	9,225	-----	6,825	2,400	783
Inland	7,338	-----	6,521	817	8,256	-----	6,756	1,500	683
Great Lakes	862	-----	62	800	969	-----	69	900	100
Indiana	2,240	-----	1,920	320	3,202	-----	2,352	850	530
Inland	2,000	-----	1,850	150	2,352	-----	2,152	200	50
Great Lakes	240	-----	70	170	850	-----	200	650	480
Planning Subarea 2.3	9,050	-----	3,650	5,400	13,969	-----	5,367	8,602	3,202
Indiana	1,412	-----	578	834	2,104	-----	862	1,242	408
Inland	1,412	-----	578	834	2,104	-----	862	1,242	408
Great Lakes	-----	-----	-----	-----	-----	-----	-----	-----	-----
Michigan	7,638	-----	3,072	4,566	11,865	-----	4,505	7,360	2,794
Inland	6,888	-----	2,822	4,066	10,265	-----	4,205	6,060	1,994
Great Lakes	750	-----	250	500	1,600	-----	300	1,300	800
Planning Subarea 2.4	5,178	3,500	-----	8,678	6,120	4,200	-----	10,320	1,642
Michigan	5,178	3,500	-----	8,678	6,120	4,200	-----	10,320	1,642
Inland	4,850	3,000	-----	7,850	5,720	3,300	-----	9,020	1,170
Great Lakes	328	500	-----	828	400	900	-----	1,300	472

(1) Demand generated within planning subarea
(2) Demand transferred into planning subarea from other areas
(3) Demand transferred out of planning subarea to other areas
(4) Total demand within planning subarea [(4) = (1) + (2) - (3)]
(5) Total needs within Basin [total 1980 demand - total 1970 demand = 1980 need]

2000					2020				
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
4,636	4,621	-----	9,257	1,178	5,403	5,484	-----	10,887	1,630
3,228	2,790	-----	6,018	854	3,679	3,273	-----	6,952	934
585	960	-----	1,545	198	639	1,130	-----	1,769	244
535	860	-----	1,395	148	569	1,000	-----	1,569	174
50	100	-----	150	50	70	130	-----	200	50
2,643	1,830	-----	4,473	656	3,040	2,143	-----	5,183	710
2,623	1,770	-----	4,393	613	3,010	2,063	-----	5,073	680
20	60	-----	80	43	30	80	-----	110	30
1,408	1,831	-----	3,239	324	1,724	2,211	-----	3,935	696
1,408	1,831	-----	3,239	324	1,724	2,211	-----	3,935	696
1,258	1,331	-----	2,589	274	1,574	1,611	-----	3,185	596
150	500	-----	650	50	150	600	-----	750	100
63,542	13,306	28,173	48,675	9,886	80,454	15,659	37,282	58,831	10,156
9,440	8,313	-----	17,753	3,636	11,938	9,827	-----	21,765	4,012
79	92	-----	171	33	89	111	-----	200	29
59	67	-----	126	18	69	81	-----	150	24
20	25	-----	45	15	20	30	-----	50	5
9,361	8,221	-----	17,582	3,603	11,849	9,716	-----	21,565	3,983
8,961	7,121	-----	16,082	3,103	11,449	8,616	-----	20,065	3,983
400	1,100	-----	1,500	500	400	1,100	-----	1,500	-----
28,459	-----	21,209	7,250	1,500	35,890	-----	28,290	7,600	350
12,805	-----	9,805	3,000	500	16,361	-----	13,361	3,000	-----
10,705	-----	8,705	2,000	500	14,261	-----	12,261	2,000	-----
2,100	-----	1,100	1,000	-----	2,100	-----	1,100	1,000	-----
11,262	-----	8,262	3,000	600	13,785	-----	10,585	3,200	200
10,079	-----	8,079	2,000	500	12,338	-----	10,338	2,000	-----
1,183	-----	183	1,000	100	1,447	-----	247	1,200	200
4,392	-----	3,142	1,250	400	5,744	-----	4,344	1,400	150
3,142	-----	2,742	400	200	4,144	-----	3,744	400	-----
1,250	-----	400	850	200	1,600	-----	600	1,000	150
18,125	-----	6,964	11,161	2,559	23,231	-----	8,992	14,239	3,078
2,536	-----	1,039	1,497	255	3,106	-----	1,272	1,834	337
2,536	-----	1,039	1,497	255	3,106	-----	1,272	1,834	337
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
15,589	-----	5,925	9,664	2,304	20,125	-----	7,720	12,405	2,741
13,489	-----	5,525	7,964	1,904	17,625	-----	7,220	10,405	2,441
2,100	-----	400	1,700	400	2,500	-----	500	2,000	300
7,518	4,993	-----	12,511	2,191	9,395	5,832	-----	15,227	2,716
7,518	4,993	-----	12,511	2,191	9,395	5,832	-----	15,227	2,716
7,018	3,993	-----	11,011	1,991	8,795	4,832	-----	13,627	2,616
500	1,000	-----	1,500	200	600	1,000	-----	1,600	100

TABLE 8–75 (continued) Summary of Sport Fishing Demand (1,000 Angler Days)

	1970				1980				
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(5)
Lake Huron Plan Area 3.0	5,793	1,650	1,300	6,143	8,368	2,550	1,715	9,203	3,060
Planning Subarea 3.1	2,150	1,650	-----	3,800	3,131	2,550	-----	5,681	1,881
Michigan	2,150	1,650	-----	3,800	3,131	2,550	-----	5,681	1,881
Inland	2,000	1,400	-----	3,400	2,631	1,650	-----	4,281	881
Great Lakes	150	250	-----	400	500	900	-----	1,400	1,000
Planning Subarea 3.2	3,643	-----	1,300	2,343	5,237	-----	1,715	3,522	1,179
Michigan	3,643	-----	1,300	2,343	5,237	-----	1,715	3,522	1,179
Inland	3,000	-----	1,200	1,800	3,887	-----	1,565	2,322	522
Great Lakes	643	-----	100	543	1,350	-----	150	1,200	657
Lake Erie Plan Area 4.0	33,535	2,000	7,685	27,850	40,891	2,450	10,616	32,725	4,875
Planning Subarea 4.1	8,400	-----	4,400	4,000	10,469	-----	5,746	4,723	723
Michigan	8,400	-----	4,400	4,000	10,469	-----	5,746	4,723	723
Inland	6,000	-----	4,000	2,000	7,569	-----	5,046	2,523	523
Great Lakes	2,400	-----	400	2,000	2,900	-----	700	2,200	200
Planning Subarea 4.2	12,000	1,000	3,100	9,900	15,080	1,250	4,161	12,169	2,269
Indiana	179	-----	62	117	1,329	-----	458	871	754
Inland	179	-----	62	117	1,329	-----	458	871	754
Great Lakes	-----	-----	-----	-----	-----	-----	-----	-----	-----
Ohio	11,821	1,000	3,038	9,783	13,751	1,250	3,703	11,298	1,515
Inland	8,821	-----	3,038	5,783	10,751	-----	3,703	7,048	1,265
Great Lakes	3,000	1,000	-----	4,000	3,000	1,250	-----	4,250	250
Planning Subarea 4.3	8,333	1,000	-----	9,333	9,423	1,200	318	10,305	972
Ohio	8,333	1,000	-----	9,333	9,423	1,200	318	10,305	972
Inland	5,533	-----	-----	5,533	6,168	-----	318	5,850	317
Great Lakes	2,800	1,000	-----	3,800	3,255	1,200	-----	4,455	655
Planning Subarea 4.4	4,802	-----	185	4,617	5,919	-----	391	5,528	911
Pennsylvania	1,058	-----	-----	1,058	1,378	-----	42	1,336	278
Inland	558	-----	-----	558	613	-----	27	586	28
Great Lakes	500	-----	-----	500	765	-----	15	750	250
New York	3,744	-----	185	3,559	4,541	-----	349	4,192	633
Inland	3,044	-----	185	2,859	3,341	-----	149	3,192	333
Great Lakes	700	-----	-----	700	1,200	-----	200	1,000	300
Lake Ontario Plan Area 5.0	8,829	3,018	-----	11,847	12,075	5,120	-----	17,195	5,348
Planning Subarea 5.1	2,380	245	-----	2,625	3,539	542	-----	4,081	1,456
New York	2,380	245	-----	2,625	3,539	542	-----	4,081	1,456
Inland	2,240	185	-----	2,425	2,489	92	-----	2,581	156
Great Lakes	140	60	-----	200	1,050	450	-----	1,500	1,300
Planning Subarea 5.2	5,096	1,120	-----	6,216	6,996	2,400	-----	9,396	3,180
New York	5,096	1,120	-----	6,216	6,996	2,400	-----	9,396	3,180
Inland	4,816	1,000	-----	5,816	5,396	1,100	-----	6,496	680
Great Lakes	280	120	-----	400	1,600	1,300	-----	2,900	2,500
Planning Subarea 5.3	1,353	1,653	-----	3,006	1,540	2,178	-----	3,718	712
New York	1,353	1,653	-----	3,006	1,540	2,178	-----	3,718	712
Inland	1,253	1,253	-----	2,506	1,340	1,378	-----	2,718	212
Great Lakes	100	400	-----	500	200	800	-----	1,000	500

(1) Demand generated within planning subarea
(2) Demand transferred into planning subarea from other areas
(3) Demand transferred out of planning subarea to other areas
(4) Total demand within planning subarea [(4) = (1) + (2) - (3)]
(5) Total needs within Basin [total 1980 demand - total 1970 demand = 1980 need]

2000					2020				
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
10,882	3,297	2,246	11,933	2,730	13,891	3,916	2,866	14,941	3,008
3,842	3,297	-----	7,139	1,458	4,776	3,916	-----	8,692	1,553
3,842	3,297	-----	7,139	1,458	4,776	3,916	-----	8,692	1,553
3,342	1,997	-----	5,339	1,058	4,276	2,416	-----	6,692	1,353
500	1,300	-----	1,800	400	500	1,500	-----	2,000	200
7,040	-----	2,246	4,794	1,272	9,115	-----	2,866	6,249	1,455
7,040	-----	2,246	4,794	1,272	9,115	-----	2,866	6,249	1,455
4,990	-----	1,996	2,994	672	6,415	-----	2,566	3,849	855
2,050	-----	250	1,800	600	2,700	------	300	2,400	600
54,616	2,305	14,926	41,995	9,270	64,644	3,000	19,083	48,561	6,566
13,186	-----	7,558	5,628	905	16,681	-----	9,821	6,860	1,232
13,186	-----	7,558	5,628	905	16,681	-----	9,821	6,860	1,232
9,686	-----	6,458	3,228	705	12,481	-----	8,321	4,160	932
3,500	-----	1,100	2,400	200	4,200	-----	1,500	2,700	300
19,116	1,300	5,241	15,175	3,006	24,661	1,500	6,600	19,561	4,386
1,848	-----	636	1,212	341	2,554	-----	880	1,674	462
1,848	-----	636	1,212	341	2,554	-----	880	1,674	462
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
17,268	1,300	4,605	13,963	2,665	22,107	1,500	5,720	17,887	3,924
13,368	-----	4,605	8,763	1,715	16,607	-----	5,720	10,887	2,124
3,900	1,300	-----	5,200	950	5,500	1,500	-----	7,000	1,800
14,798	1,005	1,296	14,507	4,202	15,005	1,500	1,614	14,891	384
14,798	1,005	1,296	14,507	4,202	15,005	1,500	1,614	14,891	384
7,788	-----	1,296	6,492	642	9,805	-----	1,614	8,191	1,699
7,010	1,005	-----	8,015	3,560	5,200	1,500	-----	6,700	-1,315
7,516	-----	831	6,685	1,157	8,297	-----	1,048	7,249	564
1,607	-----	122	1,485	149	2,022	-----	170	1,852	367
757	-----	72	685	99	947	-----	95	852	167
850	-----	50	800	50	1,075	-----	75	1,000	200
5,909	-----	709	5,200	1,008	6,275	-----	878	5,397	197
4,059	-----	359	3,700	508	4,955	-----	448	4,507	807
1,850	-----	350	1,500	500	1,320	-----	430	890	-610
15,066	6,788	310	21,544	4,349	18,412	9,077	402	27,087	5,543
4,368	840	310	4,898	817	5,413	1,500	402	6,511	1,613
4,368	840	310	4,898	817	5,413	1,500	402	6,511	1,613
3,108	-----	310	2,798	217	3,913	-----	402	3,511	713
1,260	840	-----	2,100	600	1,500	1,500	-----	3,000	900
8,921	3,331	-----	12,252	2,856	10,927	4,460	-----	15,387	3,135
8,921	3,331	-----	12,252	2,856	10,927	4,460	-----	15,387	3,135
6,921	1,331	-----	8,252	1,756	8,777	1,610	-----	10,387	2,135
2,000	2,000	-----	4,000	1,100	2,150	2,850	-----	5,000	1,000
1,777	2,617	-----	4,394	676	2,072	3,117	-----	5,189	795
1,777	2,617	-----	4,394	676	2,072	3,117	-----	5,189	795
1,527	1,667	-----	3,194	476	1,772	2,017	-----	3,789	595
250	950	-----	1,200	200	300	1,100	-----	1,400	200

TABLE 8–76 Expanded Fish Management Programs, 1980, in Thousands of Dollars

Planning Subarea	Capital Expenditures: Fish Piers	Fish Passage	Fish Product	Land Dev. & Control	Impound-ments	Fac. & Vessels	Annual: Fish Rearing and Planting Cost
1.1	0	450	3,000	650	0	80	400
Minn.	0	400	1,200	400	0	0	200
Wis.	0	50	1,800	250	0	80	200
1.2	0	200	800	380	0	100	75
2.1	0	0	510	200	0	70	115
Mich.	0	0	10	0	0	0	15
Wis.	0	0	500	200	0	70	100
2.2	1,550	0	3,300	325	4,000	135	120
Wis.	300	0	300	200	0	0	40
Ill.	250	0	2,000	25	4,000	35	40
Ind.	1,000	0	1,000	100	0	100	40
2.3	0	1,000	2,050	465	0	0	270
Ind.	0	0	50	0	0	0	20
Mich.	0	1,000	2,000	465	0	0	250
2.4	0	1,000	2,550	162	0	10	400
3.1	0	0	1,600	250	0	10	250
3.2	0	50	120	20	0	0	35
4.1	1,000	50	1,000	500	0	150	150
4.2	120	0	1,090	850	22,300	350	375
Ohio	120	0	90	270	22,300	150	145
Ind.	0	0	1,000	580	0	200	230
4.3	100	0	10	150	0	75	80
4.4	810	68	2,075	1,650	10	166	385
Pa.	750	8	75	650	10	16	85
N.Y.	60	60	2,000	1,000	0	150	300
5.1	1,000	1,000	1,000	1,000	500	500	100
5.2	500	1,000	1,000	1,500	0	500	100
5.3	500	1,000	1,000	2,000	0	500	100

Operational Expenditures for Target Year			Funds			Angler Days (thousands)	
Fish Population Control	Habitat Improvement and Prot.	Admin. Planning & Research	Total State	Total Federal	Total	1980 Needs	1980 Needs Met
70	20	8	3,630	2,510	6,140	773	463
40	0	0	2,040	920	2,960	710	400
30	20	0	1,590	1,590	3,180	63	63
25	0	0	1,080	800	1,880	214	214
15	10	0	870	470	1,340	3,107	3,107
5	0	0	65	25	90	28	28
10	10	0	805	445	1,250	3,079	3,079
35	30	15	6,832	3,278	10,110	2,584	2,313
20	10	0	680	400	1,080	1,271	1,000
10	10	5	3,942	2,628	6,570	783	783
5	10	10	2,210	250	2,460	530	530
55	80	0	3,023	2,112	5,135	3,202	1,988
5	0	0	150	0	150	408	408
50	80	0	2,873	2,112	4,985	2,794	1,580
100	110	0	3,691	2,471	6,162	1,642	1,200
20	110	0	2,070	1,310	3,380	1,881	1,400
10	25	0	254	216	470	1,179	900
50	30	0	2,700	920	3,620	723	723
50	100	130	19,431	7,899	27,330	2,269	2,269
10	50	70	18,111	5,919	24,030	1,515	1,515
40	50	60	1,320	1,980	3,300	754	754
6	25	20	555	304	859	972	972
0	525	35	4,083	4,476	8,559	911	578
0	25	5	788	1,181	1,969	278	278
0	500	30	3,295	3,295	6,590	633	300
50	100	20	3,040	3,040	6,080	1,456	1,000
100	200	20	3,090	3,090	6,180	3,180	2,500
100	200	20	3,340	3,340	6,680	712	712

TABLE 8–77 Expanded Fish Management Programs, 2000, in Thousands of Dollars

	Capital Expenditures						Annual
Planning Subarea	Fish Piers	Fish Passage	Fish Product	Land Dev. & Control	Impound-ments	Fac. & Vessels	Fish Rearing and Planting Cost
1.1	0	225	150	600	150	150	200
Minn.	0	225	0	400	150	50	0
Wis.	0	0	150	200	0	100	200
1.2	0	200	200	600	0	250	150
2.1	0	0	620	230	0	50	130
Mich.	0	0	20	30	0	0	30
Wis.	0	0	600	200	0	50	100
2.2	750	0	1,200	150	2,000	30	240
Wis.	500	0	300	100	0	20	100
Ill.	250	0	400	50	2,000	10	80
Ind.	0	0	500	0	0	0	60
2.3	500	500	200	600	650	0	540
Ind.	0	0	0	0	0	0	40
Mich.	500	500	200	600	650	0	500
2.4	100	500	400	300	0	0	400
3.1	0	50	100	600	0	0	300
3.2	500	300	200	300	500	0	200
4.1	500	200	100	200	200	0	100
4.2	200	0	130	370	5,850	310	180
Ohio	200	0	100	200	5,600	250	160
Ind.	0	0	30	170	250	60	20
4.3	100	0	20	250	850	0	95
4.4	1,000	200	1,150	600	1,000	500	112
Pa.	0	0	150	100	0	0	12
N.Y.	1,000	200	1,000	500	1,000	500	100
5.1	1,000	1,000	1,000	100	500	500	100
5.2	500	1,000	1,000	1,500	0	500	100
5.3	500	1,000	1,000	2,000	0	500	100

Operational Expenditures for Target Year			Funds			Angler Days (thousands)	
Fish Population Control	Habitat Improvement and Prot.	Admin. Planning & Research	Total State	Total Federal	Total	2000 Needs	2000 Needs Met
20	60	20	3,285	990	4,275	854	698
0	10	20	598	527	1,125	656	500
20	50	0	2,687	463	3,150	198	198
50	50	20	2,650	1,300	3,950	324	324
25	20	0	2,025	625	2,650	3,636	3,533
15	10	0	437	163	600	33	33
10	10	0	1,587	463	2,050	3,603	3,500
90	10	20	4,911	2,819	7,730	1,500	1,500
45	10	0	1,235	1,235	2,470	500	500
35	0	10	2,376	1,584	3,960	600	600
10	0	10	1,300	0	1,300	400	400
110	30	30	6,700	2,850	9,550	2,559	2,559
10	0	10	600	0	600	255	255
100	30	20	6,100	2,850	8,950	2,304	2,304
200	100	20	6,050	2,450	8,500	2,191	2,000
50	100	20	3,900	1,550	5,450	1,458	1,458
50	50	20	3,300	1,700	5,000	1,272	1,000
75	30	10	2,213	1,137	3,350	905	905
25	70	35	7,438	2,522	9,960	3,006	3,006
15	60	30	6,862	2,138	9,000	2,665	2,665
10	10	5	575	385	960	341	341
10	20	30	2,146	624	2,770	4,202	4,202
50	104	34	2,513	4,937	7,450	1,157	849
0	4	4	180	270	450	149	149
50	100	30	2,333	4,667	7,000	1,008	700
50	100	20	2,267	4,533	6,800	817	700
100	200	20	2,900	5,800	8,700	2,856	2,800
100	200	20	3,067	6,133	9,200	676	676

TABLE 8–78 Expanded Fish Management Programs, 2020, in Thousands of Dollars

	Capital Expenditures						Annual
Planning Subarea	Fish Piers	Fish Passage	Fish Product	Land Dev. & Control	Impound-ments	Fac. & Vessels	Fish Rearing and Planting Cost
1.1	0	200	200	600	150	150	290
Minn.	0	200	100	400	150	0	40
Wis.	0	0	100	200	0	150	250
1.2	150	200	500	1,000	0	400	200
2.1	50	200	500	600	0	20	190
Mich.	50	200	0	200	0	0	40
Wis.	0	0	500	400	0	20	150
2.2	500	0	1,000	425	2,000	160	350
Wis.	300	0	300	400	0	20	150
Ill.	200	0	200	25	2,000	40	100
Ind.	0	0	500	0	0	100	100
2.3	400	600	2,100	500	1,000	400	560
Ind.	0	0	100	0	0	0	60
Mich.	400	600	2,000	500	1,000	400	500
2.4	200	400	2,000	1,000	1,000	100	600
3.1	200	400	2,000	1,000	1,000	400	500
3.2	400	100	1,000	500	3,000	100	300
4.1	500	0	1,000	500	0	400	200
4.2	110	0	105	590	4,050	400	370
Ohio	110	0	75	350	3,500	250	170
Ind.	0	0	30	240	550	150	200
4.3	150	0	25	50	1,500	75	110
4.4	1,000	500	2,100	5,050	100	106	114
Pa.	0	0	100	50	0	6	14
N.Y.	1,000	500	2,000	5,000	100	100	100
5.1	1,000	1,000	2,000	2,000	100	100	100
5.2	1,000	1,000	2,000	0	100	100	100
5.3	1,000	1,500	2,000	0	100	100	100

Operational Expenditures for Target Year			Funds			Angler Days (thousands)	
Fish Population Control	Habitat Improvement and Prot.	Admin. Planning & Research	Total State	Total Federal	Total	2020 Needs	2020 Needs Met
24	20	24	2,761	2,119	4,880	934	824
24	0	24	1,085	645	1,730	710	600
0	20	0	1,676	1,474	3,150	224	224
100	25	20	3,712.5	1,987.5	5,700	696	696
80	30	10	2,644	1,826	4,470	4,012	4,012
30	10	10	900	450	1,350	29	29
50	20	0	1,744	1,376	3,120	3,983	3,983
120	20	20	6,231	2,954	9,185	350	350
100	20	0	2,232	1,488	3,720	0	0
10	0	10	2,199	1,466	3,665	200	200
10	0	10	1,800	0	1,800	150	150
210	30	20	8,900	4,300	13,200	3,078	3,078
10	0	10	900	0	900	337	337
200	30	10	8,000	4,300	12,300	2,741	2,741
300	50	30	9,700	4,800	14,500	2,716	2,716
100	50	30	7,600	4,200	11,800	1,553	1,553
100	50	10	6,000	3,700	9,700	1,455	1,200
100	10	5	3,562.5	1,987.5	5,550	1,232	1,000
65	100	30	7,780	3,025	10,905	4,386	4,386
25	70	20	5,618	1,517	7,135	3,924	3,924
40	30	10	2,212	1,558	3,770	462	462
15	30	40	2,989	761	3,750	384	384
50	200	30	4,285	8,511	12,796	564	564
0	0	0	118	178	296	367	367
50	200	30	4,167	8,333	12,500	197	197
50	200	20	3,300	6,600	9,900	1,613	1,500
100	200	20	2,800	5,600	8,400	3,135	3,135
100	200	20	2,967	5,933	8,900	795	795

TABLE 8–79 Summary of Supply and Demand Characteristics of Commercial Species

Species	Current Landings[1]	MSY 1970[1]	Landings MSY (%)	MSY Trend 1970-1980	Estimated MSY 1980[1]	MSY Trend Post 1980
Carp	6 - 8	40+	15 - 20	Up	50 - 70	Up
Catfish	1 - 2	2	75	No change	2	No change
Chubs	11 - 12	11 - 12	100	No change or down	Uncertain	Uncertain
Lake Herring	5 - 6	5 - 6	100	No change or down	Uncertain	Uncertain
Lake Trout	Under 1	Unknown	Under 100	Up	5 - 10	Up
Sheepshead	3 - 4	23+	10	Up	30 - 50	Up
Smelt	14 - 15	20	80 - 90	Down	5 - 10	Uncertain
Suckers	1 - 2	30	5	Varying	30	No change
Walleye	2 - 3	2 - 3	100	No change or down	2	Uncertain
White Bass	1 - 2	3 - 4	40 - 50	No change	3 - 4	No change
Whitefish	2.5 - 3	3 - 4	80	Up	4 - 6	Up
Yellow Perch	25 - 30	40 - 50	90 - 100	No change or down	40 - 50	No change or down

Note: MSY--Maximum Sustainable Yield

[1]In millions of pounds

Consumer Appeal and Identification	Ex-Vessel Price 1970 (cents/lb)	Nominal Price Trend 1970-1980	Major Factor Influencing Price Trend	Effect of Rising Income on Demand
Narrow; racial and ethnic	4	No change	Demand weak	Negative
Narrow; regional and racial	28 - 30	Down	Expanding supply	Unknown
Speciality; regional & ethnic	16 - 20	Slightly up	Supply constant	Slightly positive
Somewhat narrow; regional	10 - 15	Up	Supply constant	Negative
Moderately broad; regional & ethnic	65	Down	Expanding supply	Positive
Narrow; racial	1.5 - 3	No change	Demand weak	Negative
Somewhat narrow; regional	2 - 4	Up	Supply constant	Negative
Narrow; ethnic	3	No change	Demand weak	Negative
Broad; regional and ethnic	50 - 60	Up	Supply constant	Positive
Somewhat broad; regional	20 - 30	No change or up	Substitutes supply down	Unknown
Moderately broad; regional & ethnic	60	No change or down	Expanding supply	Positive
Moderately broad; regional	11 - 16	Up	Supply constant	Slightly negative

LIST OF REFERENCES

1. Crutchfield, James A., and MacFarlane, Dougald. *Economic Valuation of the 1965–1966 Saltwater Fisheries of Washington,* Research Bulletin No. 8. State of Washington, Department of Fisheries, December 1968.

2. U.S. Department of Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries, Market News Service. *Fishery Statistics of the United States, 1966,* Statistical Digest 60.

BIBLIOGRAPHY

Argonne National Laboratory, *A Proposed Study of the Effects of Heated Discharges in the Great Lakes*, 1968.

Arnold, Dean E., "Thermal Pollution, Nuclear Power, and the Great Lakes," *Limnos*, 3(1), 1970.

Aulerich, R.J., Ringer, R.K.,Seagran, H.L., and Youatt, W.G., *Effects of Feeding Coho Salmon and Other Great Lakes Fish on Mink Reproduction*, 1970.

Bailey, Merryll M., "Age, Growth, and Maturity of Round Whitefish in Apostle Islands and Isle Royale Regions, Lake Superior," U.S. Fish and Wildlife Service, *Fisheries Bulletin*, 63(1).

———————, "Age, Growth, Maturity and Sex Composition of the American Smelt *Osmerus mordax* (Mitchell) of Western Lake Superior," *Transactions of the American Fisheries Society*, 93(4), 1964.

Beeton, A.M., "Changes in the Environment and Biota of the Great Lakes, Eutrophication: Causes, Consequences, Correctives," in *Symposium Proceedings, National Academy of Sciences*, Washington, D.C., 1969.

Bodola, Anthony, "Life History of the Gizzard Shad *Dorosoma cepedianum* (LeSueur) in Western Lake Erie," U.S. Fish and Wildlife Service, *Fisheries Bulletin*, 65(2), 1966.

Brown, Edward H., "Extreme Female Predominance in the Bloater *(Coregonus hoyi)*, of Lake Michigan in the 1960s," *Biology of Coregonid Fishes*. C.C. Linberg and C.S. Woods (eds.), 1970.

Brown, Lewis R., and Tischer, Robert G., *The Decomposition of Petroleum Products in Our Natural Waters*. Water Resources Research Institute, Mississippi State University, State College of Mississippi, 1969.

Buettner, Howard J., *Commercial Fisheries of the Great Lakes: Historical Fishery Statistics*. U.S. Bureau of Commercial Fisheries, 1968.

Carbine, W.F., "Observations on the Life History of the Northern Pike, *Esox lucius*, in Houghton Lake, Michigan," *Transactions of the American Fisheries Society*, Vol. 71, 1941.

Carbine, W.F., and Applegate, Vernon C., "The Movement and Growth of Marked Northern Pike *(Esox lucius L.)* in Houghton Lake and the Muskegon River," *Papers of the Michigan Academy of Sciences, Arts and Letters*, Vol. 32, 1946.

Carlander, Kenneth D., "Growth Rate Studies of Saugers, *Stizostedian canadense canadense* (Smith), and Yellow Perch, *Perca flavenscens* from Lake of the Woods, Minnesota," *Transactions of the American Fisheries Society*, Vol. 79, 1949.

Christie, W.J., "Possible Influences of Fishing on the Decline of Great Lakes Fish Stocks," in *Proceedings, 11th Conference Great Lakes Research*, 1968.

Cleary, Donald, "The Economic Impact of Current Fisheries Management Policy on the Commercial Fishing Industry of the Upper Great Lakes," Bureau of Commercial Fisheries Economic Research Working Paper No. 6, 1970.

Clemens, H.P., "The Growth of the Burbot *Lota lota macclosa* (LeSueur) in Lake Erie," *Transactions of the American Fisheries Society*, Vol. 80, 1950.

Cushing, David H., "The Fluctuation of Year-Classes and the Regulation of Fisheries," *Fish Dir. Skr. Ser. HavUnders*, 15(3), 1969.

Denison, P.J., and Elder, F.C., *Thermal Inputs to the Great Lakes 1968–2000*, Canada Centre for Inland Waters and H.G. Acres Limited, 1970.

Dryer, William R., Erkkila, Leo F., and Tetzloff L., "Food of Lake Trout in Lake Superior," *Transactions of the American Fisheries Society*, 94(2), 1965.

Eddy, Samuel, and Surber, Thadders, *Northern Fishes With Special Reference to the Upper Mississippi Valley,* Minnesota Press, 1960.

Edsall, Thomas A., "Age and Growth of the Whitefish *Coregonus clupeaformis* of Munising Bay, Lake Superior," *Transactions of the American Fisheries Society*, 89(4), 1960.

——————, "Biology of the Freshwater Drum in Western Lake Erie," *Ohio Journal of Science*, 67(6), 1967.

Eschmeyer, Paul H., "The Lake Trout (*Salvelinus namaycush*)," U.S. Fish and Wildlife Service, Fishery Leaflet 441, 1957.

Forney, John L., "Year-Class Distribution of Walleyes Collected by 5 Types of Gear," *Transactions of the American Fisheries Society*, 90(3), 1961.

Franklin, Donald R., and Smith, Lloyd L., Jr., "Early Life History of the Northern Pike, *Esox lucius L.*, With Special Reference to the Factors Influencing the Numerical Strength of Year Classes," *Transactions of the American Fisheries Society*, 92(2), 1963.

Great Lakes Basin Commission, Fish Work Group, "Study Memorandum 8–1; Analysis of Fishery Programs and Review of Current Plans for the Management of Fishery Resources of the Great Lakes," 1969.

Great Lakes Fishery Commission, Lake Erie Committee, Minutes of Annual Meetings, 1969, 1970, 1971.

Great Lakes Fishery Commission, Lake Huron Committee, Minutes of Annual Meetings, 1969, 1970, 1971.

Great Lakes Fishery Commission, Lake Michigan Committee, Minutes of Annual Meetings, 1969, 1970, 1971.

Great Lakes Fishery Commission, Lake Ontario Committee, Minutes of Annual Meetings, 1969, 1970, 1971.

Great Lakes Fishery Commission, Lake Superior Committee, Minutes of Annual Meetings, 1969, 1970, 1971.

Great Lakes Fishery Commission, "Commercial Fish Production in the Great Lakes, Supplement to Technical Report No. 3 Covering the Years 1961–1968," 1970.

Greig, Richard A., "Preliminary Report on the Mercury Content of Fish from Waters of the Great Lakes," Paper prepared for Great Lakes Fishery Commission Annual Meeting, St. Paul, Minn., June 16, 1970.

Greig, Richard A., and Seagran, H.L., "Survey of Mercury Concentrations in Fishes of Lakes St. Clair, Erie, and Huron," Talk presented at the International Conference on Environmental Mercury Contamination, September 30 to October 2, 1970, University of Michigan, Ann Arbor, Michigan.

Gustafson, Carl G., "PCB's—Prevalent and Persistent," *Environmental Science and Technology*, 4(10), 1970.

Hile, Ralph, and Jobes, Frank W., "Age and Growth of the Yellow Perch, *Perca flavescens* (Mitchell) in the Wisconsin Waters of Green Bay and Northern Lake Michigan," *Papers of the Michigan Academy of Science, Arts and Letters*, Vol. 27.

International Joint Commission, "Potential Oil Pollution Incidents from Oil and Gas Well Activities in Lake Erie, Their Prevention and Control," Report of the International Lake Erie Water Pollution Board to the IJC, 1969.

——————, "Special Report on the Potential Oil Pollution, Eutrophication, and Pollution from Watercraft," 1970.

Jensen, S., Johansson, N., and Olsson, M., "PCB—Indications of Effects on Salmon," Paper presented at the PCB Conference, Stockholm, Sweden, Sept. 29, 1970.

Karvelis, Ernest G., "The True Pikes," Fishery Leaflet 569, 1964.

Lawler, G.H., "Whitefish Improvement—Pike Control," Fisheries Research Board of Canada, Circular No. 7, 1965.

Lawrie, A.H., "The Sea Lamprey in the Great Lakes," *Transactions of the American Fisheries Society*, 99(4), 1970.

Lewis, Donald W., "The Decline of the Lake Erie Commercial Fishery Industry in Ohio," Doctoral Dissertation, 1966.

Lucas, Henry F., Jr., and Edginton, Donald N., "Concentrations of Trace Elements in Great Lakes Fishes," *Journal of the Fisheries Research Board of Canada*, 27(4), 1970.

Maloney, J.F., and Johnson, F.H., "Life Histories and Interrelationships of Walleye and Yellow Perch, Especially During their First Summer, in Two Minnesota Lakes," *Transactions of the American Fisheries Society*, Vol. 85, 1955.

Miller, Robert Rush, "Systematics and Biology of the Gizzard Shad (*Dorosoma cepedianum*) and Related Fishes," *Fishery Bulletin 173*, Vol. 60, 1960.

Mraz, Donald, "Age and Growth of the Round Whitefish in Lake Michigan," *Transactions of the American Fisheries Society*, 93(1), 1964.

Niemuth, Wallace, Churchill, Warren, and Wirth, Thomas, "The Walleye: Life History, Ecology, and Management," Wisconsin Conservation Department Publication 227.

Nikolskii, G.V., "Concerning the Influence of Exploitation on the Structure of the Population of a Commercial Fish," *Zoologicheskii Zhurnal*, 37(1), 1958, Translated by W.E. Ricker for the Fisheries Research Board of Canada, Translation Series No. 280, 1961.

Odell, T.T., "The Life History and Ecological Relationship of the Alewife (*Pomolobus pseudoharengue*) (Wilson) in Seneca Lake, New York," *Transactions of the American Fisheries Society*, Vol. 64, 1934.

Paulik, Gerald J., "Development of a Comprehensive Simulation Model of the Fish Resources of the Great Lakes," in *Proceedings, Fourth Symposium on Water Resources Research of the Ohio State University Water Resources Center*, Oct. 1969.

Peakall, David B., and Linver, Jeffrey L., "Polychlorinated Biphenyls; Another Long-Life Widespread Chemical in the Environment," *BioScience*, 20(7), 1970.

Poston, H.W., "Defueling the Nordmeer," *Limnos*, 2(4), 1969.

Pycha, Richard, "Lake Trout Mortality in Relation to Lamprey Predation," U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife.

Regier, Henry A., "A Perspective on Research on the Dynamics of Fish Populations in the Great Lakes," *The Progressive Fish Culturist*, Jan. 1966.

Reinert, Robert E., "Insecticides of the Great Lakes," *Limnos*, 2(3), 1969.

————————, "Pesticide Concentrations in Great Lakes Fishes," Contribution No. 371, Great Lakes Fishery Laboratory, Bureau of Commerical Fisheries, Ann Arbor, Michigan, 1970.

Risebrough, Robert, and Brodme, Virginia, "Letters in the Wind," *Environment*, 12(1), 1970.

Roelofs, Eugene W., "Age and Growth of Whitefish, *Coregonus clupeaformis* (Mitchell) in Big Bay de Noc and Northern Lake Michigan," *Transactions of the American Fisheries Society*, Vol. 87, 1957.

Rothschild, Brian James, "The Life History of the Alewife *(Alosa pseudohatengus)* (Wilson) in Cayuga Lake, New York," Ph.D. Thesis, Department of Zoology, Cornell University, 1962.

Ryder, R.A., "A Method of Estimating the Potential Fish Production of Northtemperate Lakes," *Transactions of the American Fisheries Society*, 94(3), 1965.

Seagran, Harry L., "Mercury in Great Lakes Fish," *Limnos*, 3(2), 1970.

Shapiro, A.P., and Andreyev, V.C. "Optimum Relationship Between Artificial and Natural Reproduction of Commercial Populations of Fish," *American Fisheries Society*, 9(1), 1969.

Smith, Stanford H., "Life History of the Lake Herring of Green Bay, Lake Michigan," *Fishery Bulletin 109*, Vol. 57, 1956.

————————, "The Alewife," *Limnos*, 1(2), 1968.

————————, "Species Succession and Fishery Exploitation in the Great Lakes," *Journal of the Fisheries Research Board of Canada*, 25(4), 1968.

———————————, "Trends in Fishery Management of the Great Lakes," Contribution No. 422 of the Great Lakes Fishery Laboratory, Ann Arbor, Mich., 1970.

———————————, "Species Interaction of the Alewife in the Great Lakes," Contribution No. 422 of the Great Lakes Fishery Laboratory, Ann Arbor, Mich., 1970.

Stalling, David L., "Polychlorinated Biphenyls (PCBs) in Freshwater Ecosystems," A Second Draft of a Paper Prepared for the Fish-Pesticide Research Laboratory, 1971.

Stotling, W.H., "Effects of Fishery Regulation on the Processing and Marketing of Fishery Products," *Economic Effects of Fishery Regulations*, R. Hamlisch (ed.), United Nations, Food and Agriculture Organization, 1962.

Thurston, Claude E., *et al.* "Composition of Certain Species of Freshwater Fish: Comparative Data for 21 Species of Lake and River Fish," *Food Research.* 1959, Vol. 24, No. 5, p. 495.

U.S. Department of the Interior, Federal Water Quality Administration, *Clean Water for the 1970's: A Status Report*, June 1970.

U.S. Department of the Interior, Fish and Wildlife Service, *Fish and Wildlife as Related to the Water Quality of the Lake Erie Basin*, 1967.

———————————, *Fish and Wildlife as Related to the Water Quality of the Lake Huron Basin*, 1969.

———————————, *Fish and Wildlife as Related to the Water Quality of the Lake Michigan Basin*, 1966.

———————————, *Fish and Wildlife as Related to the Water Quality of the Lake Ontario Basin*, 1969.

———————————, *Fish and Wildlife as Related to the Water Quality of the Lake Superior Basin*, 1970.

———————————, *Physical and Ecological Effects of Waste Heat on Lake Michigan*, 1970.

U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries, "Commercial Fishing Gear of the United States," Circular No. 109, 1961.

U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries, Market News Service, *Receipts and Prices of Fresh and Frozen Fishery Products at Chicago*, 1967.

U.S. Senate, 90th Congress, 2nd Session, *Thermal Pollution* (Part 1), Hearings Before the Subcommittee on Air and Water Pollution of the Committee on Public Works, 1968.

Van Oosten, John, "Maximum Size and Age of Whitefish," *The Fisherman*, 14(8), 1946.

———————————, "The Lake Sturgeon," *Our Endangered Wildlife*, National Wildlife Federation, 1956.

Van Oosten, John, and Eschmeyer, Paul H., "Biology of Young Lake Trout *(Salvelinus namaycush)* in Lake Michigan," Research Report No. 42 of the U.S. Fish and Wildlife Service, 1956.

Wells, LaRue, "Effects of Alewife Predation on Zooplankton Populations in Lake Michigan," *Limnology and Oceanography*, 15(4), 1970.

Wolfert, David R., "Maturity and Fecundity of Walleyes from the Eastern and Western Basins of Lake Erie," Contribution No. 395 of the U.S. Bureau of Commercial Fisheries, 1968.

Addendum

HISTORICAL BACKGROUND OF SIMILAR INVESTIGATIONS

Great Lakes Fishery Commission

In 1964 the Great Lakes Fishery Commission published *A Prospectus for Investigations of the Great Lakes Fishery* in partial fulfillment of the conditions of the International Convention which charged the Commission, according to the prospectus, "to formulate and coordinate research programs designed to determine the need for and the type of measures to make possible the maximum sustained productivity of any stock of fish of common concern in the Convention Area (the Great Lakes). . . ." This prospectus was prepared with the assistance of Federal, State, and Provincial agencies that deal directly with fishery matters in the Great Lakes. The prospectus reviews the status of the Great Lakes fisheries in 1964 and describes appropriate research both for the Great Lakes in total and for individual Lakes. The programs outlined in the prospectus have generated numerous individual reports (Technical Reports 1–13) by the Fishery Commission and by the participating Federal, State, and Provincial agencies. The Fishery Commission's role in directing sea lamprey control has also resulted in numerous reports on the accomplishments of that program.

The Great Lakes Fishery Commission maintains a comprehensive bibliography of Great Lakes fisheries reports and periodically updates copies of this bibliography, located at agencies and universities throughout the Great Lakes Region.

Bureau of Commercial Fisheries

The Bureau of Commercial Fisheries, Fish and Wildlife Service, Department of the Interior (now the National Marine Fisheries Service), began participating in the Great Lakes-Illinois River Basin Project (GLIRB) in 1960 when the study was organized by the Public Health Service which was later taken over by the Environmental Protection Agency. To aid the development of a water pollution control plan, the Bureau of Commercial Fisheries assumed the task of preparing individual reports on the commercial fishery of each of the Great Lakes. These completed reports were utilized in the appendix.

In addition to a historical description of the commercial fishery in each Lake, these GLIRB reports by the Bureau of Commercial Fisheries describe the habitat and fishery base by Lake and discuss management and economic problems associated with each fishery. These reports also project regional needs for the fishery products. Future economic, technological, management, and water quality needs are also outlined and discussed in some detail.

The Bureau of Commercial Fisheries has published numerous reports in their program activities which include:

(1) biological and limnological research

(2) technological research in fishing methods, marketing, and processing

(3) sea lamprey control

(4) administration of Federal aid for both the Commercial Fisheries Research and Development Act and the Anadromous Fish Act

(5) river basin resource planning and development

An annotated bibliography, "United States Federal Research on Fisheries and Limnology in the Great Lakes through 1964," was published in 1966 as "Special Scientific Report—Fisheries," No. 528, by the U.S. Fish and Wildlife Service. The published reports of the Bureau of Commercial Fisheries through 1968 cover nearly every aspect of their activities.

Bureau of Sport Fisheries and Wildlife

The Bureau of Sport Fisheries and Wildlife, Fish and Wildlife Service, Department of the Interior, has also participated in the Great Lakes-Illinois River Basin Study. Two of their reports (Lake Michigan and Lake Erie) have already been combined with reports from the Bureau of Commercial Fisheries and published. In addition to a general description of each Lake basin and its pollution problems, the reports describe the distribution and relative importance of various sport fisheries. Reports on the additional three Lakes are now being compiled by the Bureau of Sport Fisheries and Wildlife. They will be published in combination with reports by the Bureau of Commercial Fisheries as special reports on fish and wildlife as they relate to water quality.

Department of Agriculture

The United States Department of Agriculture is organized into various services and agencies and includes the Soil Conservation Service (SCS). The SCS is the Department of Agriculture's technical arm of action for soil and water conservation and brings together the various disciplines needed to solve land and water conservation problems.

Through more than 3,000 soil and water conservation districts, SCS provides technical assistance to landowners, land users and developers, local units of government, and others engaged in land-use planning. It assists in the preparation of conservation plans, the application of various conservation practices, the preparation of soil and land capability maps, the distribution of soil maps and interpretations, and the provisions of guidance of maintaining measures and practices after they have been applied.

SCS provides technical assistance for soil and water conservation practices that are closely associated with fisheries. One of these practices is pond and streambank protection. Many of these ponds provide water for fish production, and many pond owners are finding that the production of fish can be profitable. When properly constructed, stocked, and managed, a pond may yield from 100 to 300 pounds of fish per surface acre per year.

Through proper vegetative and structural methods, streambanks are protected from scouring and erosion and at the same time provide improved habitat conditions for fish.

As of July 1, 1969, a total of 36,150 ponds and 364 miles of streambank protection had been established within the eight-State area comprising the Great Lakes Basin.

The Wild and Scenic Rivers Act, PL 90–542, provides that the Secretary of the Interior and the Secretary of Agriculture "shall make specific studies and investigations to determine which additional wild, scenic and recreation river areas shall be evaluated in planning reports by all Federal agencies as potential alternative uses of the water and related resources involved." The Secretary of Agriculture has designated the Forest Service as the coordinating body for the Department, and its chief as his representative in implementing the Wild and Scenic Rivers Act. In carrying out these duties, the Forest Service is responsible for coordinating all activities of the Department of Agriculture.

Where national forest lands are involved, the Forest Service will pursue the studies in close cooperation with appropriate agencies of the affected State and its political subdivisions. Studies will be carried on jointly with such agencies if a request for such joint study is made by the State, and shall include a determination of the degree to which the State or its political subdivisions might participate in the preservation and administration of the river should it be proposed for inclusion in the national wild and scenic rivers system. The studies and plans for management are in accord with applicable provisions of the National Environmental Policy Act.

Michigan Department of Natural Resources

Michigan is unique among the States in the Great Lakes Basin study in that the entire water and land area of the State is within the study boundaries. Consequently, all the published reports of the Michigan Department of Natural Resources on fisheries relate to the study area.

The best source of historical records of fish management in Michigan is found in the biennial reports which have been published since the creation of the first Michigan Board of Fish Commissioners in 1873. Since 1930 the fisheries research reports in Michigan have been published by the Institute for Fisheries Research, now part of the Research and Development Division, Michigan Department of Natural Resources. A cross-referenced index and bibliography of fisheries research reports in Michigan through 1967 was published in December 1968.

Since 1964 three management reports have been published on the Michigan fisheries. The first, "A Management Program for Michigan Fisheries—1964" (McFadden, et al, 1964), was a comprehensive review and evaluation of

Michigan's fish management programs. This report analyzed the knowledge about the resource base and recommended areas of future emphasis for both research and management. The second two reports, "Coho Salmon for the Great Lakes" (Tody and Tanner, 1966) and "Status Report on Great Lakes Fisheries" (Borgeson and Tody, 1967), describe in some detail Michigan's new Great Lakes fish management policies and program. Twenty-eight fishery watershed surveys on individual basins have been published.

Wisconsin Department of Natural Resources

The Wisconsin Fish Commission (established in 1874) and its present-day counterpart in the Wisconsin Department of Natural Resources have published numerous reports that document the past management of fish in Wisconsin waters. Both fisheries management and fisheries research activities have been summarized in the biennial reports of the Department since 1948. Since 1961 the Wisconsin Department of Natural Resources has published surface water resource reports for 13 of the 31 Wisconsin counties included in the Great Lakes Basin study areas. In addition to other information, these surface water reports describe the fishery resource base in detail and estimate present as well as potential use. A parallel inventory and classification of trout streams in Wisconsin was completed for the entire State and the results were published in 1968. Wisconsin Department of Natural Resources Technical Bulletin No. 38, "Guidelines for Management of Trout Stream Habitat in Wisconsin," is but one of several reports in this bulletin series which provides important fish management information applicable to the entire Great Lakes Region.

Great Lakes fish management policy in Wisconsin has also changed in the last few years. A statement of the new management policy was approved by the Wisconsin Natural Resources Board in 1968. Steps for implementing the new management policy have been published in "The Great Lakes, A Wisconsin Fisheries Development Program—1968."

New York Conservation Department

The State of New York probably has the most advanced comprehensive water management plan of any of the Great Lakes States. A report on this plan, including a review of the State's fishery resources, was published by the New York Water Resources Commission in 1967. This publication, "Developing and Managing the Water Resources of New York State," discusses water management needs in nine drainage basins, six of which are in the Great Lakes Basin. The *New York Fish and Game Journal*, published semi-annually by the New York Conservation Department, is an excellent reference for fish management and fish research information applicable to much of the Great Lakes Region. New York first established a Fish Commission in 1868. From 1926 to 1939, seven biological surveys were completed on New York water basins tributary to Lake Erie and Lake Ontario. These basic surveys have been updated periodically on important watersheds.

Ohio Department of Natural Resources

Published reports of the Division of Wildlife, Ohio Department of Natural Resources, indicate the State's longstanding interest in the sport and commercial fisheries of Lake Erie.

The first Fish Commission in Ohio was established in 1873. Summaries indicating the magnitude of the sport fishery for various species of fish in Lake Erie from the late 1950s through the early 1960s were published both by the Ohio Department of Natural Resources (Keller, 1964, "Lake Erie Sport Fishing Survey," Pub. W–316) and the *Ohio Journal of Science* (Keller, 1965). Fisheries research publications on Ohio's Lake Erie waters also occur periodically in the *Ohio Journal of Science* as well as the professional journals of the American Fisheries Society and Progressive Fish Culturist. Summaries of commercial fish landings from Lake Erie are published annually by the Department and most commercial fish research is now published in Ohio Department of Natural Resources reports for the Commercial Fisheries Research and Development Act coordinated by the U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries.

Annual reports issued by the Ohio State University Natural Resources Institute between 1956 and 1964 and other reports from the Institute include considerable information on the fish of Lake Erie and an exhaustive study of the limnology of the island area. Dr. Donald Lewis's doctoral dissertation, entitled *The Decline of the Lake Erie Commercial Fishing Industry in Ohio*, is another example of the published material available. The *Northwest Ohio Water Development Plan,* issued by the Ohio Water Commission, provides a good general description of the Maumee Basin's water problems. "A Study of the Food Habits of Some Lake Erie Fish" and a "Bibliography of Ohio Zoology," issued by the Ohio Biological Survey, are other sources of information on the fish of the Lake. The physical nature of the western portion of Lake Erie, especially bottom types and currents, is well documented in the reports of the Ohio Department of Natural Resources Division of Geological Survey.

Minnesota Department of Conservation

Although the portion of the Great Lakes Basin lying within Minnesota is of relatively minor geographic importance, it is a most significant and unique resource area to this State. As a result, considerable attention in the form of research studies, inventory reports, and data collection has been given this area. A list of available research and survey reports has been published and copies of the reports have been well distributed. A Statewide fish policy has been published and used in directing management programs. Fish and wildlife watershed surveys on two major river basin groups were published. Together with other hydrological, limnological, water quality, and use studies, these surveys provide the major background information useful in this framework study.

Illinois Department of Conservation

The State of Illinois borders 58 miles of shoreline on Lake Michigan in the Great Lakes. Although the part of the Lake which lies within the State amounts to only 10 percent of the total Lake surface, the fact that the largest metropolitan area on the Great Lakes is on the Illinois shoreline magnifies the importance of the value of this resource. Another unusual factor is the extremely small area of land in Illinois that is actually watershed to Lake Michigan.

Until very recently, little fishery investigation work had been undertaken on this part of Lake Michigan. Most data concern the commercial fishing catch records which date back to 1934. Although some work such as sport fishing creel census and observations of boat recreation usage is currently under way, this information is not yet completed for publication. Some recent publications at least have reference to recreation and fishing usage of Lake Michigan in Illinois. They include "Water for Illinois, a Plan for Action," Illinois Technical Advisory Committee on Water Resources, 1967; *The Illinois Angler,* Division of Fisheries, Illinois Department of Conservation, 1967; "Outdoor Recreation in Illinois," Office of Economic Development, State of Illinois, 1965; "Recreation and Open Space in Illinois," Division of Landscape Architecture, University of Illinois, 1961; "Open Space in Northeastern Illinois," Hanses, Schneeman and Associates for the Illinois Department of Conservation, 1961; and "Report of the Lake Michigan Fish Protection Commission to State," 1957.

Pennsylvania Fish Commission

Pennsylvania's portion of Lake Erie only amounts to 40 miles of shoreline and 512 square miles of drainage. Although this is a relatively small area, it has always been an important part of the overall fisheries of the Commonwealth. The 640,000 acres of Pennsylvania's portion of Lake Erie are eight times greater than the total inland standing water.

The Pennsylvania Fish Commission and its predecessor, the Department of Fisheries, have published annual fisheries reports since 1866, and the Lake Erie fisheries have always been a prominent part.

The decline of commercial fisheries activities in the Pennsylvania part of Lake Erie and the increase in sport fishing have considerably changed the management plans for this water area. In 1968 a 10-year plan was submitted for the management of Lake Erie, but it has not been officially approved at this date.

GREAT LAKES BASIN FRAME-
WORK STUDY - APPENDIX 8

AUTHOR

TITLE GREAT LAKES BASIN FRAMEWORK STUDY - APPENDIX 8

DATE DUE	BORROWER'S NAME

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